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Cutting Energy Costs in Multifamily Housing:

Practical Case Studies for the Builder and Developer

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Acknowledgments

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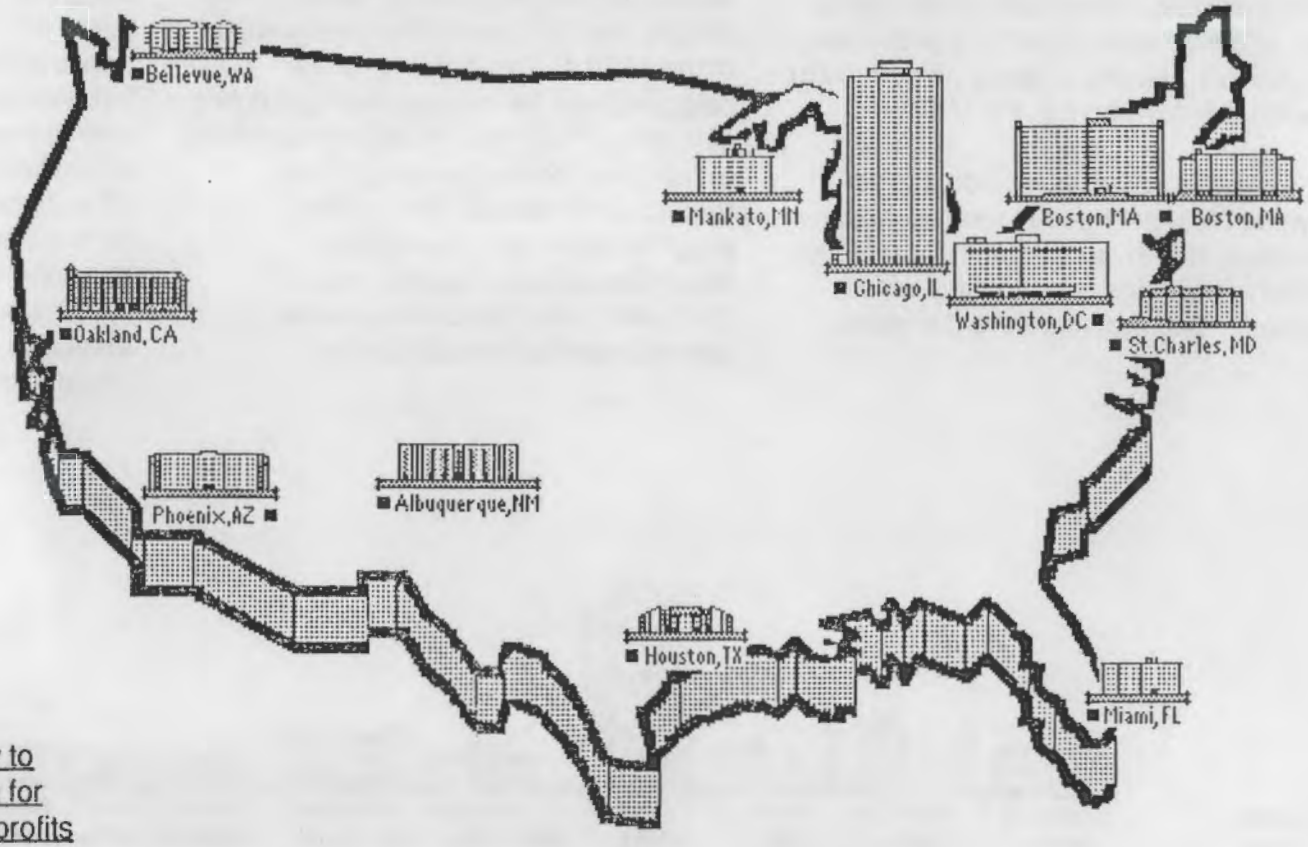
Introduction



Controlling utility costs can be a key to more affordable multifamily housing for tenants and significantly increased profits for building owners. This conclusion results from analysis of opportunities to reduce costs in a variety of existing and proposed future multifamily housing projects across the U.S. It applies to all types of multifamily housing regardless of location, ownership, utility rates or bill paying arrangements.

The difficulties are in knowing what to do, how much it will cost, and what the return on investment will be. To serve this need, the National Association of Home Builders (NAHB), working with the Institute of Real Estate Management (IREM), Pacific Northwest Laboratory (PNL) and the U.S. Department of Energy (DOE), presents this book as an aid to owners, developers and builders of multifamily housing in developing utility cost reduction strategies for their own projects.

U.S. Multifamily Housing . . .

This book is based on an expert evaluation of nine existing and three proposed multifamily housing projects (described in the table below) across the U.S.

The existing buildings include three lowrise projects (three to four stories), six midrises (five to seven stories), and three highrise buildings (nine to thirty-nine stories). Two projects were designed and built in the late 1950's, two in the late 1960's, and five late in the "energy-crisis" of the 1970's. The buildings were selected from the management portfolios of leading IREM and NAHB member-firms to represent typical housing in their respective locations. The existing projects range from municipally subsidized elderly housing, to HUD Section-8 suburban developments, to luxury urban highrise buildings.

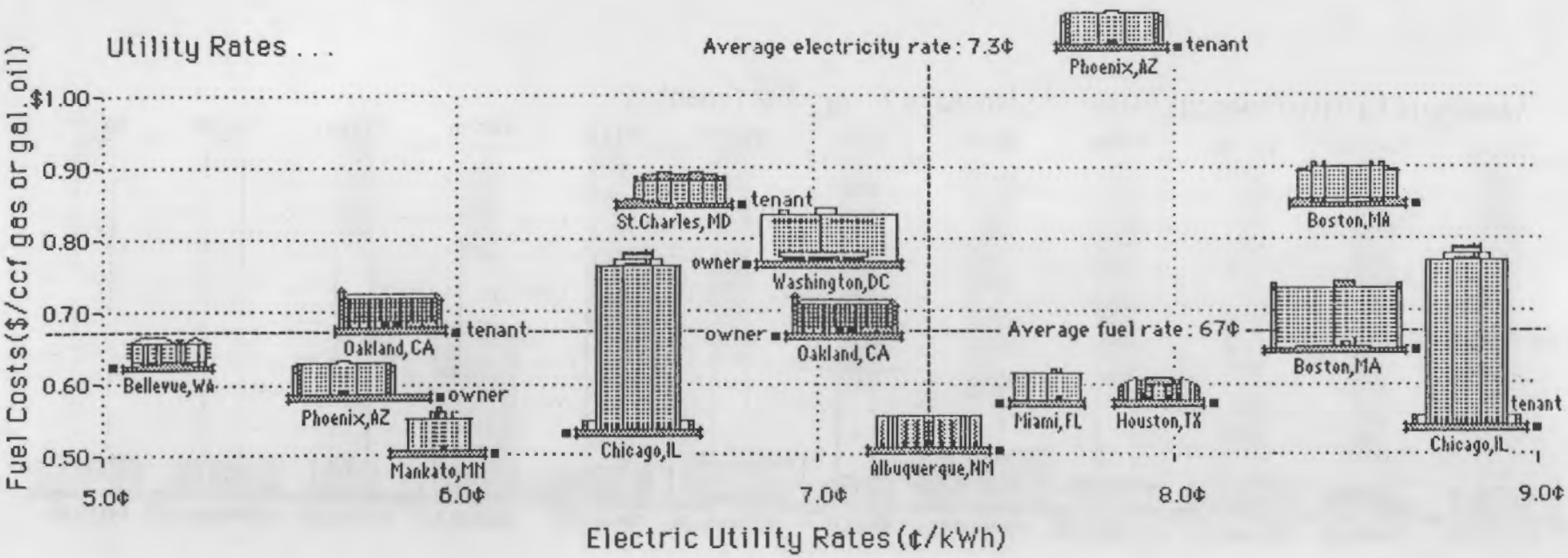
The three "future" buildings, designed by the NAHB research team, were based on trends anticipated in the multifamily industry by IREM and NAHB leaders, over the next five years. The key trends indentified were: downsizing of units (by 10 to 20 percent), increased project size (in number of units), denser developments (more midrise and highrise projects), and increased amenities -- all in the context of more affordable housing. A tall order!

Location	Boston,MA	Boston,MA	Mankato,MN	Chicago,IL	St.Charles,MD	Washington,DC	Houston,TX	Miami,FL	Albuquerque,NM	Phoenix,AZ	Bellevue,WA	Oakland,CA
Climate	Cold	Cold	Cold	Cold	Hot/Cold	Hot/Cold	Hot/Humid	Hot/Humid	Hot/Arid	Hot/Arid	Temperate	Temperate
Year Constructed	1959	Future	1959	1970	1979	1980	Future	1979	1979	Future	1967	1979
Number of Stories	7	12	6	39	4	10	3	5	6	6	3	6
Number of units	84	179	46	369	34	176	24	51	156	117	240	77
Gross Area (s.f.)	107,000	111,389	49,307	461,580	38,184	126,230	34,848	39,179	150,462	113,634	54,924	56,638
Building Efficiency	70%	85%	80%	77%	85%	74%	85%	80%	80%	80%	69%	80%
Typical Unit Size	490 (s.f.)	648	689	755	600	602	648	525	621	648	700	604
Monthly Rent	$286*	$544	$360	$661	$394*	$850	$530	$201*	$260*	$580	$379	$841

* Subsidized housing -- the rents listed are based on IREM Income/Expense Analysis.

Our work focuses on understanding the economics of energy in multifamily housing. Awareness of utility rates is the first step in the process. Utility rates for the buildings we investigated varied widely, ranging from 5¢ to 9¢ per kilowatt hour for electricity, and from $0.49 to $1.09 per hundred cubic feet of gas. While low utility rates clearly do a lot to lessen the importance of energy to the economics of multifamily housing, energy remained an issue of significance everywhere we looked.

Utility rates are frequently different for owners and tenants, with owners most often enjoying the benefit. The most dramatic instance of this occurred in our design of a future midrise for Phoenix, Arizona. There, tenants pay 30 percent more than owners for electricity (8¢ versus 6¢ per kWh) and nearly twice as much for fuel ($1.09 versus $0.57 per ccf of gas). The rate differential is an important factor when considering who is to pay the bill -- which meter will see the cost?

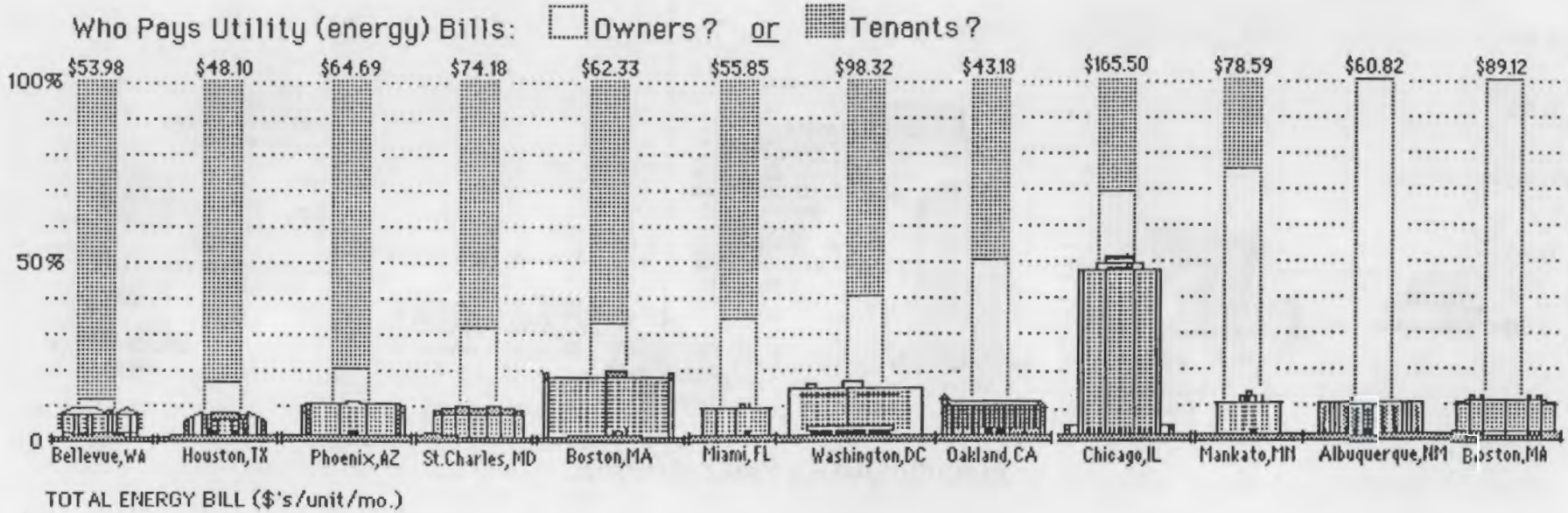


Utility Bills are High . . .

No matter what your utility rates or your location, energy bills have gotten suprisingly high for multifamily housing. In our work we found that monthly bills for energy (combined for owner and tenant) ranged from a low of $44.18 per month in mild Oakland up to $165.50 per month in a windy Chicago highrise.

Who pays the bill is an important decision. While owners can clearly shift some utility costs to tenants through submetering and other strategies, they cannot eliminate energy costs for themselves entirely. We looked at situations where owners were responsible for as little as 12 percent of the building's total energy costs and at cases where they were responsible for 100 percent of the energy bill. Interestingly, across all the buildings, owners and tenants typically split energy bills.

We do not want to suggest that the multifamily housing industry is "building them like they used to". Our future building baseline designs were limited in their focus on energy to current design practices -- that is, they incorporated energy features prevalent in new housing today. This approach leads to energy costs substantially below that of existing housing, as demonstrated by the comparison of the future Boston highrise, $62.33 per unit per month including cooling, versus the 1959 Boston midrise, $89.12 per unit per month without cooling.



. . . and Significantly Affect Shelter Costs

The net effect of high energy costs is to increase the real cost of multifamily housing. In our work energy costs for owner and tenant combined were found to be equivalent to 9 percent to 30 percent of *gross rent.*

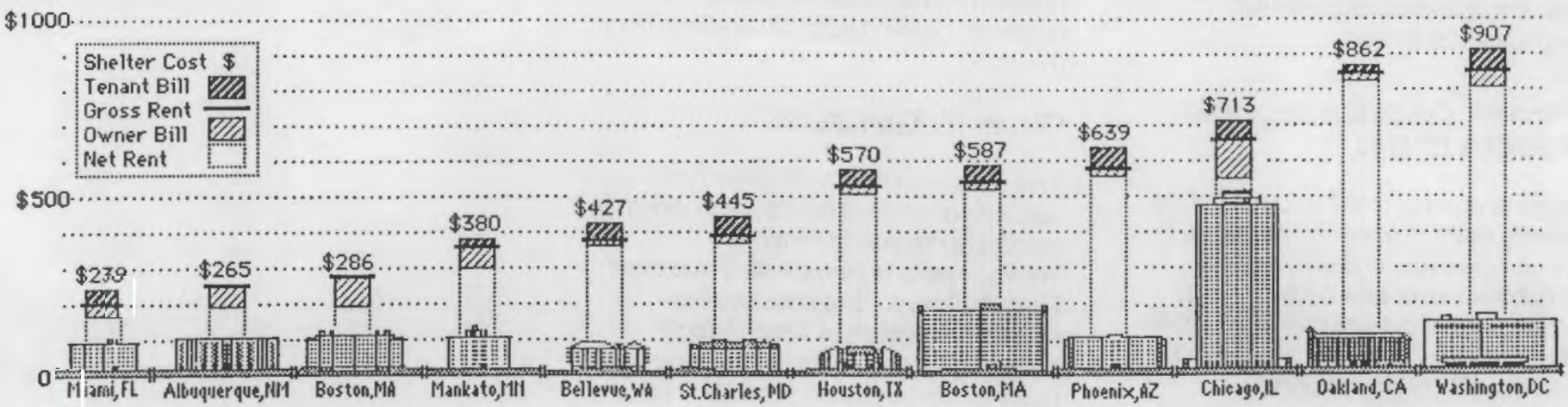
Again, who pays is important. In our buildings, *shelter costs* (gross rent paid by tenants plus tenant energy costs) ranged from 103 percent up to 118 percent of monthly rents in locations where tenants paid for a portion of the energy bill. The effect on owners is even more dramatic. *Net rents* (gross rent paid by tenants less owner energy costs) ranged from a high of 98 percent down to only 69 percent of monthly rents.

Total shelter costs averaged 108 percent of gross rent while net rent averaged only 90 percent. While there was little difference in average shelter cost between existing and future buildings, net rents were significantly better in our future buildings, averaging 97 percent of gross rent versus only 87 percent for existing buildings.

The chart below shows the components of total shelter cost for each building investigated. We have ordered the buildings from lowest to highest total shelter cost (the same order applies when based on gross rent).

What Is the Real Cost of Shelter? . . .

. . . It can be significantly higher than rent - - especially for low and moderate cost housing.



Using this Book . . .

Our work, designed to mirror the way real business is conducted, was very much a team effort -- a fact that cannot be overstressed. We attempted to bring the full range of concerns in multifamily housing to bear on each problem. Our work necessarily went far beyond energy issues, just as your decision-making process will when you consider ways to reduce energy costs in your own projects.

We have chosen to present our results, and the corollary lessons we learned, through the examples of the buildings we investigated. Each building tells a story that is unique, but each may be applicable, in one way or another, to you and your projects. Beyond the story in each building, we also present some general guidance for particular audiences as follows.

Chapter I: Cutting Energy Costs in Multifamily Housing

In general, what is the value of cutting energy costs in multifamily housing? What types of operations, retrofit, rehabilitation, or new design energy strategies should you consider? How much will they cost? What return on investment can you expect?

Chapter II: Energy Decisions for the Builder/Developer

The builder/developer is the final decision-maker about energy conservation options in any project. This chapter looks at typical builder/developer concerns, especially economic issues. Illustrations for this chapter build on economic analyses taken from the case studies.

Chapter III: The Decision-Making Process

How should architects and owners go about deciding which energy conservation options will be most beneficial? This chapter presents the problem solving approach used in this research, drawing upon illustrations from the work.

Chapter IV: Case Studies

This chapter consists of twelve case study summaries of recommendations, by two design teams, for energy improvements to nine existing and three future buildings. The case studies include an analysis of the building's current operating condition (for existing buildings) or its planned condition (for future buildings) and recommendations for improving energy performance through operations, retrofit, rehabilitation, or new design strategies. Complete cost analyses and estimates of simple paybacks are included in each case study.

Chapter V: Conclusions

Highlighting key points from the book, this chapter focuses on summarizing lessons learned from the entire project.

Chapter I: Cutting Energy Costs in Multifamily Housing

Energy bills in the nation's multifamily housing are high. Energy bills, on average, increase the cost of shelter for tenants by 8 percent of gross rents while reducing net rents to owners by 10 percent. The effects are most dramatic in low and middle income housing where the energy bill can be as high as 30 percent of the cost of shelter.

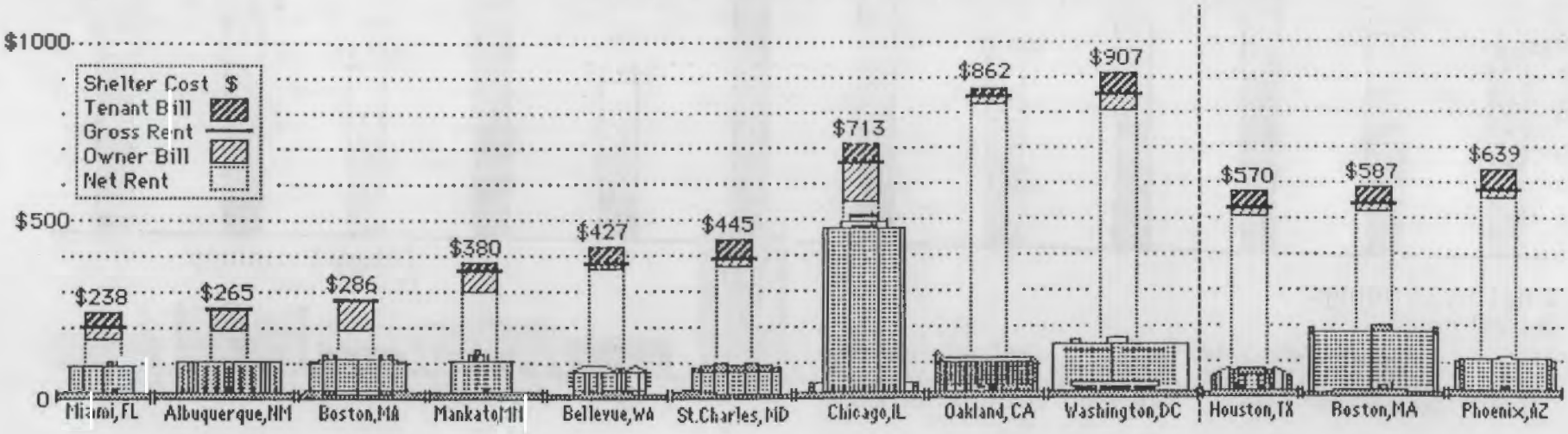
Energy costs continue to lessen the affordability of rental housing of all types. But energy costs can be reduced in multifamily housing by large amounts and very cost effectively. We will demonstrate this conclusion through real-world examples.

Before we present these specific examples, we want to discuss in general terms what you can do in your own projects -- What should you look for? What strategies work well for others? How much will they cost? What return on investment can you expect? -- We will do this in the context of when, in the life-cycle of your project, you might consider ways to reduce energy costs for yourself and your tenants.

If your project is an existing building you should consider strategies for reducing energy costs as part of day-to-day operations; every five to ten years when you are looking at renovating or retrofitting your buildings; or when you first purchase a project and you want to rehabilitate the building to adapt it to a particular niche in the rental market.

If you are thinking about developing a new project you should consider energy costs at the outset, before you present your proforma financial package to the mortgage lender.

This chapter discusses each of these situations, in turn, beginning with operations strategies for energy cost reduction. But first, let's take a look at the components of the total energy cost in each of our buildings. This would be your first step for your own project.



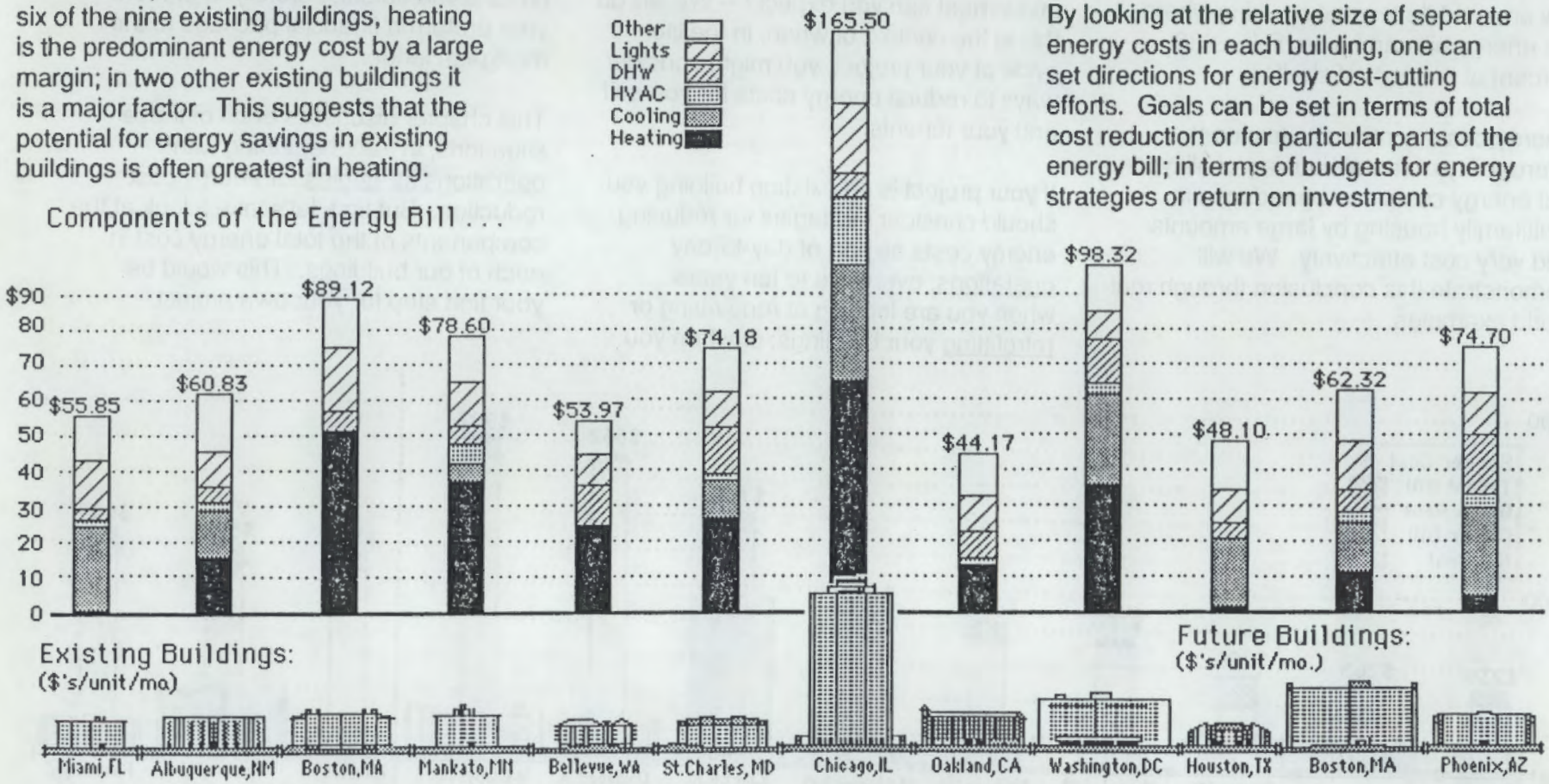
Look at the Components of Energy Costs and Set Goals for Your Effort

Total energy costs are composed of separate space heating, space cooling, HVAC equipment (fans, pumps, etc.), DHW, lighting, and other (cooking, elevators, miscellaneous) energy costs. In our buildings, definite patterns emerge for these separate costs. For example, in six of the nine existing buildings, heating is the predominant energy cost by a large margin; in two other existing buildings it is a major factor. This suggests that the potential for energy savings in existing buildings is often greatest in heating.

Cooling is a major factor in several of the existing buildings, clearly predominant in Miami and significant in Albuquerque, St.Charles, Chicago and Washington, D.C. Lighting is an issue of importance, everywhere.

The future buildings are different in that cooling increases substantially in importance in all three locations considered (primarily because current design practice is most effective in reducing heating energy requirements).

By looking at the relative size of separate energy costs in each building, one can set directions for energy cost-cutting efforts. Goals can be set in terms of total cost reduction or for particular parts of the energy bill; in terms of budgets for energy strategies or return on investment.



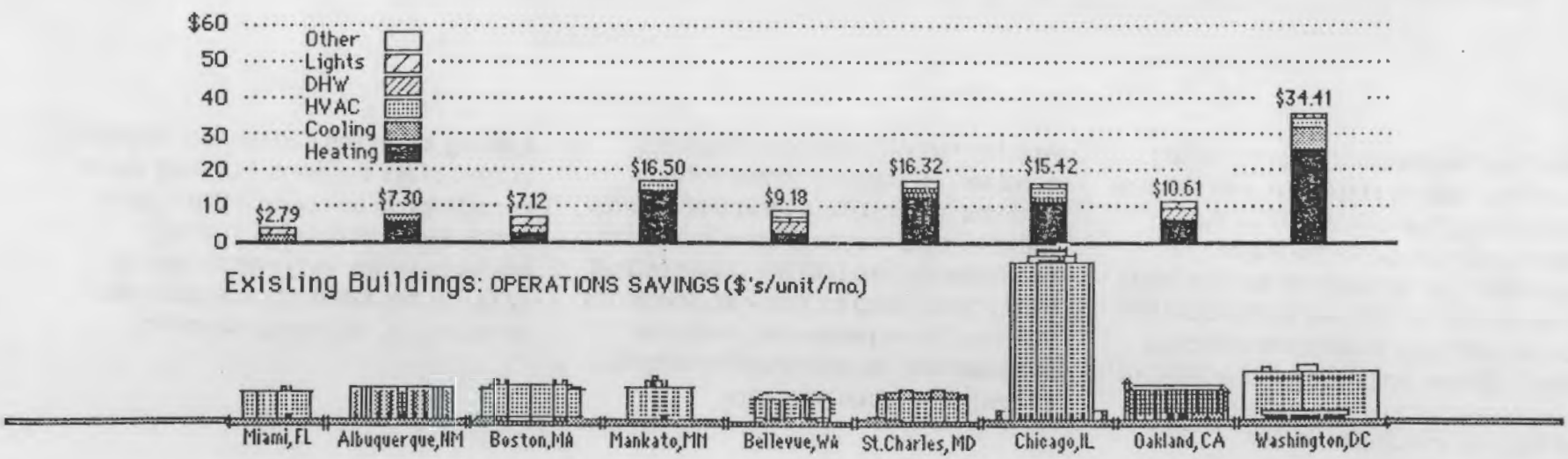
Operations Strategies . . .Heating may be the Key for You

Operations strategies are low-cost energy cost reduction measures that can be applied in the day-to-day operation and maintenance of multifamily housing projects. They include items such as: education programs for tenants; rescheduling the operation and maintenance of various equipment (ventilation fans, exterior and corridor lights, temperature set points, etc.); or caulking and weatherstripping of windows and doors. They may go as far as the installation of small equipment (programmable thermostats, screw-in fluorescent lamps water flow restrictors, etc.). The keys to adopting any of these strategies are a good working knowledge of which energy cost component will be affected, the amount of reduction that can be expected, and the cost of the strategy.

Operations strategies to reduce energy costs were very cost effective in all our buildings. Savings ranged from a low of $2.79 per unit per month to a high of $34.41, averaging $13.29. In scanning the energy cost savings achieved with operations strategies, shown below, it is clear that heating strategies produced the greatest savings, accounting for an average of 69 percent of total savings across all the buildings.

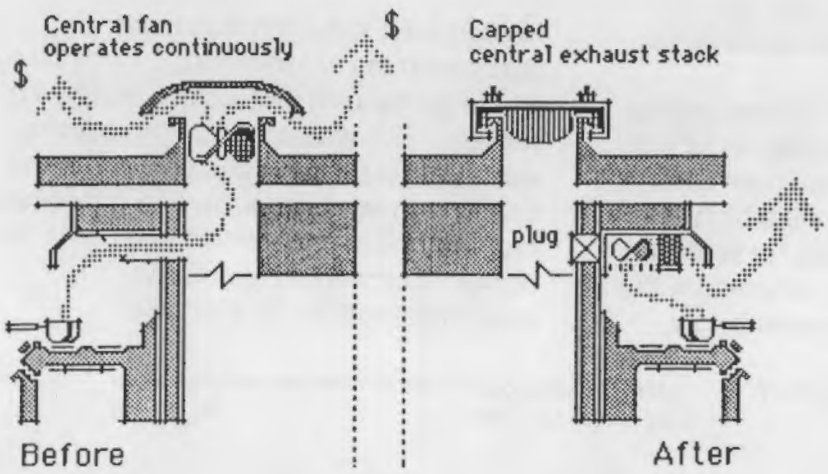
Heating cost reduction was most dramatic in the Washington, D.C. highrise where the heating bill was slashed by 70 percent. This was achieved by reducing ventilation in kitchens and baths, altering setpoints in public spaces, and providing programmable thermostats to tenants (in combination with an aggressive education program on their use).

How can you save with Operations Slategies? . . . Cutting heating cost through reduced ventilation may be the key for you.

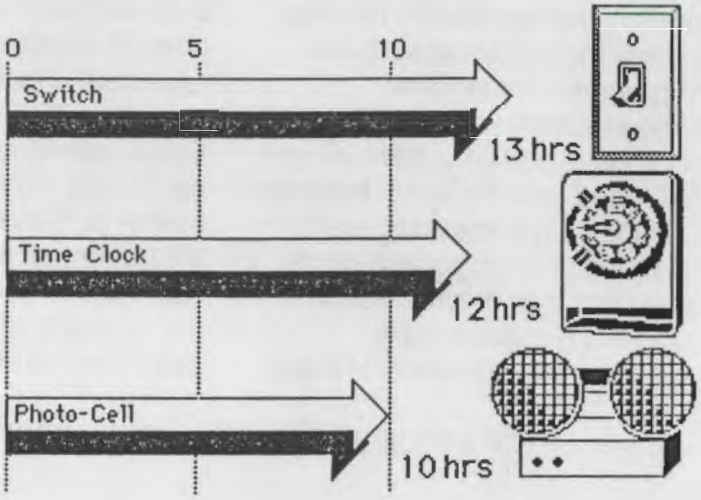


Operations Strategies. . .

USE OF RECIRCULATING FANS IN KITCHENS AND BATHROOMS CAN GREATLY REDUCE HEATING AND COOLING COSTS



PHOTOCELL CONTROLS ARE MOST EFFECTIVE IN REDUCING THE AVERAGE HOURS OF USE PER DAY FOR COMMON SPACE LIGHTING



Ventilation and infiltration (introducing outside air into the building), and exhaust (removing conditioned air from the building) are probably the major contributors to heating and cooling costs in all multifamily housing and should be looked at closely in any cost reduction effort. Simple actions, like scheduling of fan operation, can have large effects on heating and cooling costs.

Another technique to control exhaust ventilation is capping central exhaust systems and installing recirculating fans with activated charcoal filters in kitchens and baths (where building codes permit). While considered by many an operations strategy, the expense and disruption involved may suggest incorporating this strategy in a retrofit program.

Lighting strategies had modest potential in most of our buildings, but were worth considering in an operations program simply because installation of high efficiency lamps and controls can be easily incorporated into a regular maintenance (e.g. relamping) program.

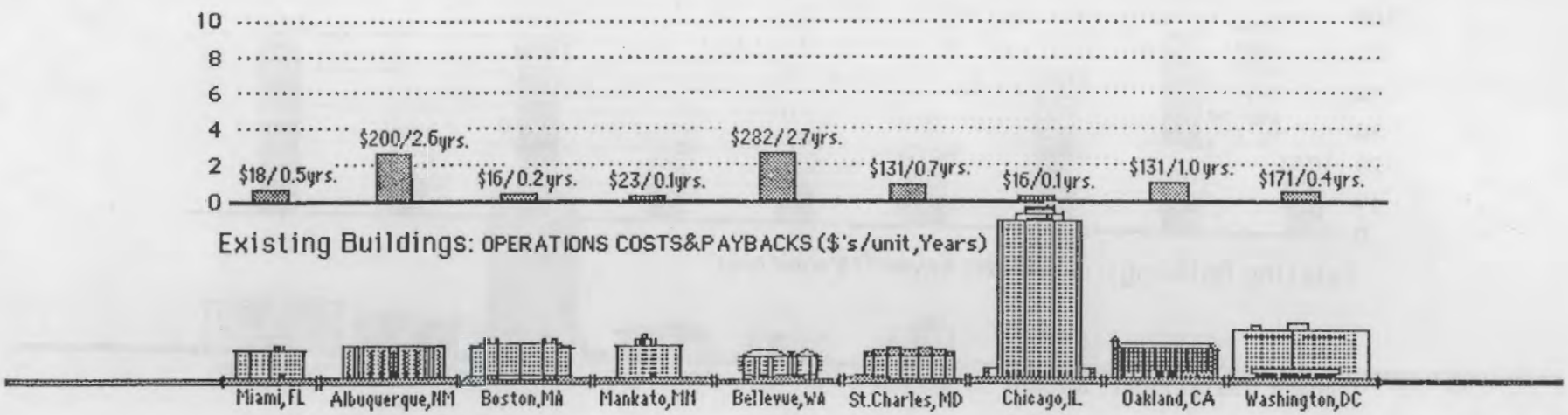
. . . Low Cost and Very Effective

Turning from savings to costs, operations strategies ranged from $16 per unit to $282, averaging $82 per unit for all the buildings. High cost items included installation of high efficiency ranges and refrigerators at replacement (an incremental cost of $140 per unit); programmable thermostats ($60 per unit); and insulation jackets for hot water heaters ($40 per unit).

In this analysis, we have chosen to measure cost effectiveness in terms of simple payback. Here, operations strategies shine. Seven of our buildings had paybacks of less than a year. The two "high cost" approaches had paybacks of under 32 months. The average payback is only 1 year.

Given this very good economic return, operations strategies make sense for all multifamily housing.

How long will it take Operations Strategies to payback? . . . Not long, don't blink!



Retrofitting for Energy Savings . . .

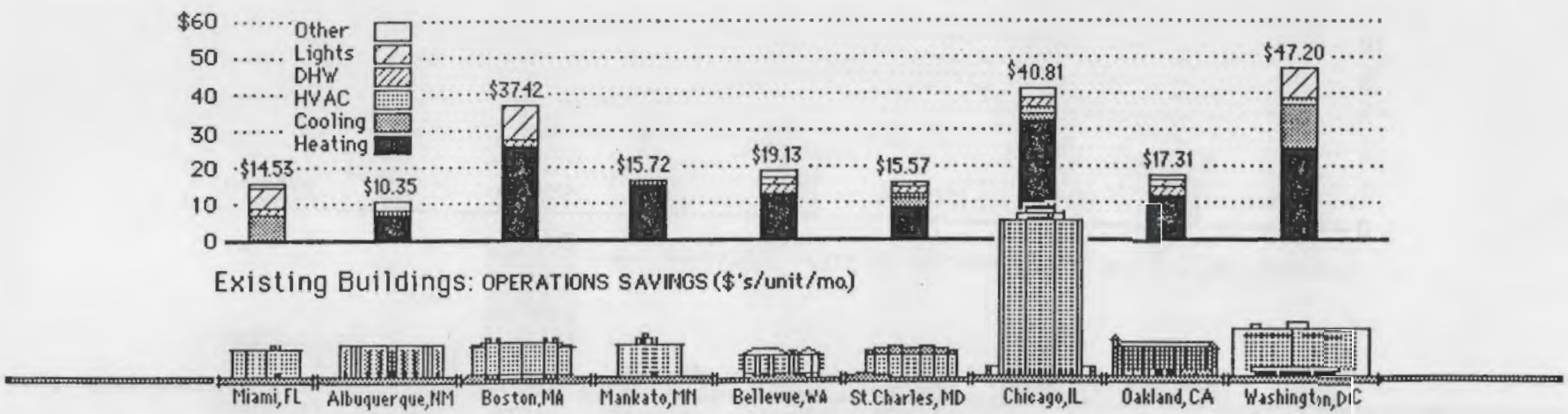
Energy cost-cutting retrofit programs for multifamily housing, most often occurring as part of a larger renovation effort, are generally more complex, expensive, and disruptive than operations measures. However, you can double your energy cost savings with very reasonable paybacks, so they are worth considering.

Retrofit programs include the same low-cost, easily implemented operations strategies discussed on the previous pages, and then focus on major alterations of building equipment and the building shell. Because of the disruption involved with many retrofit strategies, they should be thoroughly planned in advance to minimize interference with the day-to-day operation of your facilities.

Retrofit of building equipment can include actions such as fuel conversion (oil-to-gas, gas-to electricity, dual fuel capability, etc.); modification of the heating and cooling distribution system (e.g. zoning); upgrading of controls (e.g. individual thermostatic valves for radiators); changing "who pays" the bill (submetering strategies); and, in some cases, complete replacement of a system (e.g. installation of individual tenant DHW to replace an inefficient central system).

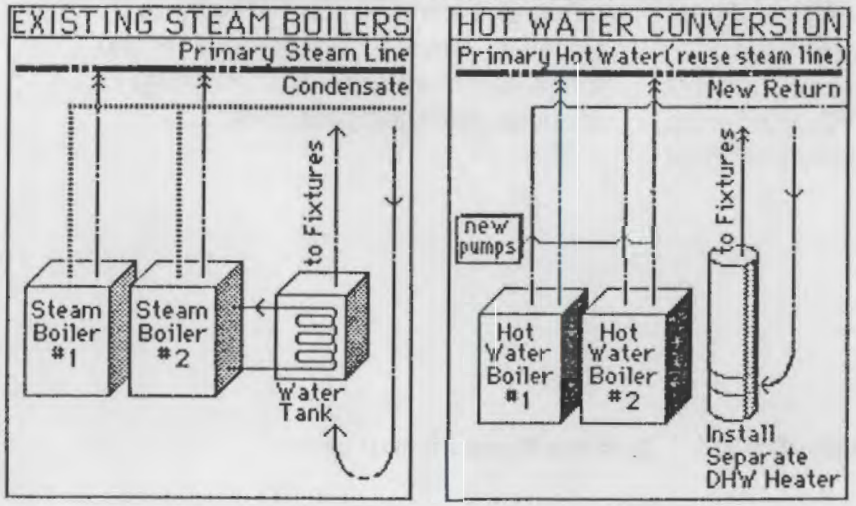
Retrofit of the building shell can include adding insulation (inside the walls, in the roof, or on the exterior of the building); storm windows; vestibules; and shading devices (awnings, overhangs, etc.).

How much can you save with Retrofit Stategies? . . . In a typical case, nearly twice as much as in operations.

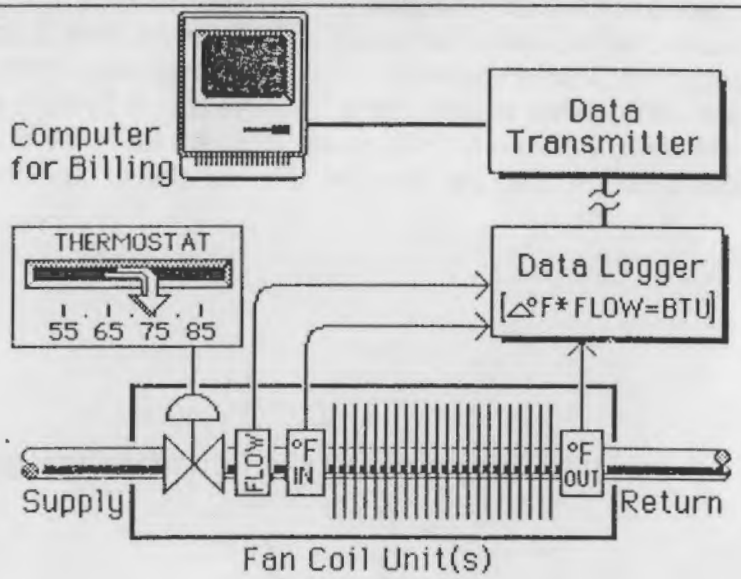


. . . Heating and Cooling are Still Most Important

RETROFIT STRATEGIES CAN INVOLVE SUBSTANTIAL MODIFICATION OF EXISTING BUILDING EQUIPMENT SYTEMS LIKE THIS BOILER CONVERSION



THERE ARE A VARIETY OF WAYS TO SHIFT COSTS FROM OWNERS TO TENANTS INCREASING THEIR INCENTIVE TO CONSERVE



All of the above are just examples of what can be done, and what we did in our buildings, as part of retrofit energy cost-cutting efforts. How did our efforts pay off? As shown on the previous page, our retrofit savings ranged from $10.35 per unit per month to $47.20, averaging $24.60, fully twice what was achieved in operations. Our focus was again on heating costs, but reduction of cooling received increased attention and success.

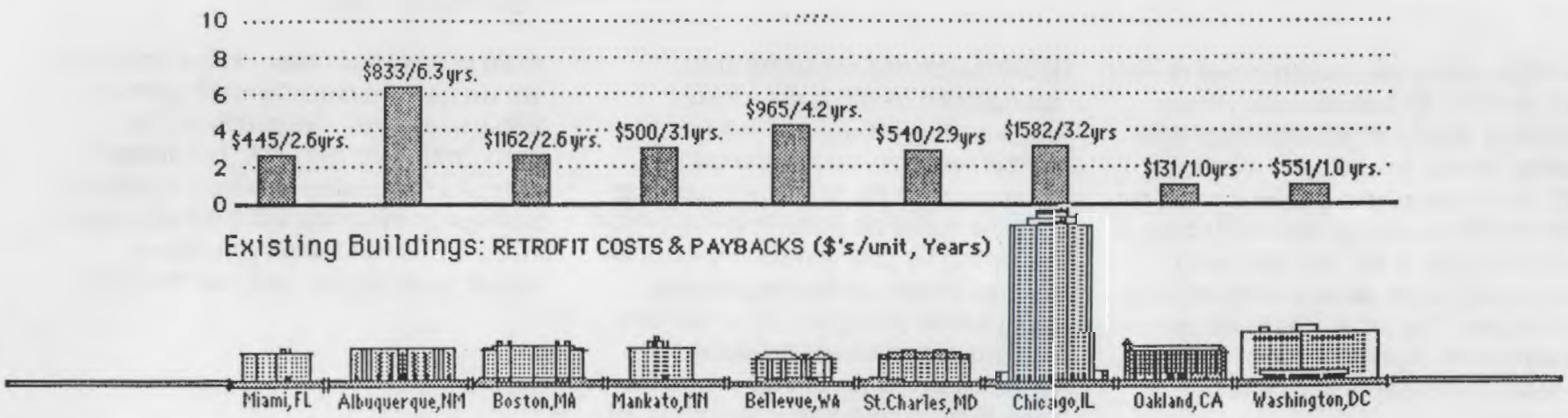
Individual control of heating and submetering methods got a lot of consideration in buildings that had central systems -- where the owner generally pays the bill. While there can be clear economic benefits to the owner for shifting bill paying responsibilities to tenants, there is another supporting argument for doing so. Other research has shown that when occupants have responsibility for costs they are much more likely to conserve -- savings of 10 to 20 percent can occur. In our analyses we did not take credit for savings from these strategies -- we simply shifted responsibility for the cost. But, though difficult to accurately estimate, additional savings on this order will probably occur. Keep this in mind when you assess retrofit strategies for your own buildings.

Retrofitting for Energy Savings . . .A Good Investment

As we said before, costs for retrofit strategies are higher. Our costs ranged from $131 per unit in Oakland, where few actions beyond operations strategies could be cost effectively undertaken, to $1,582 per unit in Chicago, where aggressive building shell modifications -- storm windows, replacement of glazing with insulated inserts, caulking and new window gaskets for a building with glazing equal to 36 percent of the floor area -- accounted for $700 per unit.

Even so, retrofit strategies are very good investments. Paybacks range from 1 year to 6.3 years, averaging just under 3 years for all the buildings. What we were not able to quantify, but is very important to consider, is the fact that our strategies, beyond cutting energy costs, would significantly improve tenant comfort. We believe that this aspect should not be ignored. Increased comfort has two benefits -- fewer tenant complaints and longer term tenancy -- both resulting in reduced management costs.

How long will it take Retrofit Strategies to payback?. . . Less than 3 years in most cases.

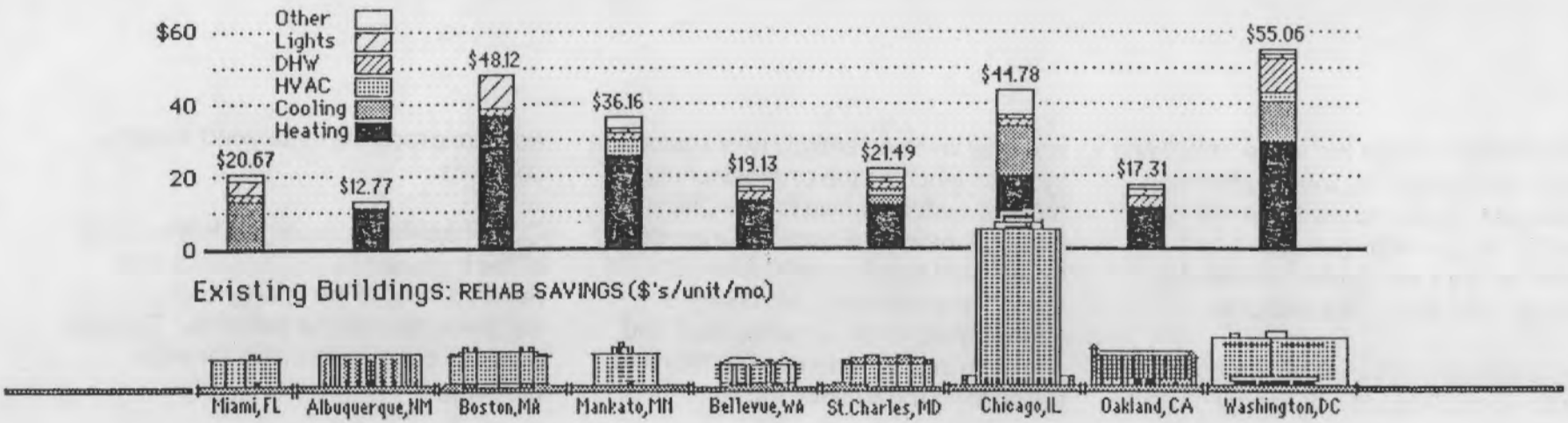


Rehabilitating Multifamily Housing . . .Looks at Broad Market Concerns

Rehabilitation of multifamily housing is an increasingly important activity in the U.S. Our housing stock is getting older; close-in urban locations are scarce and expensive; and new buildings are very expensive, so rehabilitation, even of not very old buildings, can be attractive. Rehabilitation will most likely, but not necessarily, occur when ownership of a building changes.

Energy cost reductions should be a key aspect of the rehabilitation effort. Not only can energy savings be used to help owners meet their financial objectives, as will be shown in the next chapter, they can also be used to add amenities which upgrade the project's market position -- and its rents. Our savings increased over our retrofit efforts by a significant amount, ranging from $12.77 per unit per month to $55.06 and averaging $30.64 across all the buildings (a 25 percent increase over retrofit).

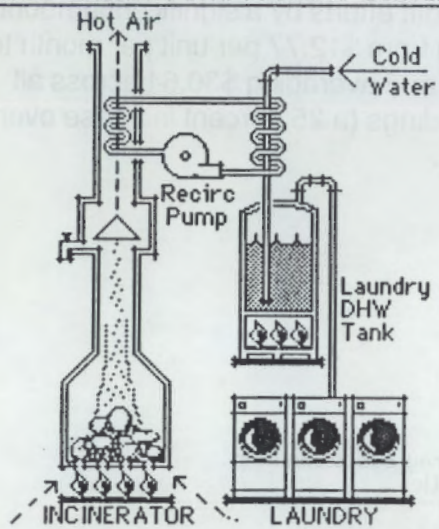
How you can save with Rehabilitation Strategies . . . Greatly reduced energy costs can help pay for added amenities.



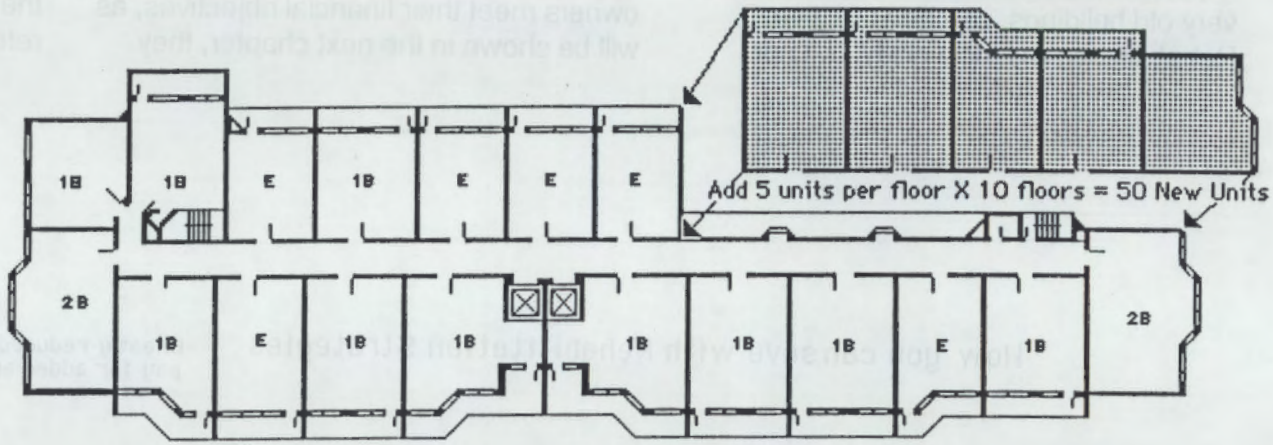
Rehabilitating Multifamily Housing . . .

REHABILITATION STRATEGIES OFTEN WORK WITHIN THE CONSTRAINTS OF EXISTING BUILDING SYSTEMS . . .

CHICAGO LAUNDRY DHW PREHEAT CONVERSION



. . . BUT MAY ALSO INVOLVE TOTALLY NEW SYSTEMS AND, IN SOME CASES, MAJOR BUILDING ADDITIONS – Such as in the Washington, D. C. highrise where 50 new units were added to the building



Rehabiilitation is not the same as building new. Energy cost-cutting rehabilitation strategies must be considered within the context of the existing structure and systems, but there is more latitude for change than in retrofit situations.

Rehabilitation strategies will probably touch upon all aspects of energy costs and may involve: entirely new equipment systems (such as the central laundry preheat system shown for the Chicago building); new shell systems (exemplified by the fixed shading system for our Washington highrise); site changes (landscaping for St. Charles, etc.); and can even include extensive additions to the building (new floors, etc.) for economic reasons far beyond energy concerns.

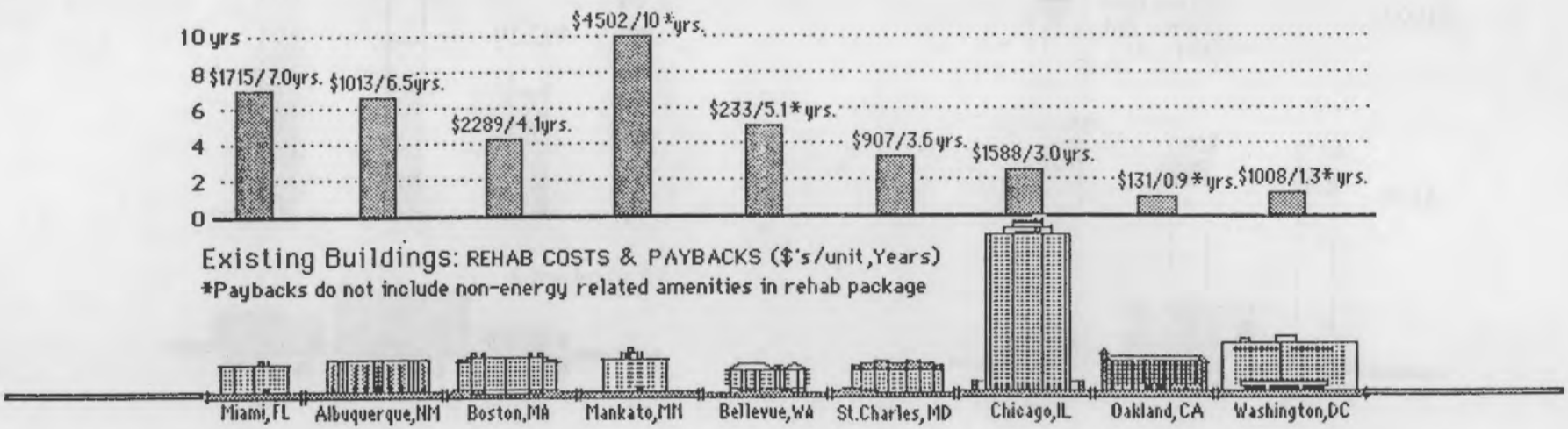
Our rehabilitation strategies looked at all of the foregoing for our buildings and reduced most of the energy cost components in all the buildings. The lists of things done is extensive for each building.

. . . Energy Should Be an Important Part of the Solution

Rehabilitation strategies are more costly than either operations or retrofit efforts, however. Our rehabilitation strategies costs ranged from a low of $132 per unit (we just could not do much to the Oakland building) to $4,502 for the Mankato midrise. In fact, our Mankato package, with a payback of 10 years for the energy items alone, is very questionable as an investment. Excluding the Mankato building results, the highest rehabilitation cost is $2,290 per unit for the Boston midrise, yielding an average rehabilitation cost of $1,111 per unit.

Paybacks for our rehabilitation strategies were also generally higher, as shown below. Excluding the Mankato building, they ranged from less than 1 year (Oakland again) to 7 years (the Miami midrise), averaging 3.9 years.

How long will it take Rehabilitation Strategies to payback?

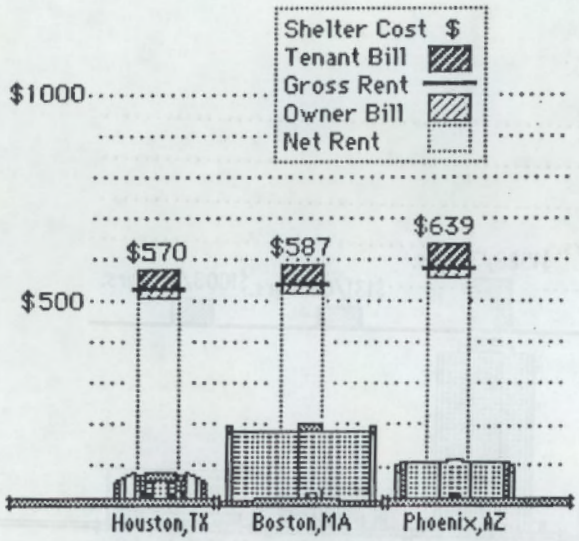


Multifamily Housing in The Future. . .

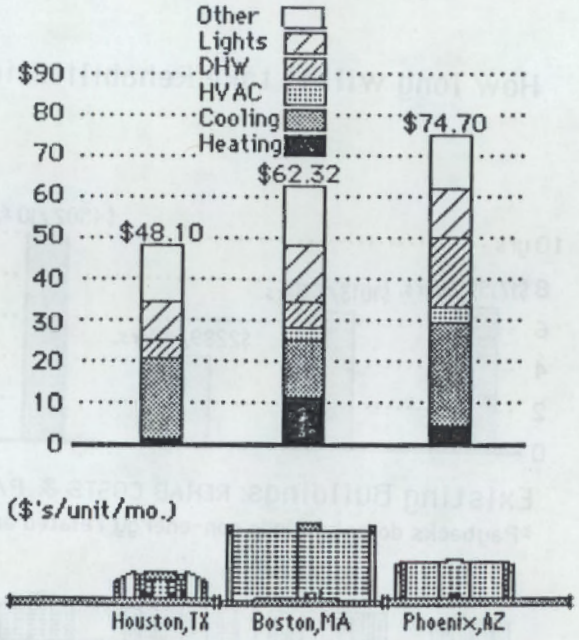
Energy cost-cutting in new multifamily designs is much different than efforts for existing buildings. Right now, the multifamily housing industry is undergoing fundamental changes -- rents are high, going higher and housing is becoming less affordable; the population is getting older; and the industry has already made significant strides in cutting energy costs in new buildings.

In order to assess the energy cost cutting potential in future multifamily housing, we wanted to take into account as many trends as possible. An NAHB roundtable "Multifamily Housing: Planning for the Next Five Years" was conducted by industry leaders in January, 1985 to identify changes anticipated in the U.S. multifamily housing. The key trends identified were: downsizing of units (by 10 to 20 percent); increased project size (in number of units); dense developments (more midrise and highrise projects); and increased amenities -- all in the context of more affordable multifamily housing.

What is the Real Cost of Shelter?



Components of the Energy Bill . . .

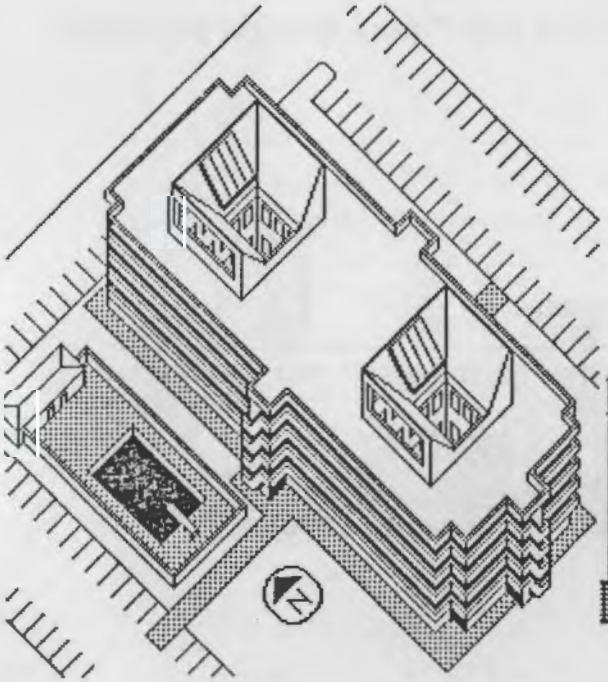


. . .Must Respond to a Changing Industry

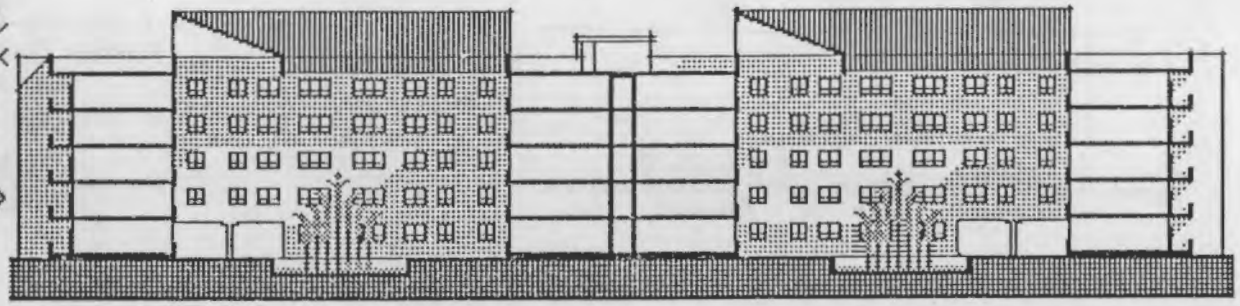
In turn, the NAHB research team conducted a design charette with leading IREM representatives to develop three baseline future buildings: a lowrise complex in Houston, Texas; a midrise for Phoenix, Arizona; and a highrise in Boston, Massachusetts.

The team used current practice as a guideline, but did not make energy an overriding concern in the designs. The projected energy costs for these buildings, shown previously, were nonetheless very good in comparison to costs in our existing buildings.
Our charge was to then redesign these buildings, with energy as a major focus, to see if significant additional savings could be achieved.

In this exercise we looked at fundamental changes in how multifamily housing might be configured: we looked at atrium buildings; we considered exterior corridors and solar strategies; we looked at using the natural environment and siting to take advantage of climate conditions; we investigated opportunities and the potential need for code exceptions and changes; all in the context of an owner's requirements for return on investment and the original building costs.



A redesigned future Phoenix Midrise creates shaded courtyards with fountains for evaporative cooling -- a "man-made oasis"

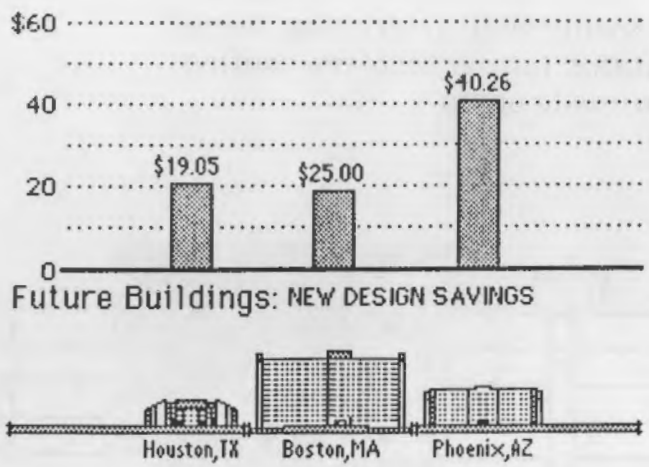


Multifamily Housing in the Future Can Have Even Lower Energy Costs

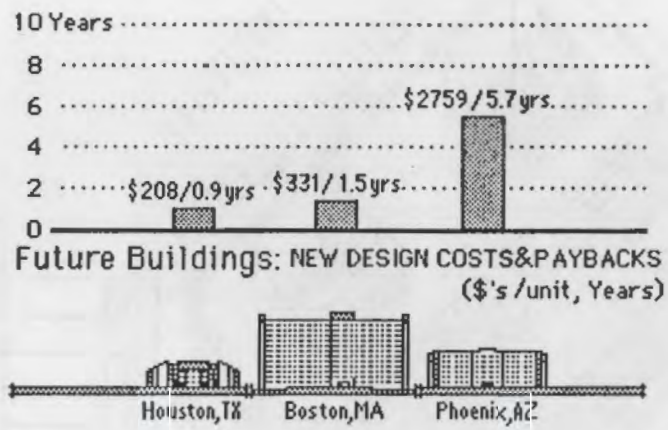
Results are significant. Looking at energy cost reductions, average savings were $26.45 per unit per month--ranging from $19.05 to $40.26 -- over 42 percent of already low energy costs.

The costs for the new design configurations were very modest in two cases, adding $331 per unit to the building cost in the Houston lowrise, and just $208 per unit in the Boston highrise project. The approach used in the Phoenix midrise was much higher in cost, $2,759 per unit, but changed the character and quality of the building so much that the team felt that rent increases would be easily justified. Even without rental increases for increased amenities, average payback for our new designs was only 2.7 years, ranging from less than 1 year (Boston) to 5.7 years (Phoenix).

How much can be saved in future designs?



How quickly will new future designs payback?



Cutting Energy Costs in Multifamily Housing Will Work for You

In summary, cutting energy costs in multifamily housing can be a good investment no matter when it is considered in the life-cycle of your projects.

Restating our results, energy cost-cutting operations strategies, the most easily implemented and cost-effective actions you can take, on average saved $13.29 per unit per month, and cost only $78.42 per unit, yielding a payback of less than 1 year.

Retrofit strategies, while more expensive and somewhat disruptive to facility operations, saved $24.60 per unit per month, cost $754 per unit, and paid for themselves in 2.9 years.

Rehabilitation strategies, usually undertaken when the ownership of the building changes, and always in the context of broader market concerns, involve substantial changes to building equipment and shell. They saved, on average, $30.64 per unit per month, cost $1,487 per unit, and paid for themselves in 4.5 years.

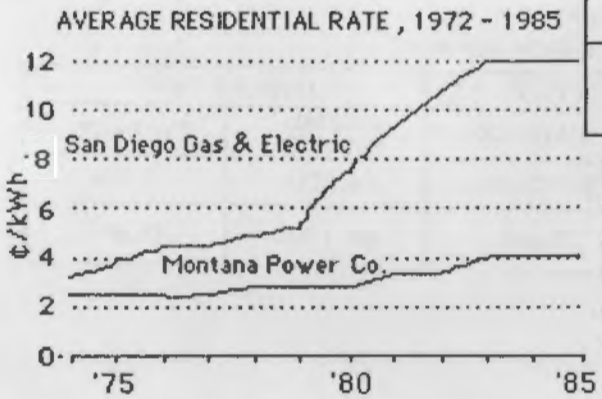
New building design strategies with a sharp focus on energy can produce very impressive energy cost reductions, savings that can be used to significantly improve the quality of your proposed housing project. Our savings in new designs averaged $26.45 per unit per month, over 40 percent of already low energy costs, at a cost of $1,099 per unit, paying for themselves in an average of 2.7 years.

Remember that the specific solutions we derived for our buildings may or may not apply to your particular project and circumstances. You will need professional evaluation of our strategies (and others not listed), especially in instances of retrofit, rehabilitation, or new design, to see whether they are appropriate and cost-effective for you.

Chapter II: Energy Decisions for the Builder/Developer

With all the concerns on a builder's or developer's mind, why bother about energy? From the conception of a project idea, a typical developer is "at risk" for the cost of a site, a market analysis, legal and filing fees, an architectural design fee, and preparation of a mortgage package to be presented to the lender. As one industry analyst put it, "Given everything on the developer's mind, energy usually gets about twenty minutes attention...max."

The purpose of this chapter is to suggest to builders and developers why energy costs merit attention. The earlier energy costs are considered in the project planning process, the greater are potential energy savings. These savings can mean happier tenants and improved financial return for owners.



As shown on the graph below, the increase in residential electric rates is a very good reason to consider energy costs. In some areas, rates are as much as four times higher than just a decade ago. Not only do rate increases of this magnitude cut into owner profits, they have made prospective tenants sensitive to "shelter costs" -- the total of utilities and base rent.

The matrix of "Estimated Savings", below, shows the energy cost savings that are possible based on the case studies in Chapter IV. Although savings vary depending on building type, the case studies in this book illustrate that improving building operations can cut energy costs 15-25%, making energy conserving retrofits can save 25-45%, and rehabilitation can save over 50%.

Estimated Savings with a 5-Year Payback or Less

Strategies	Buildings		
	Highrise	Midrise	Lowrise
Operations	15-35%	8-24%	18-22%
Retrofit	34-49%	26-41%	26-39%
Rehabilitation	27-56%	21-54%	31-45%

Savings of this magnitude are significant. In a Chicago highrise, for example, a 15% savings in operations is over $100,000 in reduced costs. A 34% savings based on retrofitting the building saves $250,000 a year. Savings in midrise buildings are typically in the $10,000--50,000 range per year. These investments all pay for themselves with savings in 5 years or less.

As shown in the comparison below, if tenant energy bills are reduced only $30 per month, the income needed to qualify for an apartment can be reduced by over $1,100. This is a benefit to owners in terms of more potential tenants and to the country in terms of more affordable housing.

Lower Energy Costs Make Housing More Affordable

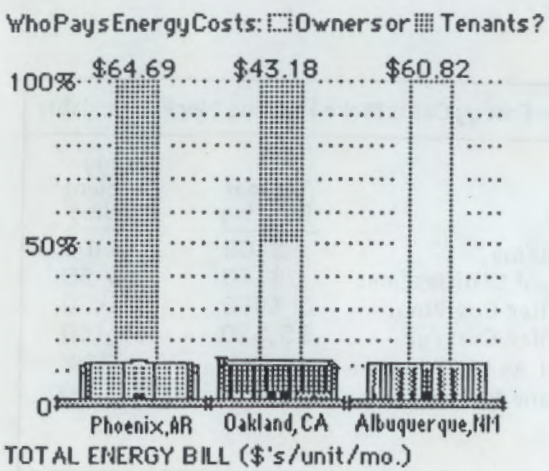
	Typical Building	Energy Efficient Building
Rent/mo.	$400	$400
Tenant Utilities/mo.	$ 60	$ 30
Shelter Cost/mo.	$460	$430
Shelter Cost/yr.	$5,520	$5,160
Rent As % Of Income	35%	35%
Income to Qualify	$15,800	$14,700

Energy Cost Savings Can Increase Profits . . .

The issue of who pays the energy bill is an important one, because it determines how much capital an owner has to make energy improvements. Who pays is both a matter of tradition and timing. In highrise buildings, owners have traditionally paid all or most of the utility costs. The opposite is true in lowrise apartment buildings. Central meters are very common in old buildings, whereas individual tenant meters are used in virtually all new buildings. There are no hard and fast rules, however. As shown on the bar graph of three roughly equivalent midrise buildings in different parts of the country, the owner's pay 20%, 50%, and 100% respectively of the annual building energy costs.

Owner's who pay a majority of utility costs carry the risk of increasing electricity and fuel prices but they also have the benefit of direct access to savings from energy improvements. On the otherhand, owners who pay little of the total energy cost of a unit must rely on the marketplace to give them increased rents in return for more energy conserving units if they are to have the cash flow necessary to pay for the improvements.

For example, in the case of a lowrise building in Maryland, one design team recommended changes to the building during rehabilitation that cost $31,000 but gave annual energy savings of $8,600. Of that, $6,200 were reductions in the owner's annual energy bill and $2,400 was shared among thirty-four units. From the owner's perspective, these savings gave a reasonable payback of five years. However, from a whole building perspective, the payback is actually a much more attractive 3-1/2 years. Obviously, it is much more of a problem when the majority of energy savings fall to the tenant. In the Maryland case, the second design team proposed strategies that cost $75,000 and gave annual energy savings of $9,500, the majority of which went to the tenants. In this case, if owner savings alone were required to pay for all improvements, the payback on this investment is an unacceptable eighteen years.



WHO GETS COST SAVINGS IN A MARYLAND LOWRISE?:
PAYBACKS ARE VERY DEPENDENT ON WHO BENEFITS FROM SAVINGS

REHABILITATION STRATEGY		WHOLE BUILDING VIEW		OWNER'S VIEW	
Team	Cost	ANNUAL SAVINGS	PAYBACK	ANNUAL SAVINGS	PAYBACK
A	$31,000	$ 8,600	3-1/2 yrs.	$6,200	5 yrs.
B	$74,000	$ 9,500	8 yrs.	$4,100	18 yrs.

. . . Increase Building Value and Reduce Equity Requirements

Simple payback is used as the basic economic indicator in this study. It is an easy to understand comparison of first cost and annual savings. However, it does not account for savings which continue long after the original investment has been paid back. Following are three examples of how more sophisticated financial analysis can be used by different investors.

Current Owner Refinances & Makes Energy Improvements

GOAL: Take Maximum Equity Out Of Building

Building	Existing	Improved
Rent	$400/mo.	$400/mo.
Owner Paid Utilities	$ 50/mo.	$ 30/mo.
Annual Savings Per Unit		$240/yr.
Capitalized Savings (at 9%)		$2,640/unit
Increased Loan Value (at 80%)		+$2,100/unit

This owner wishes to refinance a building in order to withdraw equity for other purposes and uses energy savings to increase the loan value of the building. A savings of $20 per month is capitalized (at nine percent) to a value of $2,640. Assuming a loan of eighty percent, the loan value of the building is increased $2,100 per unit.

New Owner Includes Energy Improvements in Financing

GOAL: Minimize Initial Equity

	Existing Building	Improved Building
Initial Cost	$30,000/unit	$31,080
Rent (average)	$ 500/mo.	$ 500/mo
Owner Paid Utilities	$ 60/mo.	$ 30/mo
P & I on 70% Initial Cost (@ 10% for 30 yrs.)	$ 184/mo.	$ 191/mo
Net Cash Flow	$ 256/mo.	$ 279/mo
Capitalize (@ 10%)	$30,720	$33,480
Loan Value (70%)	$21,504	$23,436
Required Equity	$ 8,496	$ 7,644
Equity on Improvements		$ 324
Net Equity Required		$ (528)

In this case a new owner uses an increase in cash flow to reduce the amount of equity required to purchase a building. Assuming that owner-paid utilities be reduced by half ($30 per month), the owner is willing to add $1,080 per unit to the original cost of the building. Net cash flow is increased and therefore the loan value can be increased. Even after the owner pays the portion of the initial cost of the energy improvement which is not financed, the net equity for the project is still reduced over $500 per unit.

Current Owner Borrows To Make Energy Improvements

GOAL: Increase Long Term Return

Building	Existing	Improved
Rent/mo.	$400	$400
Owner Paid Utilities	$50	$30
P&I	($1,080@11%-3yr.)	$37
Net Cash Flow:		
years 1 - 3	$350/mo.	$333/mo.
years 4 - 15	$350/mo.	$370/mo.
Lost/Added Income per unit		
years 1 - 3		-$715
years 4 - 15		$4,600
Net Future Added Income		$3,885

In this example, the current owner of a building wishes to maximize long term return on investment and chooses to borrow the funds necessary to make energy improvements to the building. It is estimated that energy costs can be reduced 40% from $50 per unit per month to $30. The owner is willing to accept a three-year payback on the initial cost of $1,080. This is borrowed at 11% for three years.

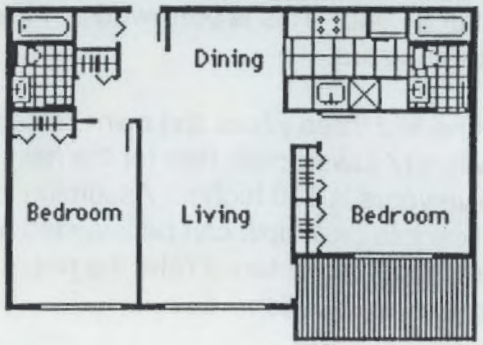
For the first three years, the owner's cash flow is $17 lower; cash flow for the next twelve years is $20 higher. Assuming that excess cash flow can be invested at an eight percent interest rate, the net increase is $3,885.

Energy Cost-Cutting Yields Economic Opportunities...

In reviewing market analyses as background for this study, two trends were noted again and again (1) that the demographics of the apartment population are changing significantly, and (2) that cost reductions are necessary if housing is going to be affordable in the future. Although not strictly energy issues, these trends were considered by the design teams while looking for energy cost reduction alternatives.

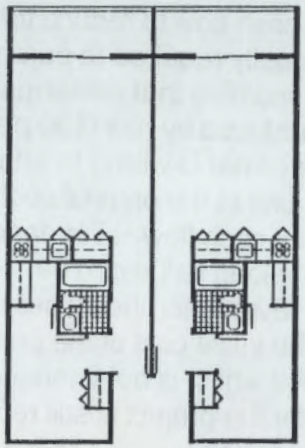
The number of elderly in the U.S. is increasing; single parents are also increasing; and many likely first time home buyers are delaying purchases. All three groups commonly share housing with others. In response to this need, new "split" units are being developed that separate bedroom and bath areas while sharing living and kitchen facilities, as illustrated in the drawing below. Shared appliance use and greater individual room HVAC control are just two of the energy issues raised by this new housing alternative.

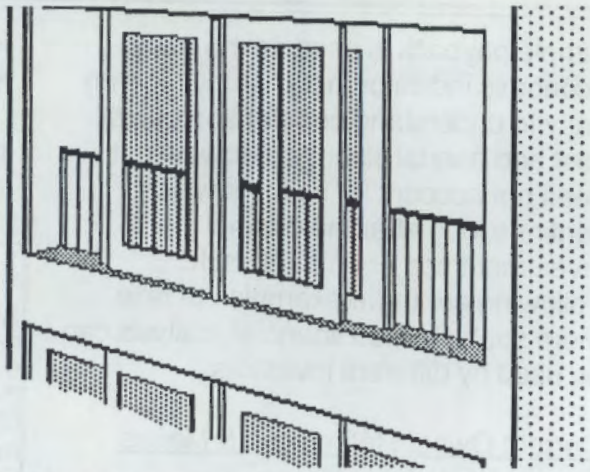
TWO BEDROOM - SPLIT



Another common assumption about the future is that apartment sizes will have to decrease to make housing and utility costs more affordable. However, an analysis by the study team indicated that only about one-third of the average cost per unit are variable depending on square footage. Will future renters be willing to "trade" simpler kitchens and bathrooms for larger units?

The requirement that all bedrooms have outside windows increases the costly exterior skin of a building. One design team questioned whether or not tenants might give up the amenity of windows in one bedroom for more space elsewhere in the unit.





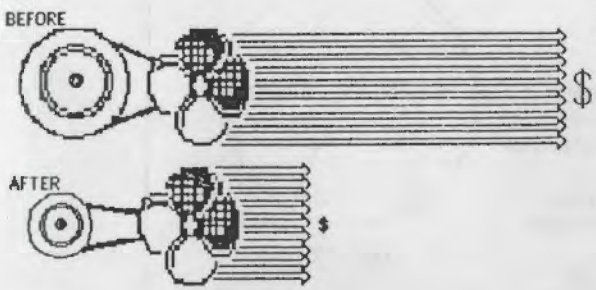
INSTALL PATIO DOORS ON SOUTH BALCONIES TO CREATE SUNSPACES

The question of amenity came up in another context as well. In several case studies, design teams found that enclosing existing balconies with improved exterior walls could significantly reduce energy use. Although inspired by energy conservation motives, added rents from the additional space not only pay for the improvement in the short run but continue to add value by increasing cash flow in the long run.

. . . But There Are Economic Tradeoffs

Energy conservation also raises questions about a number of important economic tradeoffs. Three examples are given here.

The amount of corridor ventilation currently required by most building codes is considered by many to be excessive. In addition, many existing corridor ventilation systems are actually operating far in excess of code requirements. The excess ventilation creates unnecessary energy costs for both owners and tenants. The design teams felt the rate of ventilation could be decreased significantly in most of the buildings studied without decreasing indoor air quality.



HALVING FAN PULLEY SIZE AND CUTTING OPERATION HOURS IN HALF RESULTS IN A 75% REDUCTION IN HEATING COSTS DUE TO VENTILATION

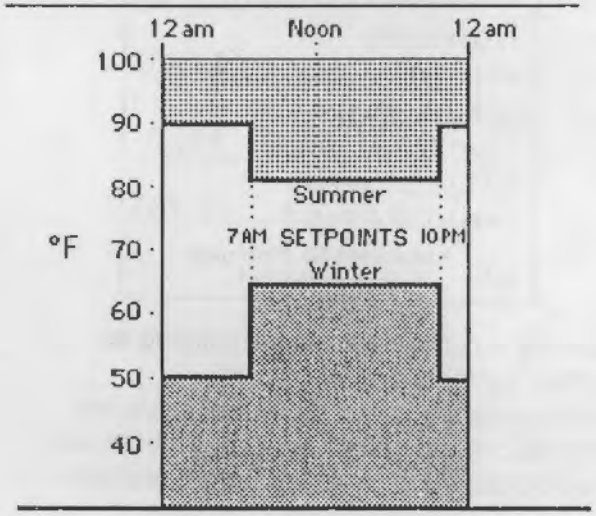
Lighting is another area of tradeoff. The availability of new screw-in fluorescent lights means that owners and tenants can replace existing incandescent lamps with

LAMP	First Cost 9,000 hrs	Operating Cost 9,000 hrs @ 7¢/KWh	Total Cost 9,000 hrs
Incandescent 60 W	$6.75 (9 bulbs)	$37.80	$44.80
Screw-in Fluor 15 W	$7-15.00 (1 bulb)	$9.45	$16.45 - 24.45

fluorescent alternatives without having to change fixtures. As shown on the table, long term cost savings can be significant but not all tenants are happy about the quality of light from fluorescent lamps.

Another tradeoff is in the area of common area temperatures. Owner energy bills can be significantly reduced by extending the temperature setpoints of corridor HVAC systems -- especially during unoccupied hours. The issue is whether warmer corridors in summer and cooler ones in winter will be acceptable to tenants.

THERMOSTAT SETTINGS IN PUBLIC CORRIDORS



Energy Economics in Subsidized Housing is Complex for All Concerned

The federal government has been a major factor affecting the multifamily housing industry since World War II. Through a sequence of support programs (608, 221d3, 236, Section 8), the government has extended its influence to over 3-1/2 million units of housing.

As shown in this example from a public housing project, energy costs can be

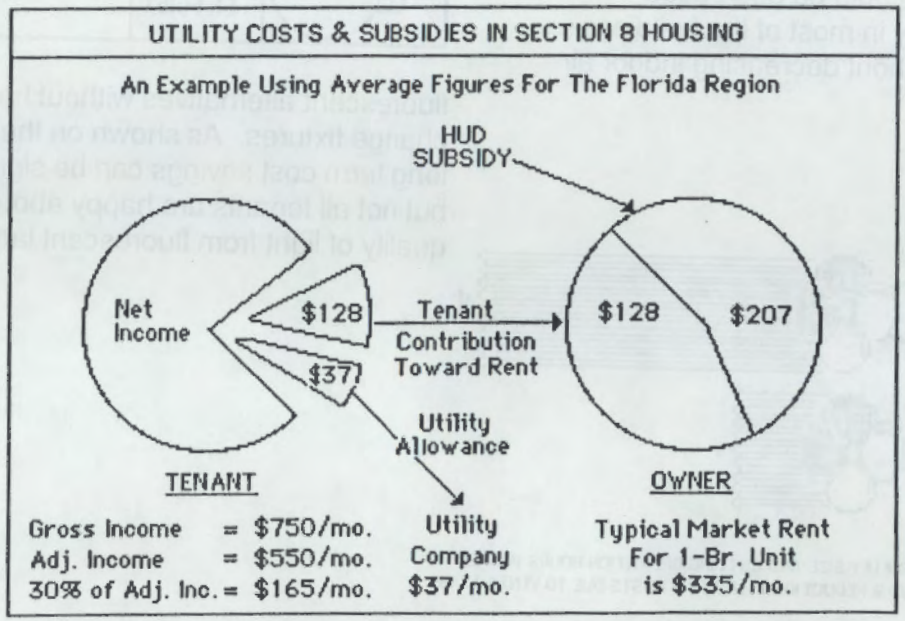
Energy and Rent Analysis	
(Typical One-Bedroom Unit)	
Tenant's Monthly Energy Cost/Unit	$ -0-
Owner's Monthly Energy Cost/Unit	($ 89)
Monthly Operation &Maintenance Cost	($109)
Total Monthly Cost/Unit*	($198)
Typical Monthly Rent (max: 30% of income)	$125
Net Operating Profit (Loss)/Unit/Month*	($ 73)
*Assumes No Mortgage Payment Cost	

nearly as great in an older building as other monthly operating and maintenance costs. In the case shown, these costs together are greater than the rent charged to tenants under this public housing program. Any savings achieved through energy conservation would directly reduce operating losses in this building.

As illustrated in the diagram below, the relationship between utility costs and HUD subsidies is more complex in the Section 8 program. Basically, rent may not exceed 30% of a tenant's adjusted income.

HUD pays the balance as a subsidy to the building owner. Tenants are typically required to pay their own utility bills but they receive a credit or "utility allowance" against these costs.

If energy conservation is to be taken seriously in Section 8 housing, ways must be found to give all the participants in this transaction an incentive to participate. Tenants need to receive a share of monthly energy cost savings to be encouraged to save. Owners must receive a share also in order to pay the capital cost of improvements. For example, market rents might be



increased modestly to reflect the value of a higher quality energy efficient apartment unit, and HUD should receive a share of cost reductions so that subsidies might be reduced -- giving them an incentive to participate.

Given the age of much of the existing subsidized housing stock, it is likely that significant energy savings are possible in most buildings. The issue is not whether improvements will save money but how the improvements can be financed.

The final illustration shows a scenario for funding energy conservation improvements without federal grants. In this example, the cash flow generated from annual energy savings is used to pay off state-backed housing improvement bonds. As shown, savings of $40 per month on a unit utility bill can support an investment of $2,900 per unit after accounting for all financing and overhead costs. For this scenario to be possible, however, local housing authorities must be able to pledge the underlying value of their housing assets. This is not typically possible under current federal regulations.

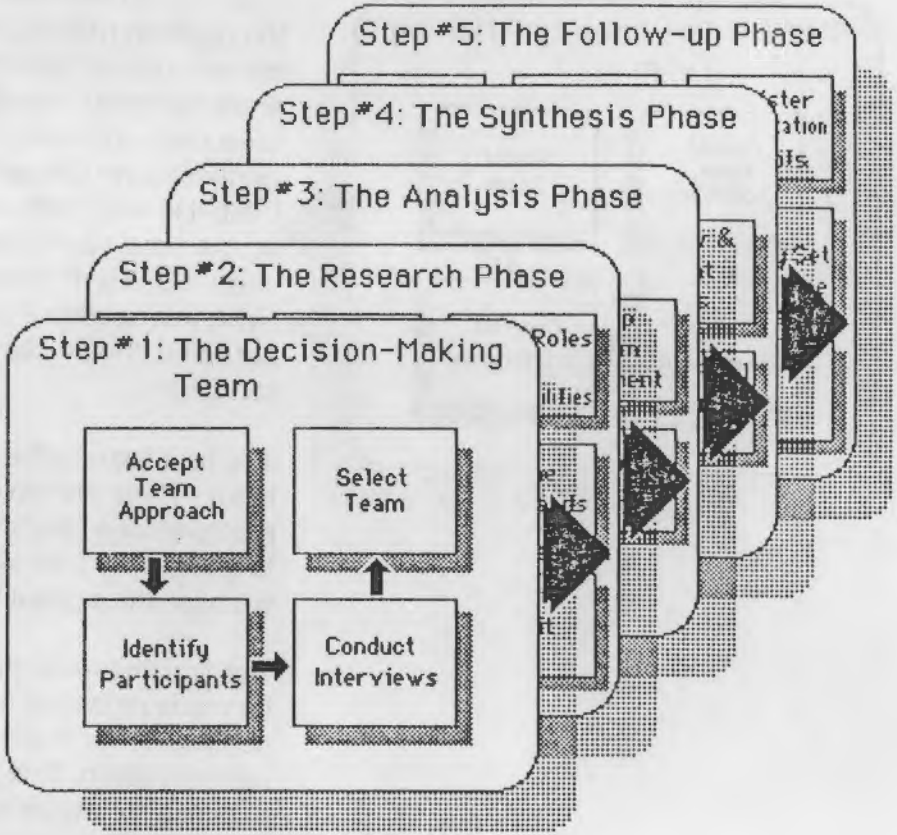
A SCENARIO FOR FINANCING CONSERVATION IMPROVEMENTS WITHOUT FEDERAL GRANTS --	
Use Utility Savings to Payback State-Backed Bonds	
Monthly Savings (assume 45%)	$40/Unit x12Mos
Annual Savings	$ 480/Unit
Equivalent Loan Value (Max. loan value at 10% with annual payment of $480)	$4,800/Unit
Less "Soft" Finance Costs -	$1,200/Unit
Less Housing Authority Overhead - (15% est.)	$ 700/Unit
NET CASH to Finance Energy Improvements	$2,900/Unit

In Summary....

Energy conservation merits the attention of even the busiest builder or developer. This study illustrates how energy operating costs can typically be reduced by 20-40% in most buildings -- even more in older or poorly operating buildings. The cash flow generated from these savings can then be used to meet the owner's own financial goals -- to increase value, to improve long term return on equity, or to decrease the equity required for a new purchase.

As is shown in this study, energy improvements help justify other amenity improvements in a building to the benefit of tenants and owners alike. There are tradeoffs, however, and each owner must judge what is advantageous for his or her own market segment. The purpose of this study is to illustrate the cost and benefit of many different strategies in real and proposed buildings so owners can see for themselves why energy merits their attention.

Chapter III: The Decision-Making Process



To make the most cost-effective investments in energy conservation, one must commit to a formal problem-solving process. Understanding the steps involved and maintaining a constant focus on the original goal are essential elements of this process. Each step must be consistently and thoroughly carried out.

STEP 1: THE DECISION-MAKING TEAM discusses the rationale for accepting a team approach, outlines the key disciplines required and offers criteria for the selection and organization of the team.

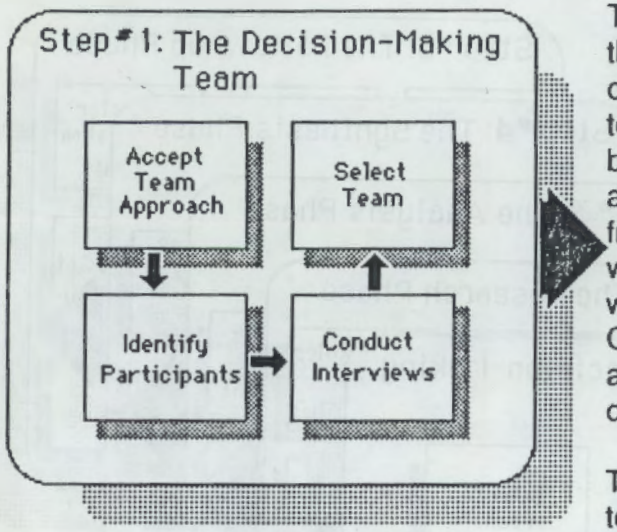
STEP 2: THE RESEARCH PHASE lists the key elements and limits of the research effort and establishes the primary roles and responsibilities of each team member.

STEP 3: THE ANALYSIS PHASE presents the goals and objectives of the analysis effort, discusses analysis methodology and stresses the importance of defining the energy problem.

STEP 4: THE SYNTHESIS PHASE addresses the development and evaluation of energy conservation strategy sets.

STEP 5: THE FOLLOW-UP PHASE describes the key points of implementation of these strategy-sets and the significance of their proper operation, monitoring, and maintenance.

The Decision-Making Team . . .



The first and most essential ingredient in the decision-making process is the owner's recognition of the need for a team approach. It may sound expensive, but it costs a lot less in the long run to get all necessary data and points-of-view up-front. It is very costly to redo work or, worse, have your effort fail because input was missed until too late in the process. Once this need has been recognized and accepted, the problem-solving process can begin.

The next issue is the composition of the team. There are seven key disciplines, points-of-view, that must be represented to adequately address the concerns that will arise throughout the process.

The first and most important decision to be made regarding the team's composition is to determine Owner representation. This position is critical because the owner or his/her representative must assist in establishing the goals for the team. The Owner plays the major role in acquiring necessary historical information regarding the project, and is the only source for establishing investment assumptions.

The second position to be filled is that of the Project Manager and information coordinator. This position is typically held by an architect. The Architect is traditionally responsible for the supervision of team members and for the coordination of the information which arises from the application of their specialized skills.

The third position to be filled is that of the Energy Analyst. The unique skills of the energy analyst are absolutely required to determine how the existing facilities use energy, and how recommended changes will affect energy use. These skills must include experience with computerized energy analysis programs.

Positions four and five are engineering positions. Both a Mechanical Engineer and an Electrical Engineer are essential, as both bring special knowledge of local practices regarding mechanical and electrical systems, codes, ordinances, and climate.

The sixth team member is a Cost Estimator and the seventh is a budget or Financial Analyst. These two positions are complementary and essential, as the final decisions in this process will be primarily based on economic issues.

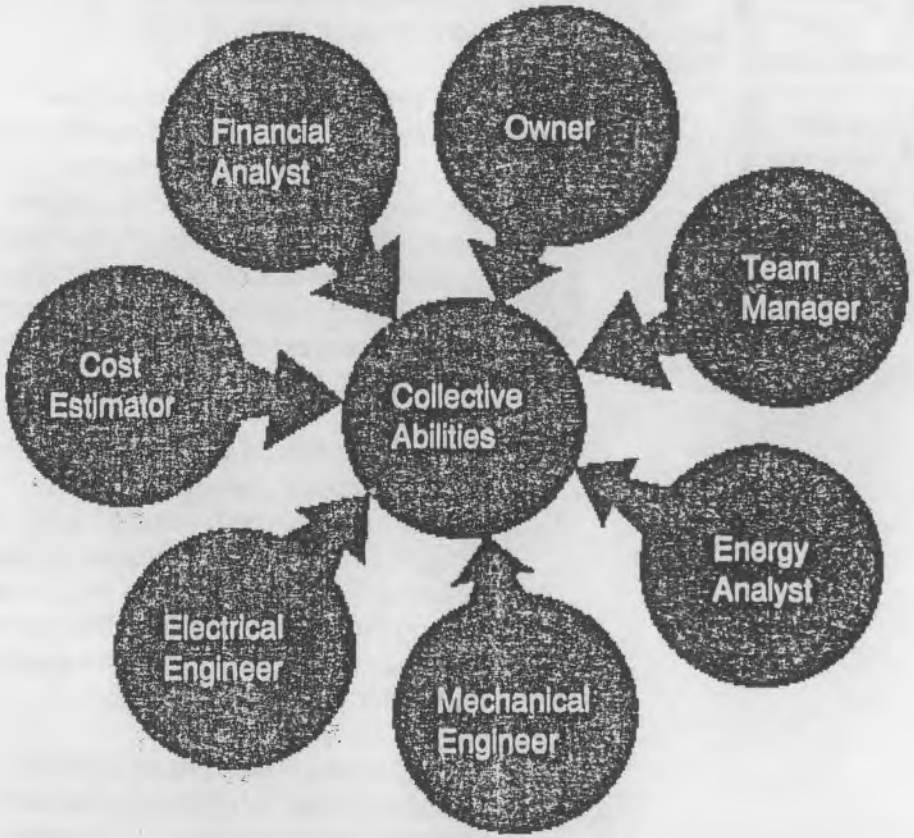
. . . Seven Key Points of View

All seven of these positions must be filled; however it is not necessary that each position be held by a separate individual. Make sure someone wearing more than one hat consciously brings each separate perspective to the table.

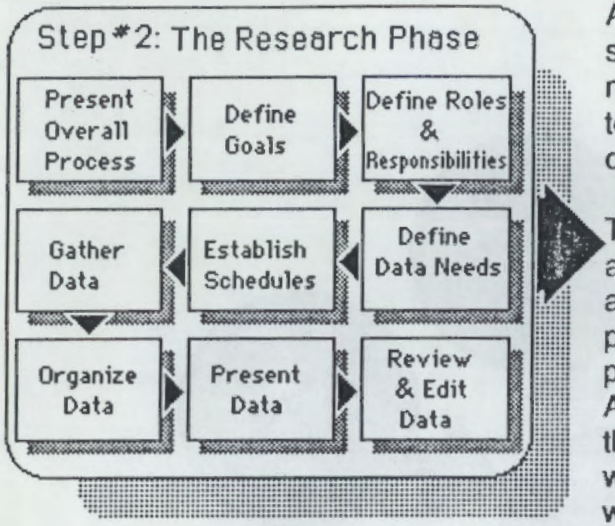
Operation of the team is organized around formal and not so formal meetings, so the members must be good at working in groups and in "real-time". Because of the nature of multifamily housing development and operation, you probably cannot afford or tolerate a leisurely, "I'll get back to you on that next week", approach.

Team meetings should always include as many members as can be practically assembled. A team that meets frequently benefits enormously from the immediate exposure of ideas, the efficient exchange of information, the pressure, and the intensity of the group dynamic.

Every team meeting should have a specific written agenda and the proceedings of every meeting must be documented, both to inform those not present and to serve as a record of decision-making for future reference.



The Research Phase . . .



At the first team meeting the Owner should make certain that all the team members understand the Owner's Goal: to identify cost-effective energy-conservation strategy-sets.

The Project Manager should then assume the leadership role for the team and begin the research effort by presenting an overview of the entire process to be undertaken by the team. A clear presentation of the key steps of the process before actual work begins will give context to the many tasks that will need to be performed.

Once the decision-making process has been discussed, understood and accepted by all the team members, the Project Manager should focus the team's attention on the tasks to be performed during the research phase. Each team member will have specific tasks relative to his/her individual expertise.

The Owner will need to facilitate the research effort by identifying known sources for the data and documents needed. Additionally, the Owner will need to advise the property manager and staff of the research effort and clear the way for each team member to get access to the specific information each will be seeking.

If the project is an existing building, the original architectural drawings and specifications should be obtained and verified by the Architect for accuracy. In many cases changes made during construction are not indicated in the drawings and specifications available.

It is not necessary that the drawings and specifications be completely modified to reflect exact "as-built" conditions. However, the Architect or building designer should conduct a site visit to compare and note discrepancies between the existing building construction and the construction documents.

There are many energy analysis programs and each has a specific requirements and formats for input data, output reports, and computational capabilities. The Energy Analyst must discuss options with the other team members, determine the most important features for the project, and then select the appropriate energy analysis tool.

Weather data or climatic data for use by

the Energy Analyst is available from several sources. The National Oceanic and Atmospheric Administration (NOAA) is an excellent source for compiled weather tapes, as are local airport weather bureaus.

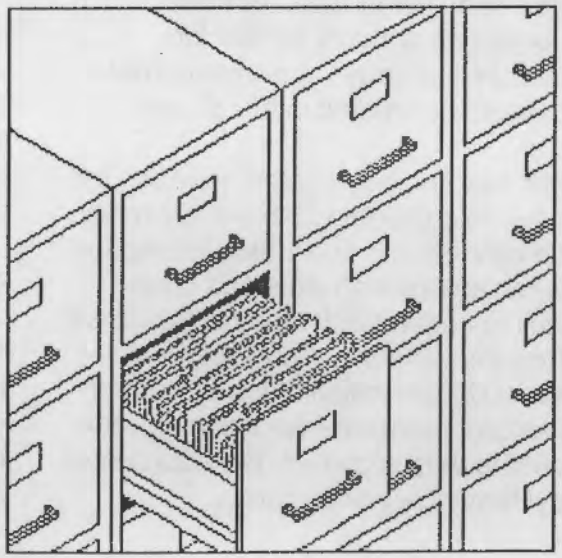
The Mechanical Engineer and the Electrical Engineer should check both available construction documents and actual conditions in the field. The age and condition of both mechanical and electrical systems should be carefully assessed.

The Engineers are also responsible for acquiring equipment maintenance logs, talking to maintenance personnel (often a source of great insight),obtaining utility rate information, and gathering together system manuals and warranties. The mechanical and electrical engineers should also identify pertinent codes and ordinances.

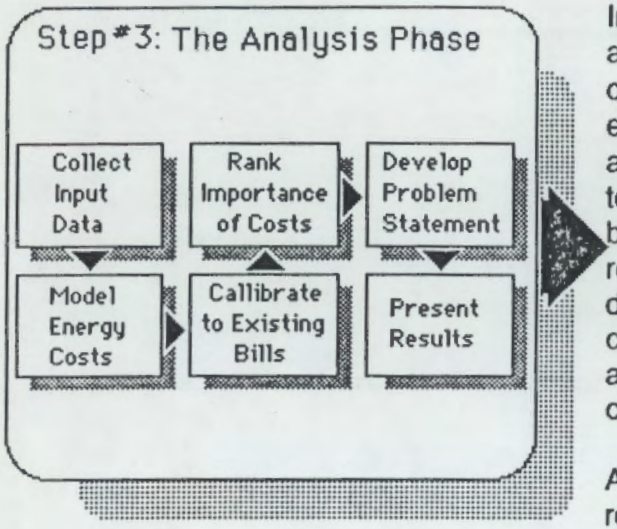
The Cost-Estimator provides the team with current industry-based construction cost data. Most professional cost estimators maintain their own cost data bases for this purpose.

Finally, the Financial Analyst should gather the project's utility bills, assemble current rent rolls, and identify and collect any expense data that may be relevant to the economic analysis. The Financial Analyst should also meet with the Owner to determine and agree on the Owner's financial criteria and the assumptions that will be used in the economic analysis.

The Project Manager should establish realistic schedules for gathering and assembling the data. As the quality of all future work will depend on the data gathered during the initial research phase, the importance of accuracy and thoroughness should be stressed.



The Analysis Phase . . .



In this phase, the team should develop an accurate and thorough understanding of how the facility being studied uses energy, and how energy costs are allocated between the owner and the tenants. This is true for both existing buildings (for operations, retrofit, or rehab) and future buildings (for new design) being studied to reduce energy costs. The analysis phase will establish a bench mark against which all energy cost-cutting concepts will be measured.

As a group the team will review the research data to identify misleading or inaccurate data, to openly discuss the research findings, and to establish an agreed-upon set of data. Graphic presentations are very helpful for understanding arrays of numerical data that should be studied in this phase.

In their raw and segregated condition the data tell us some things, but leave many of the connections and interrelationships between energy end uses and costs difficult to understand. Many opinions will surface immediately. To avoid the potential degeneration of the discussion into an argument over whose interpretation of the data is correct, the data should be systematically analyzed.

Computers and energy analysis programs are extremely useful and time-saving tools, but their effectiveness depends on the accuracy of the data input and the ability of the software to accurately project "real world" conditions. The team as a whole must rely on its experience and professional judgement to determine the value, relevance and acceptability of computer analyses.

From the output of the analysis, the team develops an Energy Problem Statement. This document should answer the following questions, both quantitatively and graphically:

1. Where is the energy being used and for what?

2. Who is using it and who is paying for it, the owner and/or the tenant?

3. When is it being consumed?

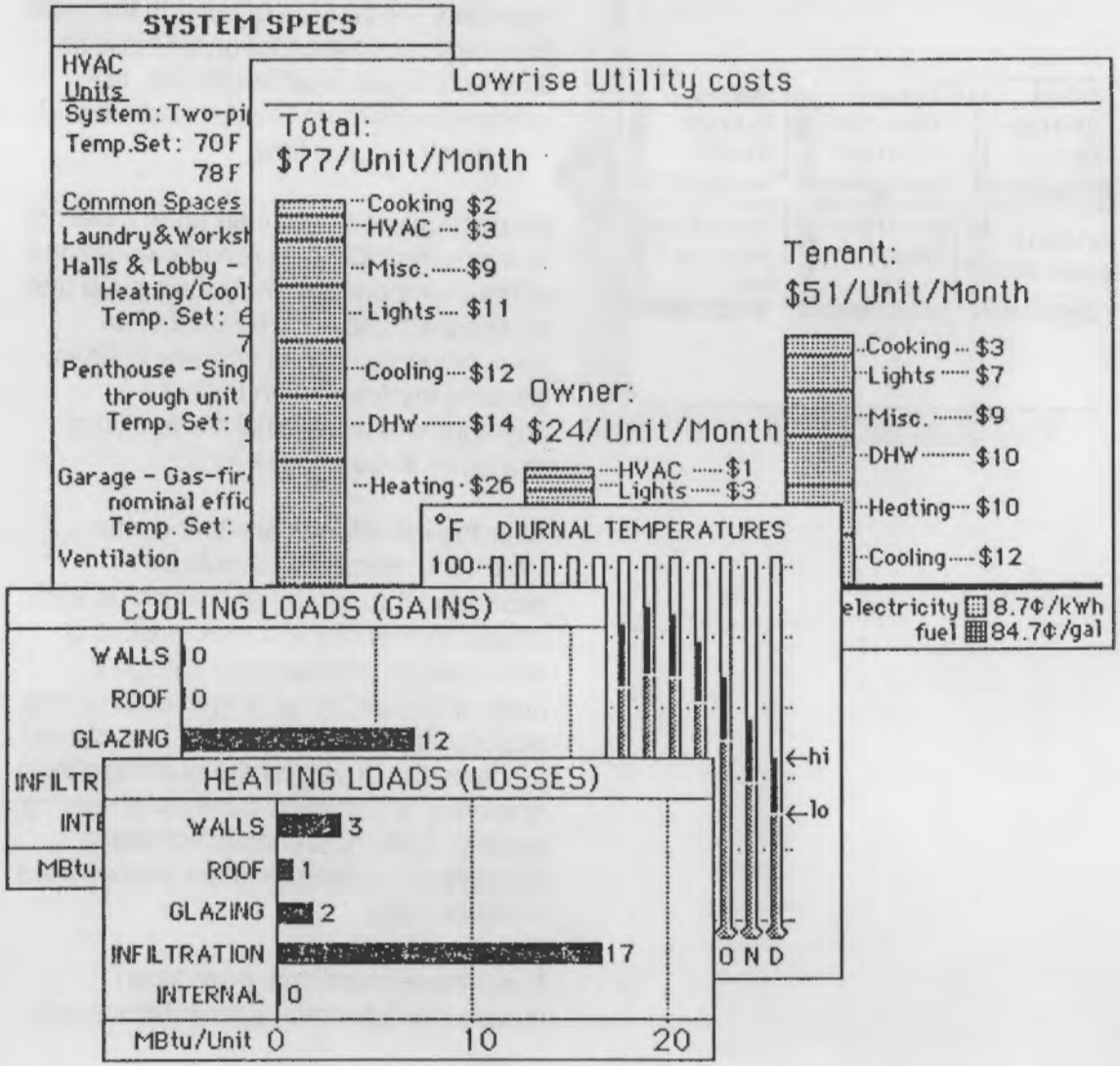
4. How much does it cost?

This statement should include and discuss a ranking, from highest to lowest, of all energy costs for the building (e.g. heating, cooling, hot water, equipment, appliances, elevators, lighting, laundry, etc.

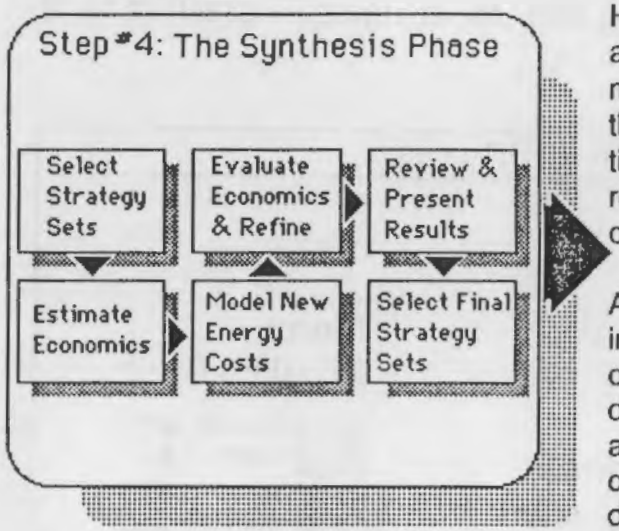
Once the Energy Problem Statement is available, individual members and the team as a whole can begin developing cost-effective energy strategies and sets of strategies to cut energy costs. If the analysis has been carefully and thoroughly carried out, the problem will have been clearly defined and the opportunities to cut energy use and cost will become apparent.

An Energy Problem Statement was prepared for each of the twelve buildings investigated in our research. These Statements are summarized on the "Energy Analysis" and "Economics" pages of each case study in Chapter IV. The case studies can serve as prototypes for developing your own "Energy Cost Problem Statement."

Organizing data for analysis -- Graphics Help



The Synthesis Phase . . .



Having now spent time gathering data and studying the analysis results, team members will be able to bring to the table their best recommendations. This is the time to fit together all the pieces, to release the pent-up stream of ideas and opinions. Let them flow!

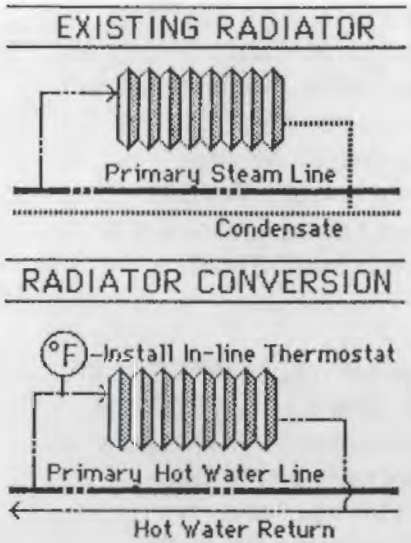
An unstructured and open team meeting in which the individual recommendations of the members are freely discussed and debated will allow the release of an astounding barrage of strategy options, creating the foundation for the development of an initial master list of strategies to be considered.

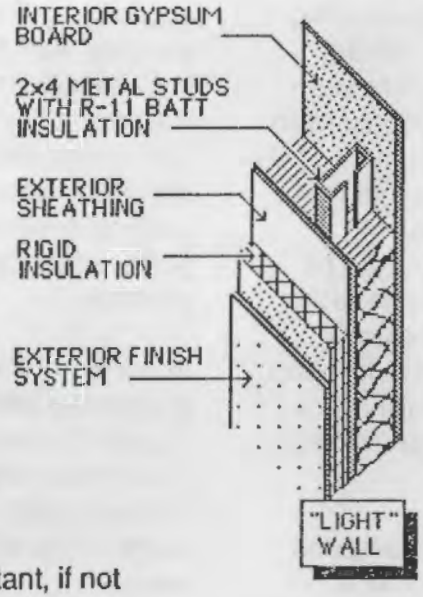
After the initial ideas are "put on the table", the master list should be expanded through team discussion and careful review of the characteristics of each energy end-use cost category, looking for specific or unique cost-cutting opportunities. These discussions should focus on the development of strategies in response to particular aspects of heating, cooling, lighting, domestic hot water, ventilation, cooking, or other energy uses in the building.

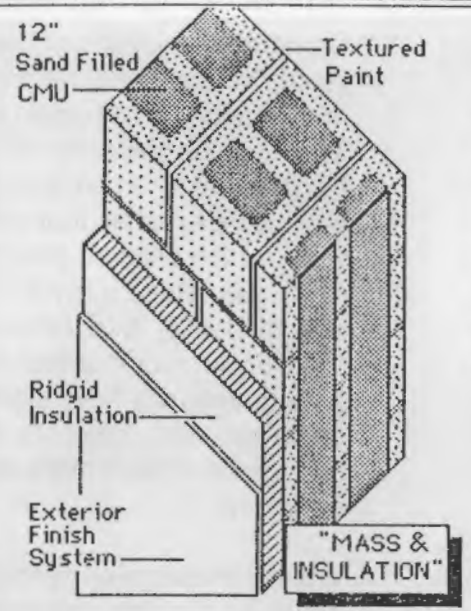
From the discussions, each team member will discover inter-relationships between others' ideas and the preconceived strategies which he or she brought to the table. A review of cost-effective energy conservation efforts that have worked well in other projects may also be useful in identifying strategies for consideration. When utilized as a cueing aid, prior results may reveal concepts that might otherwise be overlooked. These techniques should add substantially to the master list.

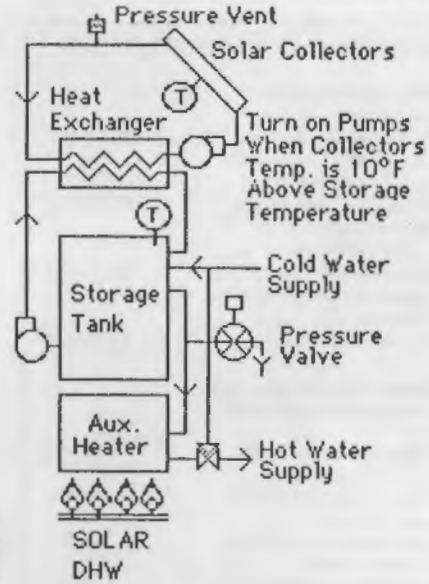
The expanded master list should then go through an edit process. Editing of the master list by the team is itself an interactive process. The object, of course, is to utilize the full range of professional judgement available on the team to select a limited number of strategies and combinations of strategies sets for more thorough quantitative analysis and evaluation. The illustrations on the following page are examples of the diverse strategies that were selected by the decision-making teams involved in our research.(The case studies discuss strategies that were rejected as well.)

One might think that all strategy sets, ie. the full master list, should be formally evaluated. However, the experience, knowledge, and consensus opinions of



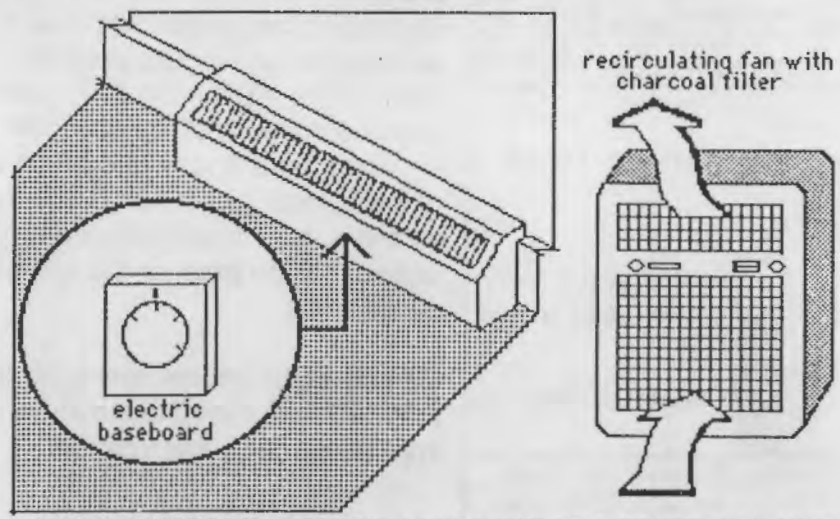






the team members are as important, if not more important, than the computations that will be made to determine the final value of particular strategies and strategy sets. The practicality, marketability and overall appropriateness of strategies in particular applications cannot be determined by simply "running the numbers". Experience is the best guide at this critical juncture.

The edited list(s) of strategies, a preliminary strategy set or sets for further analysis, is composed only of those strategies that have endured the test of professional judgement and are supported by team consensus.

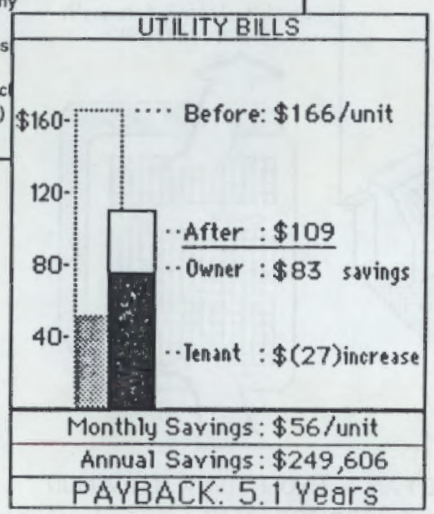


ELECTRIC BASEBOARD, RECIRCULATING FAN & TWO-HOUR VENTILATION "FLUSHING" REPLACE CONSTANT VOLUME CORRIDOR HVAC

Evaluating Strategies . . .

ECONOMICS OF A NEW ENCLOSED BALCONY

• Capital value of enclosed living room/balcony	
- Added rent from enclosed balcony (60s.f. x $1/mo/s.f. base rent x 50%)	$30/DU/MO
- Value of enclosed balcony ($30.s.f ,annualized & capitalized @10%)	$3,600/DU
- Actual Cost of remodeling ($30/s.f. including recycled materials)	$1,800/DU
- Net increase in capital value	$1,800/DU
• Value of Reduced Energy Costs	
- Assume energy savings of $7/DU/yr.	
- Capitalize savings at 10%	$70/DU
• Value of tax benefits	
- Depreciation of $1,800/DU over 25 years	$72/DU
- Cash value of depreciation in 50% bracket	$36/DU
- Capitalize cash value at 10%	$360/DU
• Total capitalized value of enclosed balcony	$2,230
Less Const. Cos	
• Net value of enc balcony (year 1)	



Computer simulation of the preliminary list of strategy set(s) begins with the modification of basecase input data. Team discussion of the modifications to the basecase can be an extremely instructive exercise that prepares the team for the ultimate selection of strategies. The energy analyst will be able to identify and demonstrate to the team how minor changes to some parameters may have significant impact on energy end-use costs, while major changes in other factors achieve little or no benefit.

While the energy analysis simulations are being run, the cost estimator is generating the component costs for each strategy set under consideration. These first-cost (and recurring cost) data become one side of the economic equation used to rank and select the ultimate strategy set to be implemented, so first-cost estimates require as close scrutiny by the team as the energy cost calculations.

Results of the energy cost analysis and first-costs are combined to arrive at the all-important, motivating indicator -- economics. We used simple Payback; you may want to look at more sophisticated measures. For instance, a Payback analysis, when carried to the next logical step, reveals a more important indicator -- Yield. A Yield analysis assesses the implications of a positive cash flow occurring post-payback.

In our work, Payback results tell the team, in calendar units, how long it will take to recover the initial investment. This puts final evaluation of revisions of the strategy set(s) in terms of one comparative indicator, the payback period.

In summary, during the Synthesis Phase, the decision-making team uses qualitative (experience) and quantitative (computational) indicators to recommend a final set of energy cost-cutting strategies for the owner's consideration.

Examples of final strategy sets from our work are shown at right and discussed in detail in Chapter IV. The preceding discussion only hints at the complexity in identifying, evaluating, and selecting the

. . . and Selecting the Final Strategy Set

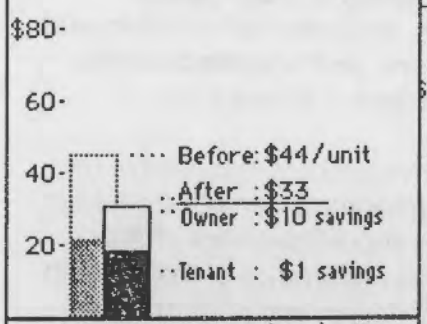
final stategy sets. To give you an idea, because of budget and time constraints, our results are based on simulations of sets, i.e. logical combinations, of strategies. But, even with this limitation, we were able to look at details within the analyses to get a handle on the effectiveness of individual strategies. The answers will probably be found in those details for you as well.

So, there is a lot behind those numbers, but the effort can really pay off -- the process will work for you. Try it!

STRATEGIES & COSTS

Infiltration/Exhaust:	
- Reduce corridor vent fan speed	-0-
- Install corridor vent. time clock	200
HVAC:	
- Add setback t-stat all BR	9,000
- Reduce corridor temperature	-0-
Lighting/Appliances:	
- Replace 17 inc. lamps w/screw -in fluorescent; add dimmer on 5	260
- photocell control on ext. lights	400
- Relamp stair.with screw-in fluor.	50
DHW:	
- Reduce DHW temp. to 115°F	-0-
- ins. jacket on central DHW tank	250
Training:	
- Conduct ed.prog. on setbacks	-0-
TOTAL	$10,160

UTILITY BILLS



Monthly Savings: $11/unit

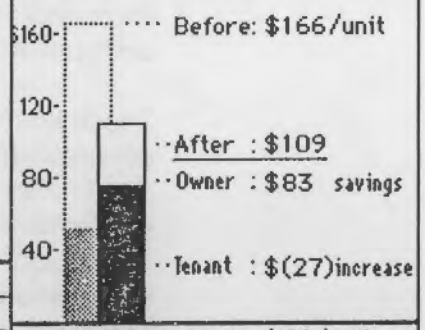
Annual Savings: $9,933

PAYBACK: 1 Year

STRATEGIES & COSTS

- Repeat Team A operations strategies	$ 296,300
Envelope:	
- Insulate garage roof and suspend ceiling with R-11 batts; convert to dry sprinkler	29.,300
- Install interior storm windows	283,800
Infiltration/Exhaust:	
- Install time clock for laundry exhaust, occupied hours only	300
HVAC:	
- Reduce corridor temp to 60F	-0-
- Install H/C setback thermostat with water valves to units	123,400
- Install flow rate BTU meter in each unit	280,500
- Install 550 ton centrifugal chiller/ remove absorption unit	163,000
Lighting/Appliances:	
- Use high efficiency ranges for replacements	36,900
- Install trash compactor/remove incinerator	25,100
DHW:	
- Install dedicated 90 HP DHW boiler	22,000
TOTAL COST:	$1,260,600

UTILITY BILLS

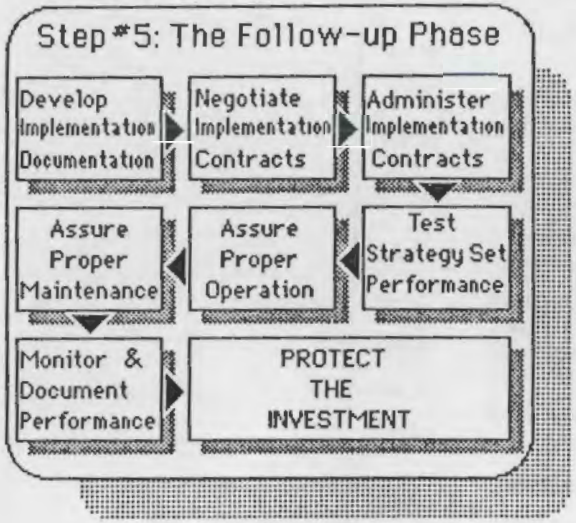


Monthly Savings: $56/unit

Annual Savings: $249,606

PAYBACK: 5.1 Years

The Follow-up Phase . . .



The analytical and creative efforts of the previous steps in the decision-making process now give way to the task of implementing the final strategy-set. Bidding and Contract Negotiations, Implementation Contract Administration, Operations, Maintenance, Monitoring, and a continuing commitment are all necessary to achieve energy cost savings through conservation.

The documentation of the strategy set to be implemented must accurately and adequately describe the intent, performance criteria, and expectations of the Decision-Making Team and the Owner/Investor/Developer. Documentation should consist of implementation contract documents, including memos of management instructions, implementation orders and authorizations, and working drawings and specifications as required.

Those team members responsible for generating the implementation contract documents should be aware of the fundamental importance of maintaining the original design and performance intent when carrying out their documentary tasks. Thorough instructions make proper implementation feasible.

With documentation complete, bids are sought. Bidders should be fully informed of the performance requirements of the contract documents. The potential for failure to achieve the targeted results can be minimized by a special clause in the Owner/Contractor agreement. This clause should require replacement of components which fail to meet performance specifications, regardless of subsequent approval of substitutions.

After bids have been received and reviewed for compliance with the requirements of the Contract Documents, a contractor is selected and work begins. Regular and diligent on-site observation of the actual installation, construction, and/or implementation of the final strategy set by the appropriate decision-making team member(s) is necessary to assure compliance with the intent of the Implementation Contract Documents.

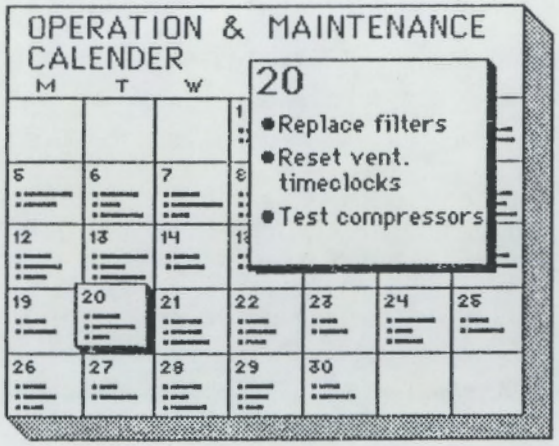
Final testing of all systems should occur at the completion of the Implementation Phase. The final test and performance results should comply with the contract documents, and should be documented in appropriate operation and maintenance logs.

Energy cost savings benefits begin accruing as soon as the implementation of the strategy set is complete and operational. Thus begins the never-ending need for proper operation and maintenance.

The proper Operation and Maintenance of the implemented strategy-set will require adequate instruction and training for the responsible individuals. O&M instruction, training, and references should include: O&M schedules, manufacturers' O&M manuals, copies of all warranties, and all direct or indirect service contracts. O&M personnel will also require standardized reporting and record-keeping formats and systems for their routine use.

Improper operation or maintenance of the strategy set will obviously be detrimental to the goal of minimizing energy costs. Continuous or periodic monitoring of the O&M records allows management to monitor both the performance of the responsible O&M personnel and of the performance of the original investment. Thorough documentation is the best aid in facilitating and maintaining an effective operation and maintenance program. The transience of the modern O&M worker (or contractor) dictates an ongoing need for such documentation.

This concludes the description of our decision-making process for architects, engineers and owners involved in consideration of energy cost-cutting for multifamily housing. Chapter IV, which follows, presents our results when we applied this approach to nine existing and three future buildings across the U.S.



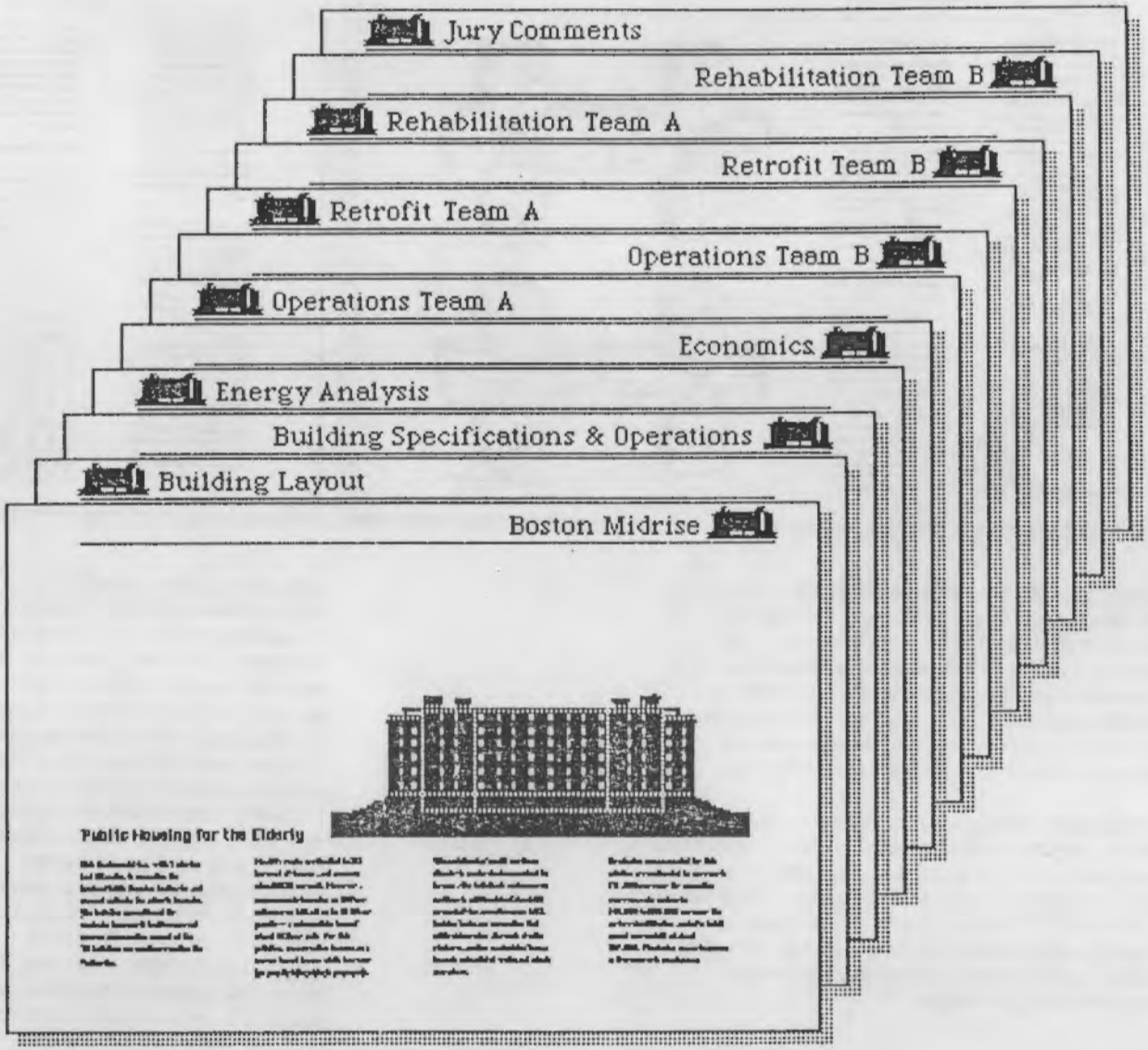
Chapter IV: Case Studies

This chapter contains twelve case studies illustrating how expert design teams would change real buildings to reduce energy use. The buildings have been carefully selected to represent a wide spectrum of climates, building configurations, and operating conditions including:

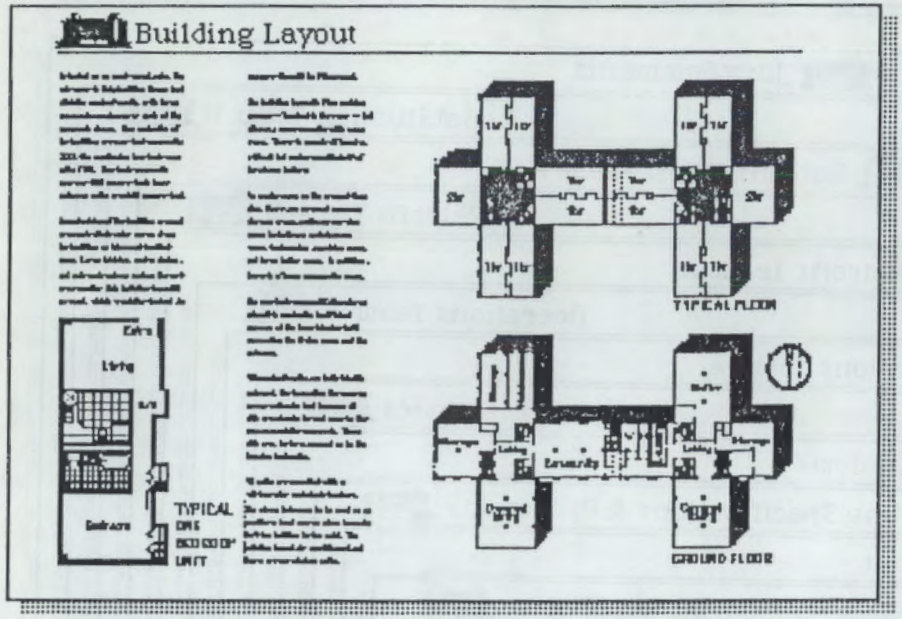
- 2 Existing Highrise Buildings (Chicago and Washington, D. C.);
- 5 Existing Midrise Buildings (Boston, Mankato, Albuquerque, Miami, and Oakland);
- 2 Existing Lowrise Buildings (Maryland and Washington State); and
- 3 Future Buildings (Boston, Phoenix, and Houston).

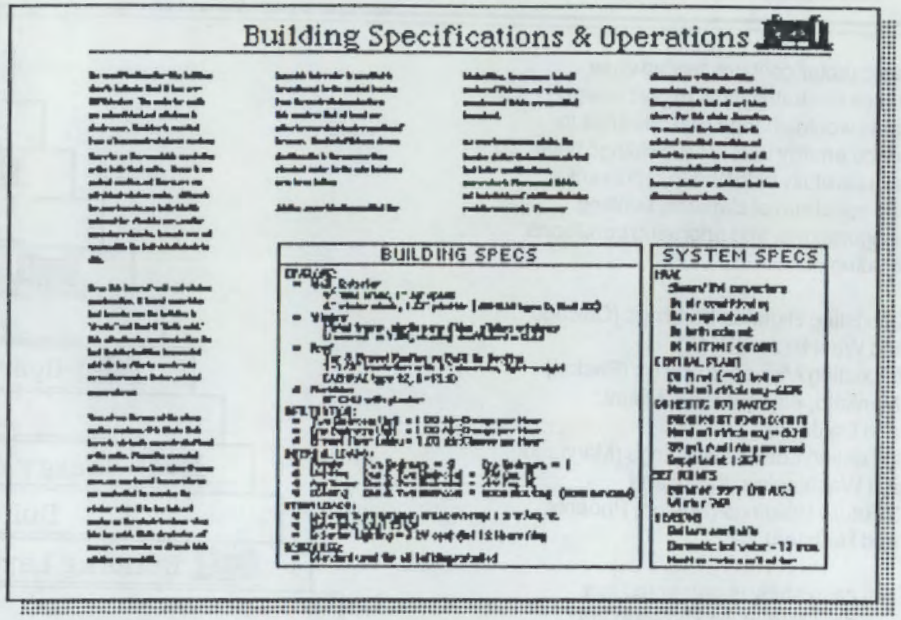
Each case study is presented in a consistent format, as shown in the illustration at right. Following a brief overview of the building, more detailed information is given about the building layout, specifications, energy use, and economics. The opinions of two independent design teams (called "Team A" and "Team B" for convenience) are then presented for each of three different levels of building improvement: "operations", "retrofit", "rehabilitation." The case study concludes with comments from a jury of experts who reviewed the proposed design changes.

The next few pages describe in greater detail how to read a typical case study. This introductory material is followed by the twelve case studies themselves.



CASE STUDY FORMAT





Building Layout describes the physical configuration of the building and its site. This page often includes a site plan, a typical floor plan, a ground floor plan, and one or more unit plans. The drawings vary from case study to case study and are selected to illustrate particular points of interest in a given building. This page also illustrates the mix of units in the building and the location of common areas and support services.

The purpose of this page is not only to familiarize the reader with the building but also to begin investigating energy issues -- like orientation. From the site plan and typical floor plan it is possible to determine the principal orientations of building glazing. This suggests a possible explanation for building heating and cooling loads and gives some preliminary indications for possible energy strategies.

Building Specifications and Operations includes more detailed descriptions of the building structure, envelope, and mechanical systems. This page serves two purposes. It is both a further description of the building and a partial list of the assumptions used to prepare a computer model of the building. This computer model is used throughout the remaining analysis of the building to estimate energy consumption by end use, to do sensitivity analyses for evaluating possible energy conservation strategies, and to estimate likely energy savings due to the application of selected conservation measures. The team used the most advanced version of the DOE-2 computer model available for this analysis. Complete documentation of these analyses was compiled but is not reported in this book due to the magnitude of technical data involved.

BUILDING SPECS

Building specifications are reported for each building in a standard format. The four main categories of information given are: envelope, infiltration, internal loads, and other loads.

The "envelope" section describes the materials and construction techniques used for exterior walls, windows, the roof, and floor. An effort has been made in presenting this information to use standard building construction terminology. There is, however, additional information presented which relates more to the way in which the building was modeled by computer (for example the "U-value" and the "shading coefficient" of windows).

The "infiltration" section gives the assumptions used by the team concerning the uncontrolled introduction of outside air into the building. These assumptions are a combination of technical analysis of the wall sections of the building and the best judgements of the design teams and energy analysis team.

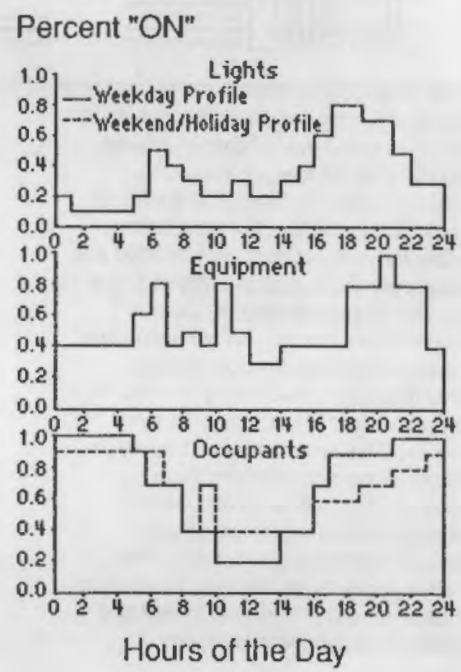
In the case of "internal loads" and "other loads", the teams reviewed actual building plans and specifications to estimate as accurately as possible the energy use of lights and equipment in the building. In the case of the three future buildings in the study, the design teams estimated these figures based on proposed plans and typical current practice.

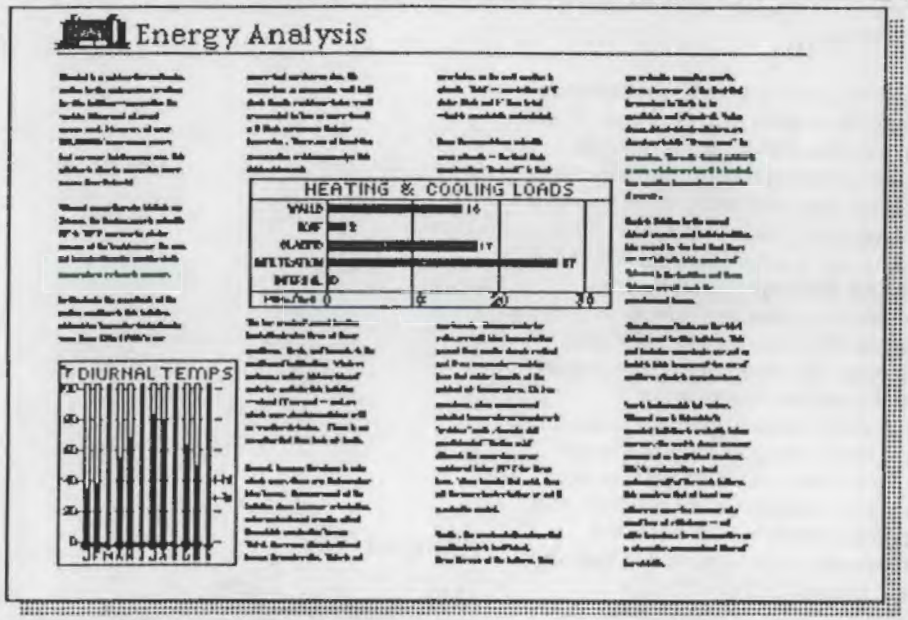
SYSTEM SPECS

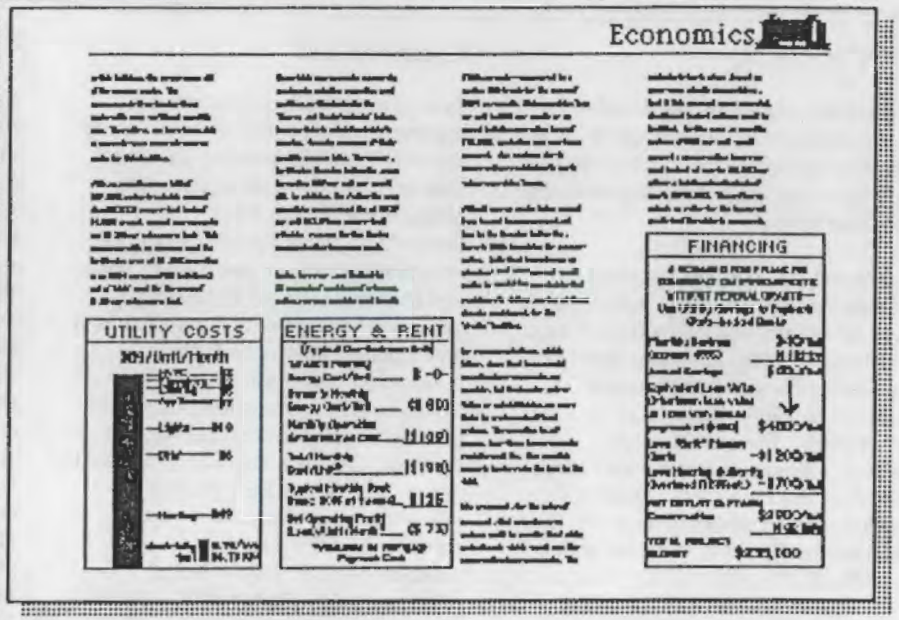
System specifications describe the heating, ventilation, and air conditioning system (HVAC) for both the apartment units and the commmon spaces; the central plant (if there is one); the domestic hot water system for both the units and the laundry; and the set- points and seasonal changes in the control system. The purpose of this section is to give a general description of the mechanical systems in the building. Space limitations make it impossible to give highly detailed descriptions of all systems. Common abbreviations used in this section include EER (energy efficiency ratio), cfm (cubic feet per minute), DX AC (direct expansion air conditioner), COP (coefficient of performance), T (thermostat), and Btuh (British thermal units per hour).

SCHEDULES

The way in which a building is used has a tremendous affect on energy use. The longer lights are left on, the more air conditioning that is used, the more baths taken or loads of laundry done, the more energy used. It was impossible for the team to get precise operating schedules for each building in the study, but a schedule was required in order to prepare and run the computer model for each building. The teams decided to prepare standard schedules for lights, equipment, and occupancy and use them in all the buildings studied. Although there would be modest variations from actual schedules in some buildings, this approach would facilitate both the preparation of the computer models for each building and would make comparisons from building to building easier. The three schedules agreed upon are shown on the graphs at right.







Energy Analysis describes the climate of the city in which the building is located and the affect of this climate on the building in terms of heating and cooling loads. In this section, the main energy issues for each building are identified and discussed. Each energy analysis page includes a graph of daily or "diurnal" temperatures, bar graphs of heating and cooling loads, and, in special cases, other illustrations necessary to describe an important or unusual aspect of the climate. This analysis draws heavily on the computer simulation for each building. The estimates of building heating and cooling loads are taken directly from these simulations. The loads bar charts are drawn in thousands of Btus per unit (MBtu/unit) to facilitate comparisons between buildings.

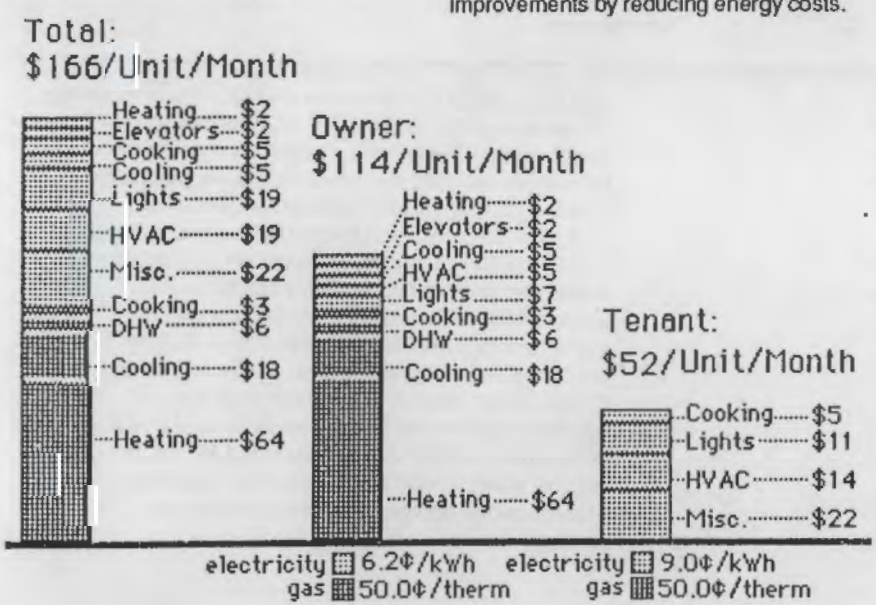
Economics presents a summary of the key operating cost issues in the building. A typical page includes a summary of total energy costs for the building by end use, owner energy costs by end use, tenant energy costs by end use, an energy and rent analysis (where rent figures are available), and illustrations of special economic issues when necessary. For the nine existing buildings, the energy analysis team made special efforts to match the results of computer simulations to actual gas and electric bills. This "calibration" of the computer models serves to increase the reliability of computer estimates in the study. The two most important summary illustrations in this section are discussed in greater detail on the next page.

UTILITY COSTS

It was decided from the beginning of this study, that the driving force for energy conservation should be the allocation of energy costs in a building -- not energy use. After all, both owners and tenants want to reduce costs and not simply alter energy use. Because of the differential in cost among fuels and the complex interaction of building loads and mechanical systems, the most important energy cost item is often not the highest energy use item.

The bar graphs below are based on a "reasonable" match (+/- 10%) between a computer simulation of the building and actual gas and electric bills. The bars are average amounts per unit per year, to facilitate comparison across buildings in the study. The division between natural gas (or oil) and electricity is indicated by different shading and is taken directly from utility bills. The disaggregation of bills into various end uses is based on computer simulation and has been checked where possible against actual equipment specifications and operating schedules.

The division between owner and tenant bills is based on actual owner records in most cases and on typical tenant bills as reported by building owners. This distinction is important because it indicates the amount of capital that is directly available to an owner for energy improvements by reducing energy costs.



RENT ANALYSIS

The purpose of this section is to put energy costs in perspective relative to owner concerns (rent) and tenant concerns (shelter cost). The basis for this analysis is monthly rent -- where figures are available. The owner's monthly energy cost is subtracted from the monthly rent to yield the "net" rent to the owner. From this amount the owner must take other operating costs, the cost of financing, and profit. Because these figures vary so greatly from building to building, no effort was made to disaggregate this net amount further.

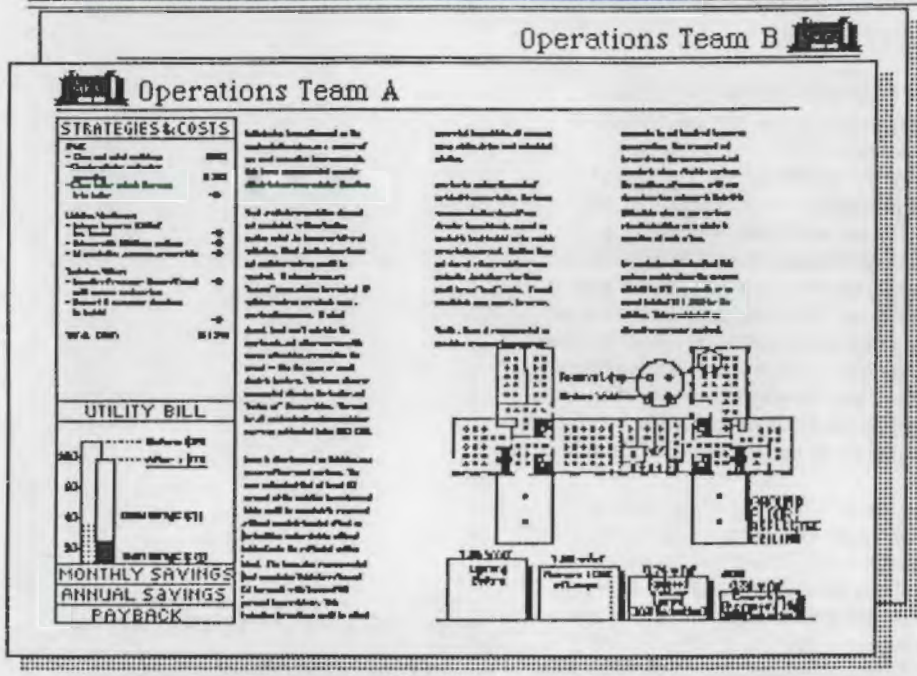
The tenant's monthly energy cost is added to monthly rent to yield total "shelter cost." The concept of shelter cost has received much more attention since the significant rise in tenant utility costs in the 1970's. It is now used by HUD in the computation of housing costs and subsidies. The "income to qualify" for an apartment is computed by applying the rule-of-thumb that shelter cost cannot exceed 35% of annual income. Including energy costs in calculations of income-to-qualify is a conservative approach. If energy costs were not included, the income-to-qualify figure would be lower.

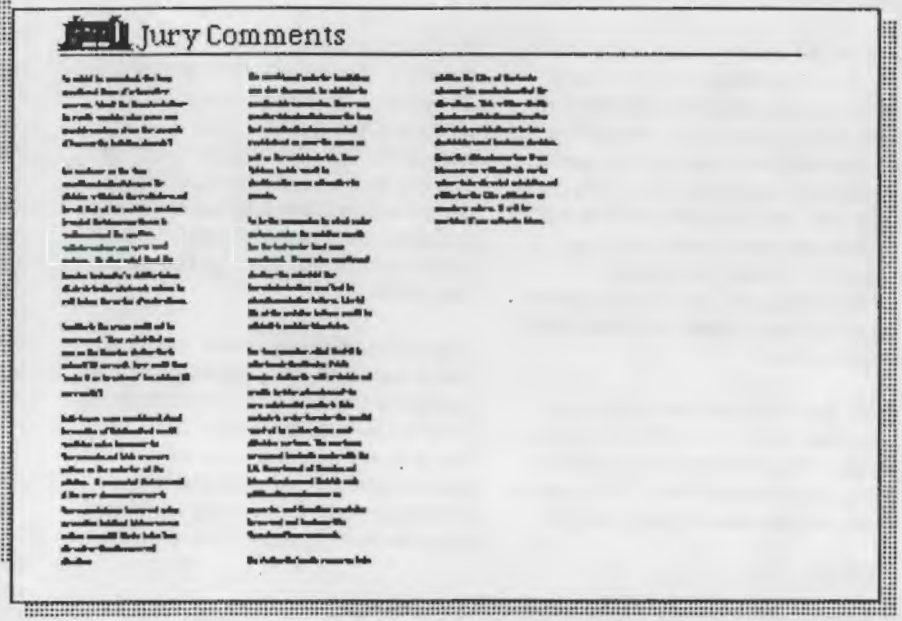
Energy and Rent Analysis

(Typical Two-Bedroom Unit)

Net Rent to Owner	$661
Owner's Monthly Energy Cost/Unit	$114
TOTAL RENT	$775
Tenant's Monthly Energy Cost/Unit	$ 52
SHELTER COST	$827

INCOME TO QUALIFY: $28400





TEAM A and TEAM B pages summarize proposed energy cost-cutting strategies developed by two design teams working independently on each building. For existing buildings, the teams proposed changes in "operations", additions of materials or equipment to the building (called "retrofit"), and complete "rehabilitation" of the building to reduce energy costs. In the case of future buildings, the teams proposed just one major redesign of the building to improve energy performance. A summary of the strategies proposed, the estimated cost of each, and the resulting decrease in energy costs are summarized in a single column for each team. This "side bar" is discussed in greater detail on the next page. This section is highly illustrated to provide ctear guidance and easy review by owners, architects, builders, and developers alike.

JURY COMMENTS summarize the reactions of a number of reviewers to the strategy sets proposed by the design teams. Reviewers included members of the National Association of Home Builders, representatives from the Institute of Real Estate Management, the Technical Advisory Panel formed for this project, and building owners themselves. Members of the design teams also reviewed each other's solutions. The purpose of this section is to expand upon important points raised by the design teams. Often, the jury supported new ideas or concepts proposed by the design teams. In other cases there were honest disagreements concerning the application of a strategy or its outcome. This section is included, in part, to suggest where readers should consider additional analysis before applying a controversial energy strategy.

STRATEGY SETS

Each list of proposed energy conservation strategies, called a "strategy set," is reported in a side bar as shown at right. The cost of each strategy is based on estimates prepared by a professional cost estimating firm. If strategies are used again in the following strategy set, they are not listed again but simply noted as being repeated. These estimates are based on the best information available to the cost estimating team and apply only to the particular building under study. They give a good indication of approximate costs of applying these strategies in similar buildings but should not be considered accurate estimates for all applications.

UTILITY BILLS -- "BEFORE"

The "before" bar in the graph of "utility bills" is the total of existing utility bills in the building as reported in detail on the "economics" page. The bar shown here distinguishes between owner and tenant costs but does not disaggregate end uses due to lack of space.

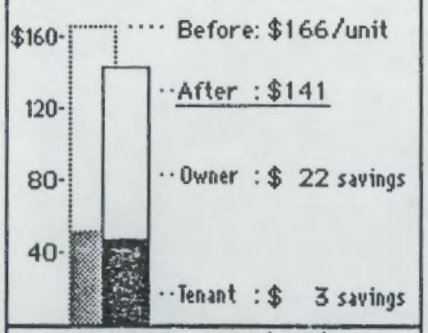
UTILITY BILLS -- "AFTER" (sub-head)

The "after" column on the "utility bills" bar chart is a summary of the reduction in energy costs as a result of applying the strategy set. This reduced bill is based on careful computer simulation of the building including the new strategy set. This estimate is based on the interaction of all strategies combined and does not attempt to compute the effect of any single strategy in the set.

STRATEGIES & COSTS

Envelope:	
- Weatherstrip:	
windows	$104,400
corridor doors	13,900
elevator doors	29,300
Infiltration/Exhaust:	
- Replace 24,000 CFM exhaust fan with 8000 CFM unit	1,500
- Cap exhaust duct and replace w/activated charcoal fans for kitchen and bath	124,000
- Add vestibule for lobby doors	17,200
HVAC:	
- Reduce garage temperature to 40 F	-0-
- Reduce corridor temperature to 60 F	-0-
Lighting/Appliances:	
- Photocell control for entry canopy lights	1,100
- Storage area time switches	400
- Install elevator controller	4,500
DHW:	
- Close laundry 8 hrs at night	-0-
- Reduce DHW temp to 120 F	-0-
- Require contractor to install high efficiency washers/dryers	-0-
TOTAL COST:	$296,300

UTILITY BILLS



Monthly Savings: $25/unit

Annual Savings: $112,161

PAYBACK: 2.6 Years

ANNUAL SAVINGS

Monthly savings per unit is the simple total of monthly owner and tenant savings per unit. Annual savings are derived by multiplying monthly savings by 12 and by the number of units in the building.

PAYBACK

Payback is a very simple measure of financial performance. It shows how long it takes to "pay back" the original investment with savings generated by the investment. To compute payback, divide the total cost of the strategy set by annual savings.

OPERATIONS

Operations strategies propose changes to the way in which a building is controlled or operated. These changes are typically less costly and involve only modest alteration of the materials or mechanical systems in the building. These strategies can often be applied by existing building maintenance staff.

RETROFIT

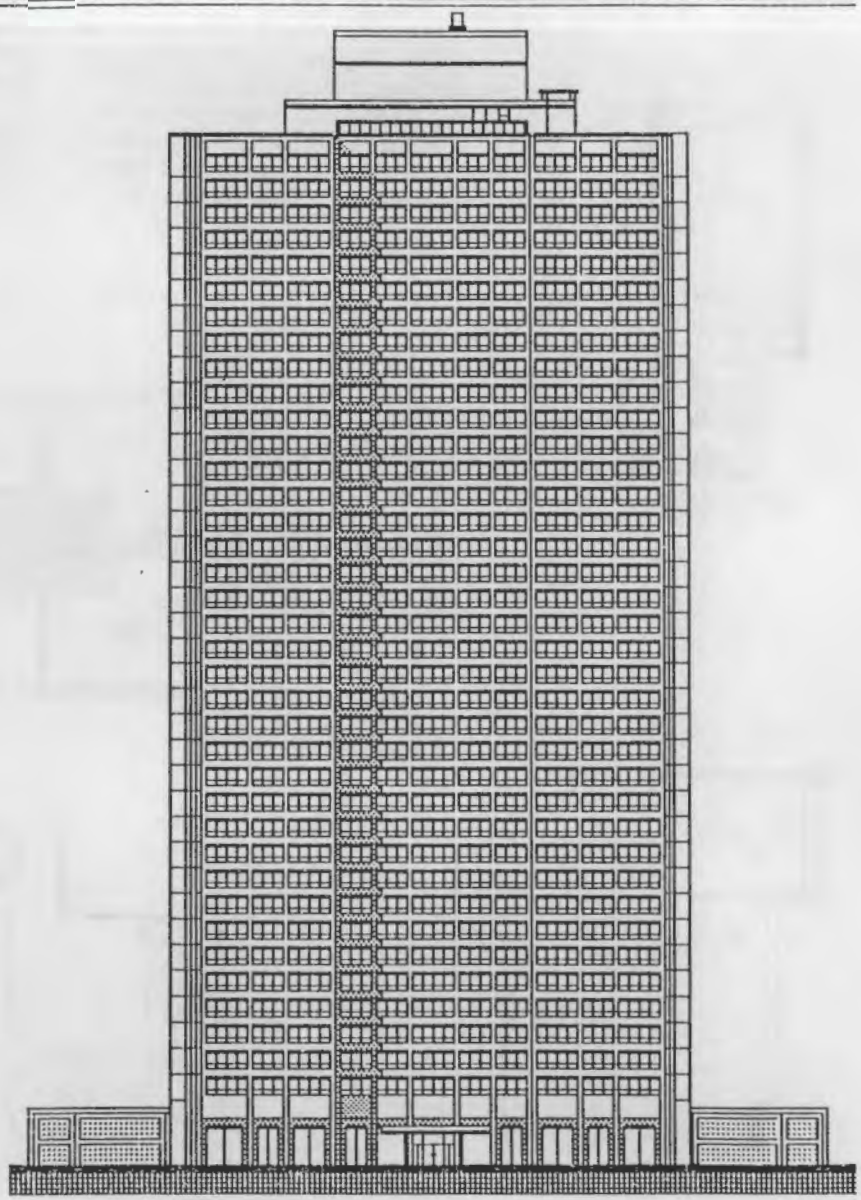
Retrofit strategies include more major modifications to the building or its systems. Retrofit strategies can be major projects but are defined for this study as falling short of complete renovation. Many retrofit strategies will require using contractors instead of in-house maintenance staff and may cause some disturbance to individual tenants or an entire floor of tenants at one time.

REHABILITATION

Rehabilitation typically occurs at a time when the ownership of a building is changing. It can include a complete change of building materials and systems, limited only by a requirement to retain the existing shell of the building. Design teams were virtually unlimited in the changes they could propose in this scenario. These strategies are typically applied only to an empty building.

The following twelve case studies use the general format described above. The length of each case study varies depending on the number of illustrations used to cover key points.

Chicago Highrise



This Chicago Highrise is a 450,000 square foot building with 37 floors of apartments (369 units) and 2 floors of commercial space. Completed in 1969, it is esimated this building would cost over $27 million to build at current costs. Situated in Chicago, the building has a mix of elderly and young professional tenants.

As might be expected for a highrise building in a cold and windy climate, the major energy problem for this building is heating, which is paid for entirely by the owner. Because windows are not well sealed, air infiltration and conduction losses are key contributors to this large heating load.

The owner's annual energy bill exceeds $500,000 -- 80 percent of which goes for natural gas and fuel oil. Utility rates to the owner are modest, however, with electricity costing just over $0.06 per kWh and natural gas costing about $0.50 per therm. The average tenant bill, for individually metered electricity, is estimated at $52 per month.

In spite of this building's overall high quality, the design teams have identified significant opportunities for energy savings with good paybacks. Savings in operations alone are estimated to range from $65,000 to $100,000 per year with at most a 2-1/2-year pay-back. One team got a payback in just 1 month. Retrofit strategies can save an estimated $180,000 to $250,000 per year with a 3 to 5 year payback. Rehabilitation strategies can save up to $200,000 a year with as little as a 3-year payback.

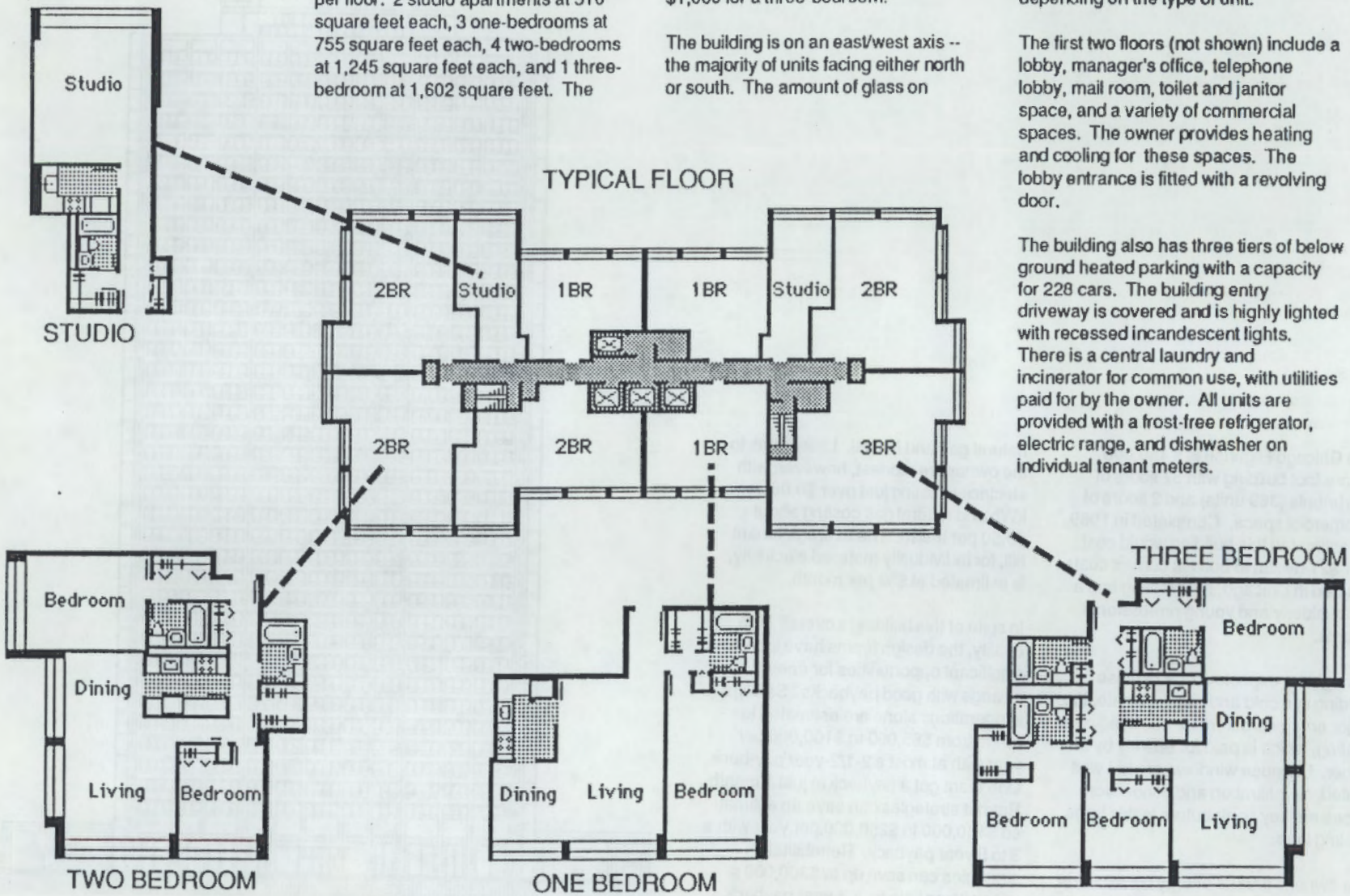
Building Layout

As illustrated in the sketches below, the Chicago highrise typically has 10 units per floor: 2 studio apartments at 510 square feet each, 3 one-bedrooms at 755 square feet each, 4 two-bedrooms at 1,245 square feet each, and 1 three-bedroom at 1,602 square feet. The building has a total of 369 units. Rents range from $425 for studios to over $1,000 for a three-bedroom.

The building is on an east/west axis -- the majority of units facing either north or south. The amount of glass on exterior walls is unusually high, ranging from 23 to 36 percent of the floor area depending on the type of unit.

The first two floors (not shown) include a lobby, manager's office, telephone lobby, mail room, toilet and janitor space, and a variety of commercial spaces. The owner provides heating and cooling for these spaces. The lobby entrance is fitted with a revolving door.

The building also has three tiers of below ground heated parking with a capacity for 228 cars. The building entry driveway is covered and is highly lighted with recessed incandescent lights. There is a central laundry and incinerator for common use, with utilities paid for by the owner. All units are provided with a frost-free refrigerator, electric range, and dishwasher on individual tenant meters.



Building Specifications & Operations

This is a luxury highrise apartment building. It is located in downtown Chicago just off the lake. Completed in 1969, it houses over 500 residents providing them with a wide variety of tenant and commercial services. The quality of the building can be seen in the rather large unit sizes and in the large amount of exterior glass. Building specifications reflect that this is a pre-1970 building. All glass is single pane and there is only 1" of rigid exterior insulation. Roof and first floor insulation are also minimal.

Heat is provided through a closed loop, two-pipe, chilled/hot water system and is distributed to individual units through a combination of convectors with fan/coil units. There is no thermostatic regulation, the only control is through the use of the fan unit. The heating plant comprises two low-pressure steam boilers -- one with a high efficiency gas burner, the other a high efficiency combination gas/oil unit. They were replaced with new units in 1984.

Air conditioning is provided through an absorption air conditioning system. The chiller, a 650-ton gas-fired steam unit, is roof mounted. Domestic hot water is provided via a steam heat exchanger with three-way mixing valves on the hot water side of the system.

Ventilation is provided primarily by the kitchen and bath exhausts and air handlers. The building also has a gas fired incinerator with a "wet scrubber". Prior to the start of this energy study, the owner had improved the boilers by installing high efficiency burners, turbolators, and flue dampers. He had also installed time clocks to control kitchen and bath exhausts to 15 hours per day and to reduce circulating pump time. All public lighting in the building had been converted to fluorescent.

BUILDING SPECS

ENVELOPE:

- Exterior Wall
  8" concrete, 1" rigid insulation with 5/8" sheetrock; Wall U=0.08, R=12.5; medium color surface.
- Window
  Single Pane clear glass with aluminum frames. Bottom Panel operable, projection type assumed U=1.35 including frame.
- Roof
  Tar & Gravel roofing over 1.5" cellular glass insulation on top of 7"concrete with air space and acoustical tile. (U-value=0.06, lightweight concrete R=15.7)

INTERNAL LOADS

- Lights: 0.5 Watts/s.f.
- Appliances: 0.4 Watts/s.f.
- Infiltration: 1.0 Air Change/hr.

VENTILATION/EXHAUST

	3-Br.	2-Br.	1-Br.	Efficiency
Bath	165 cfm	110 cfm	55 cfm	55 cfm
Kitchen	125 cfm	125 cfm	110 cfm	95 cfm
Total	290 cfm	235 cfm	165 cfm	150 cfm

Time Clock control on all exhaust fans. Fan schedule is 5 pm to 8 am everyday.

SYSTEM SPECS

HVAC
Two pipe fan coil system with supplemental radiators

TEMPERATURE SETPOINTS
Heating: 70°F
Cooling: 78°F

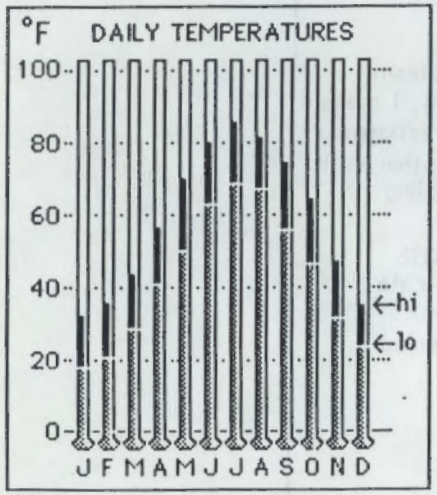
CENTRAL PLANT
2-low pressure steam boilers 1 gas only; 1 gas/oil comb. with 80% efficiency
1-650 ton absorption chiller roof mounted cooling COP=0.68

DOMESTIC HOT WATER
2500 BTUH usage rate during occupied hours w/efficiency assumed @47%

Energy Analysis

Due to the severely cold climate (see average daily temperature graph), heating is the largest energy problem in this building--accounting for nearly 60 percent of the owner's annual energy bill. Heat losses of 11 to 14 Btu's per square foot per degree day and cooling loads of 368 to 260 square feet per ton are typical. Over 2,000 hours per year are below 30° F.

The Chicago climate has cold winters, hot summers, and short swing seasons



As can be seen on the bar graphs of heating and cooling loads, glass is the single largest contributor to both heating and cooling loads. High conductive losses through single pane metal frame windows (U=1.35), and poorly insulated walls are aggravated by uninsulated concrete spandrels. High infiltration losses (induced by bath and kitchen exhausts) are the second highest cause of heating loads. Internal heat gains (from occupants' lights and cooking) are the second highest contributor to cooling loads.

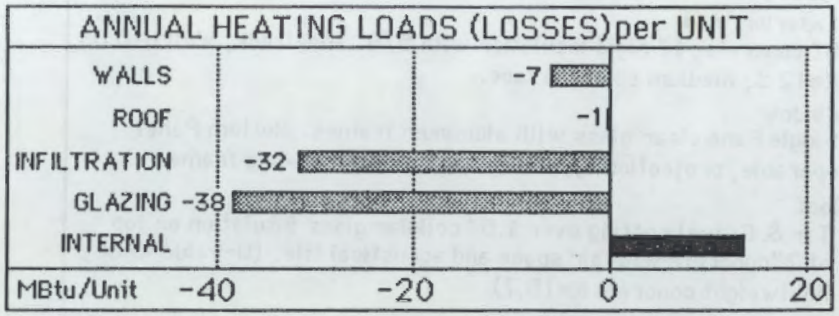
The existing HVAC system also has some energy problems. The two-pipe system can deliver either heating or cooling on a seasonal basis; it cannot do both simultaneously. On cool clear days in the spring or fall, sunlight passing through the large glass areas will create cooling needs on the sunny side of the building while heating will still be required on the shady side. To maintain comfort, the owner must supply enough heat to keep shady side tenants warm. As all units lack thermostats, tenants on the sunny side of the building will simply open windows to stay comfortable -- with a net loss of costly heat. Since all utilities are paid for by the owner, the tenant has little incentive (and no alternative) to avoid this costly solution.

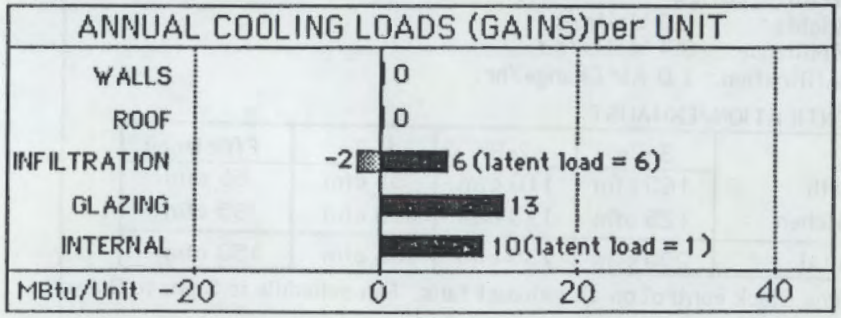
At current commercial electric rates ($0.062 per kWh) and natural gas rates ($0.50 per therm) it costs the owner about the same to cool with either fuel after system efficiencies are considered. Should the cost of natural gas rise relative to electricity, it would be reasonable to consider changing to high efficiency electric chillers.

Other areas of particularly intense energy usage include the laundry, which is dominated by hot water and exhaust air requirements, and the incinerator, which operates 12 hours a day. The corridors use almost the same amount of heating energy that the apartments use. Garage lighting energy is low, at about one third of a watt per square foot, however, garage heating is significant.

Sensitivity studies indicate that double glazing would save 20 percent of total energy consumption. Infiltration control would save about 14 percent. Cooling strategies are far less profitable. Replacing the absorption chiller could save about 4 percent.

The large areas of single pane glazing are the principal cause of heating and cooling loads





Economics

As we have said previously, this is a high quality building. It would cost roughly $27 million to replace at today's prices or about $50 per gross square foot. That price excludes added insulation and improved windows that would certainly be used in a current design.

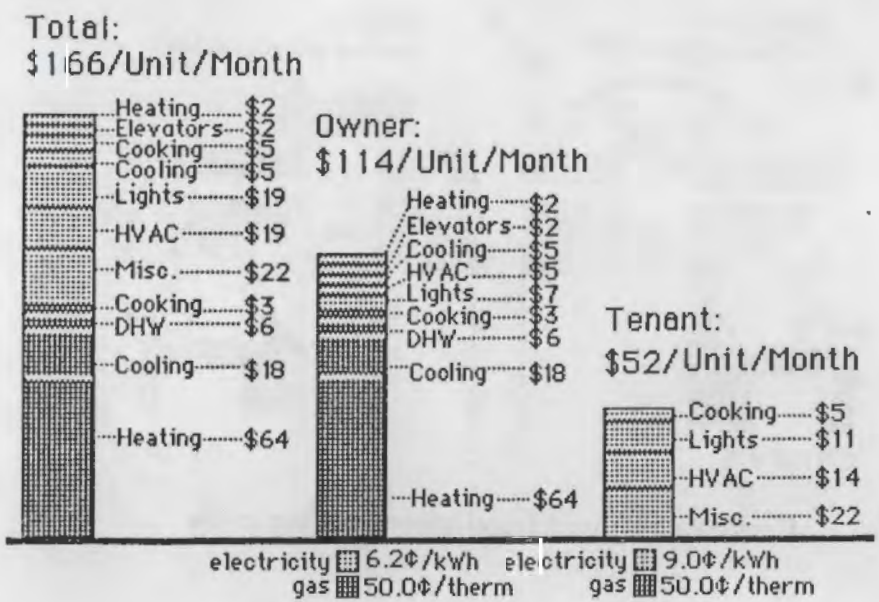
The quality of the building is also evident in the rents which the owner can command. An average two-bedroom unit renting for about $775 per month is $100 per month higher than the median for Chicago, according to IREM. As part of these higher rents, the owner provides all heating and cooling to the units. Tenants pay only for electricity for lights and appliances, which are individually metered. Utility rates in Chicago are about average for the nation. It is interesting to note, however, that at commercial rates for electricity of $0.062 per kWh, the owner is a little below average, while the tenants at residential rates of $0.09 per kWh are slightly above average. Note that there is a cost penalty when electric use is shifted from the owner to tenants.

With an annual utility bill of $537,000, or a $114 per month average, the owner pays twice per unit what tenants do. As shown in the bar chart, natural gas for space heating and cooling accounts for over 70 percent of the owner's bill. Of the remaining, the largest single component is lighting--a distant third behind heating and cooling.

On the tenant's side, appliances (refrigerators, electric ranges, dishwashers, etc.) are the highest cost energy item, followed closely by auxiliary uses (the fans used to blow heating and cooling out of unit heaters), and lighting.

Although the owner's annual utility bill is above the median for the area, according to IREM, it is not unusually high. In this building utility costs (excluding water, sewer, and trash removal) are roughly 15 percent of the rental income for an average unit. IREM median for the area is about 13 percent.

As shown at right, when all utility costs are included, the "shelter cost" of a typical two-bedroom unit is $827 per month. Assuming that rent cannot exceed 35 percent of gross income, a potential renter would need over $28,000 in annual income to "qualify" for this apartment. If utility costs could be cut in half (and all savings were passed through to the tenant) shelter cost could drop to only $744 per month and income to qualify would drop to about $25,000. Reducing qualification requirements in this way may be of significant interest to owners in a competitive market.



Energy and Rent Analysis

(Typical Two-Bedroom Unit)

Net Rent to Owner	$661
Owner's Monthly Energy Cost/Unit	$114
TOTAL RENT	$775
Tenant's Monthly Energy Cost/Unit	$ 52
SHELTER COST	$827

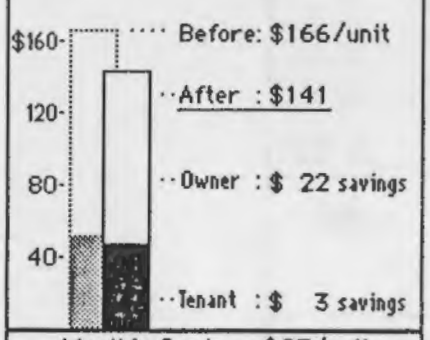
INCOME TO QUALIFY: $28,400

Operations Team A

CHICAGO, IL

STRATEGIES & COSTS	
Envelope:	
- Weatherstrip:	
windows	$104,400
corridor doors	13,900
elevator doors	29,300
Infiltration/Exhaust:	
- Replace 24,000 CFM exhaust fan with 8000 CFM unit	1,500
- Cap exhaust duct and replace w/activated charcoal fans for kitchen and bath	124,000
- Add vestibule for lobby doors	17,200
HVAC:	
- Reduce garage temperature to 40 F	-0-
- Reduce corridor temperature to 60 F	-0-
Lighting/Appliances:	
- Photocell control for entry canopy lights	1,100
- Storage area time switches	400
- Install elevator controller	4,500
DHW:	
- Close laundry 8 hrs at night	-0-
- Reduce DHW temp to 120 F	-0-
- Require contractor to install high efficiency washers/dryers	-0-
TOTAL COST:	$296,300

UTILITY BILLS



Monthly Savings: $25/unit

Annual Savings: $112,161

PAYBACK: 2.6 Years

Several factors combine to create the large infiltration problem in this building. Located near Lake Michigan, wind loads on the building are very high. Second, single pane glass, operable windows, and cracks around corridor doors create many opportunities for air infiltration. Finally, large "stack" effects, caused by long elevator and exhaust ventilation shafts, are aggravated by corridor ventilation.

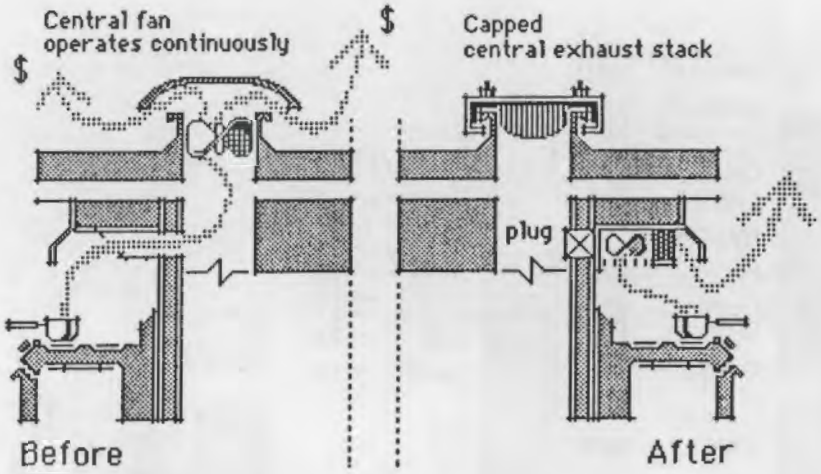
To cut infiltration losses, Team A recommended sealing the exterior envelope by general weatherstripping and caulking. A special recommendation was made to replace neoprene seals on all operable windows. With over 4,000 windows, this was a costly item.

To reduce stack effects, the team recommended weatherstripping elevator doors on all floors and adding a vestibule to lobby entry doors. In addition, one of the team's major recommendations was to cap all bathroom and kitchen exhaust vents and install activated charcoal recirculators.

Finally, 24,000 CFM corridor exhaust fans were replaced with 8,000 CFM units to reduce ventilation losses while still providing the minimum ventilation required by code. The team also recommended reducing corridor temperature set points to 60° F and garage set points to 40° F to further reduce heating costs. Taken together, computer modeling shows a 35 percent reduction in heating due to these strategies.

Photocell control was recommended to replace manual control of entrance canopy lights. Incandescent lights should be replaced with screw-in fluorescents. Lower wattage, longer-life fluorescents will not only cut the cost of electricity but also reduce labor costs for changing lights. Improved elevator controls, which call the nearest elevator, were also recommended. Three no-cost operation strategies were recommended to cut domestic hot water costs. Simply closing the common laundry for eight hours per night would not only help insure tenant security but also reduce heating costs by cutting supply and exhaust air. In addition, it was proposed that hot water temperatures be reduced to 115° F. The owners should also negotiate with laundry equipment suppliers to have higher efficiency equipment installed. This equipment could significantly reduce hot water costs.

Two-thirds of the $300,000 total cost of this strategy set is for weatherstripping and capping exhaust vents -- key to reducing infiltration losses. However, owner utility bills are reduced about $100,000 per year, an attractive 2.6-year payback from the owner's point of view.



Recirculating range hood lowers heating loads

Operations Team B

CHICAGO, IL

Team B focused on a set of low cost strategies to reduce heating costs and to cut lighting and domestic hot water costs.

The greatest opportunity to save energy was found in reducing the heat losses through central bathroom and kitchen exhaust systems. By reducing the exhaust fan operation time from 15 hours to 8 hours and scheduling the operating periods to occur at times of actual need, fan energy requirements were reduced and heating energy requirements diminished significantly. In addition to the reduction of heat losses through the stack, infiltration of cold air would also be cut down due to a diminished need for make-up air. Computer simulation indicated that space heating could be cut up to 20 percent by this simple operating modification. This strategy cost virtually nothing to implement as time clocks are already installed to control fan operation.

The exterior entrance canopy and the exterior soffit are currently lit with 150 watt recessed incandescent lights. Team B recommended selective relamping to reduce total wattage to 74 percent of the original connected wattage. Photocell controls on exterior and lobby lighting were recommended. The total cost for lighting strategies was estimated to be $1,100.

Flow restrictors were recommended to reduce hot water usage. Changeover would occur at tenant turnover to insure acceptance. The reduction in domestic hot water usage was estimated at 8 percent. To understand the significance of this strategy, it must be considered in the context of the inefficiencies of the centralized boiler system. The total cost of installing flow restrictors was $4,800.

The primary goal of a proposed education program is to raise the general awareness of the tenants to energy cost savings achievable through the appropriate positioning of blinds and draperies. The fact that the building is single glazed in a cold climate and that the glazing area is roughly 70 percent of the surafce area of the building implies large potential energy cost savings by closing all blinds or draperies on winter nights and closing all blinds to reduce solar gains in summer.

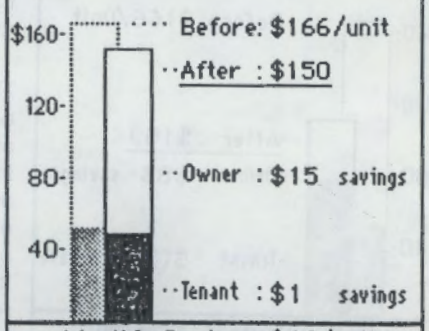
The education program would also include instructions on proper thermostat settings -- setting back to 55° F at night and when out during the day in winter, and setting up to 85° F when out during the summer. Water conservation would be stressed as a part of the education program. No energy savings were estimated although pumping requirements and water bills would be diminished.

Total cost for this set of operations strategies was estimated to be a modest $5,900. Potential energy cost savings are estimated to be significant, however. The owner's average monthly utility bill drops $15 per unit ($68,000 total for the building per year) while the tenant's bill is reduced one dollar or so per month. Simple payback would be only one month--very attractive from the owner's point of view.

STRATEGIES & COSTS

Infiltration/Exhaust:	
- Bath exhaust schedule reduced to 8 hours on from 15 hours on (winter only)	$ -0-
Lighting/Appliances:	
- Photocell on exterior lights and canopy lights	1,100
DHW:	
- Flow restrictors	4,800
Training:	
- Education program	-0-
TOTAL COST:	$5,900

UTILITY BILLS



Monthly Savings: $16/unit

Annual Savings: $68,280

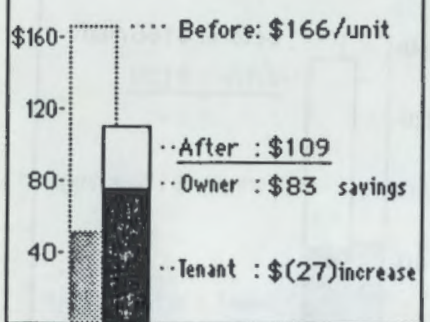
PAYBACK: 1 Month

Retrofit Team A

CHICAGO, IL

STRATEGIES & COSTS	
- Repeat Team A operations strategies	$ 296,300
Envelope:	
- Insulate garage roof and suspend ceiling with R-11 batts; convert to dry sprinkler	29.,300
- Install interior storm windows	283,800
Infiltration/Exhaust:	
- Install time clock for laundry exhaust, occupied hours only	300
HVAC:	
- Reduce corridor temp to 60F	-0-
- Install H/C setback thermostat with water valves to units	123,400
- Install flow rate BTU meter in each unit	280,500
- Install 550 ton centrifugal chiller/ remove absorption unit	163,000
Lighting/Appliances:	
- Use high efficiency ranges for replacements	36,900
- Install trash compactor/remove incinerator	25,100
DHW:	
- Install dedicated 90 HP DHW boiler	22,000
TOTAL COST:	$1,260,600

UTILITY BILLS



Monthly Savings: $56/unit

Annual Savings: $249,606

PAYBACK: 5.1 Years

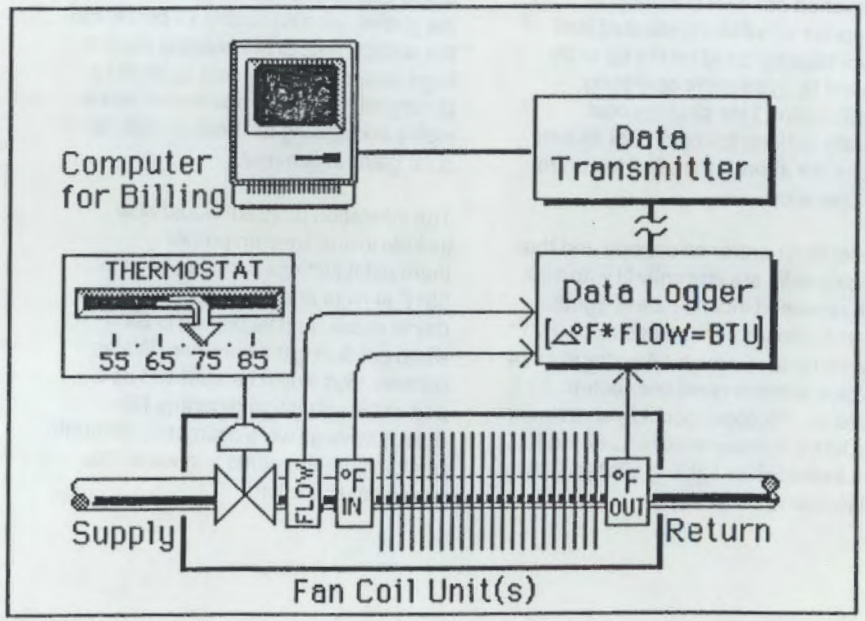
The central theme of Team A's retrofit strategy is to combine improvements in the HVAC system with control changes that will make it possible for the owner to shift apartment heating and cooling costs to tenants. Also, strategies to reduce conduction losses are added to the operation strategies aimed at reducing infiltration. The effect is a whopping $83 per unit per month reduction in the owner's energy bill or $365,000 per year. This is possible, of course, only if it is acceptable for tenant bills to rise from about $51 to $78 per month on average.

The heart of systems related strategies is to add a thermostatic control and metering at each fan coil unit (see diagram). By adding a control valve and thermostat to each fan coil, control is significantly increased from the previous "hi/lo" fan settings. This not only allows for increased unit comfort (in the face of significantly different solar loads on different sides of the building), but also gives tenants the opportunity to set back thermostats at night or when away.

The team investigated two options for accomplishing individual metering of use of a central heating and cooling system. In the first option, a Btu flow meter is added to supply and return piping at each fan coil unit to measure the amount of heating or cooling each is taking from the central system. This meter is then read by a third party contractor and the tenant is billed monthly for energy used as though from a utility. This approach takes advantage of central system efficiencies while more fairly allocating tenant energy costs. Although no credit was taken in our current modeling of this issue, it is estimated that tenant energy use drops 10 to 30 percent when tenants become responsible for their own energy bills. The high cost of this strategy shown in the cost summary, reflects the assumption that each fan coil unit must be retrofitted by cutting pipe and installing sensors at each fan coil unit. If installations can be made on an apartment basis, costs would be reduced to one-fourth of the current estimate.

As an alternative, the team also investigated the potential of using a new "counting" thermostat, which monitors the temperature setting each tenant selects. A simple but precise oscillator produces a different number of "counts" or blips per minute for each temperature setting -- the higher the setting the

A third party can transfer apartment energy costs from the owner to the tenant -- several devices are available for third party billing



greater the number of blips per minute. At the end of each month, tenant bills are computed using a formula which allocates total system costs to a tenant based on each tenant's proportion of total energy use.

The cooling system is modified by installation of a 550 ton (electric) centrifugal chiller in place of the current absorption chiller. Installing a high EER model would cost about $163,000 but the increase in efficiency is estimated to save the owner about $65,000 per year-- or a 2.5-year simple payback. Without the absorption chiller, both main boilers can be shut down over the summer, as long as a dedicated domestic hot water boiler is installed. This is not a bad idea in any case, as it increases DHW system efficiency from about 47 percent to over 70 percent. Additional savings would be possible if waste heat from the chiller were used to preheat incoming DHW water.

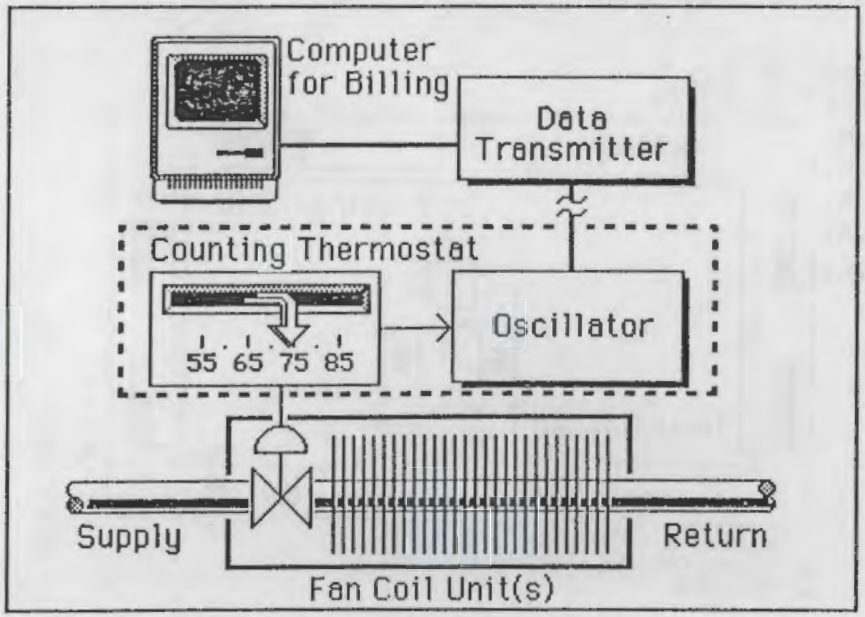
Once infiltration losses have been reduced by the operation strategies, conduction losses become relatively more significant. Two strategies are proposed to cut conduction losses. First, Team A recommended installing interior storm windows on both fixed and operable glass. The team reasoned that on a building this large, it would be possible to fabricate the necessary hardware to make the job cost effective. The second pane of glazing would significantly reduce conduction losses but would have the added advantage of modestly helping reduce infiltration.

Second, the team recommended insulating the garage ceiling not only to cut conduction losses from the first floor to the garage but also to make it possible to reduce garage air temperatures. By adding a suspended ceiling with batt insulation (R-11), a heated plenum is created in the garage. The heated plenum protects pipes while maintaining the thermal comfort of the first floor. By converting the current "wet" sprinkler system to a "dry" system, garage set points could be lowered to 35° F. This would significantly reduce heating costs while maintaining ventilation required by code.

As a final recommendation, the team suggested removing the incinerator and replacing it with a garbage compactor which would be supported with a contract for hauling away garbage. The team felt that it would surely be less costly to haul garbage than to pay for virtually constant operation of the incinerator and scrubber.

At $1.25 million, this is a costly strategy set. The most significant item is the cost of modifying fan coils, which might be reduced if control and metering can be done on an apartment basis. Nevertheless, savings to the owner are estimated to be $365,000 per year for a simple payback of only 3-1/2 years. This assumes, of course, that it is acceptable to increase tenant bills by some $27 per month. If this is not acceptable, net savings from this strategy set are still $250,000 per year resulting in only a 5-year simple payback.

As a means of mitigating tenant energy cost increases, the team suggested, then rejected, installing high efficiency appliances at the owner's expense. Preliminary modeling estimates are that this would reduce tenant electric bills roughly 10 percent or about $5 per month ($22,000 total for the building per year)-- not nearly enough to justify the estimated $73,000 increase to buy high efficiency stoves and refrigerators.



Retrofit Team B

In addition to the four operations strategies recommended previously, Team B took an aggressive approach to retrofit--recommending 17 additional strategies. In general, these strategies focused on three areas: reduction of energy gains and losses through large glass areas; reduction of unwanted air infiltration; and major overhaul of the heating, ventilation, and air conditioning system to improve both control and system efficiency.

Analyzing the building envelope revealed several opportunities for saving heating energy. The team recommended that 13 percent of the total glazing area be replaced with an R-24 insulating panel, designed and constructed to replace one hopper window in each unit. Heat conductance losses would be significantly reduced.

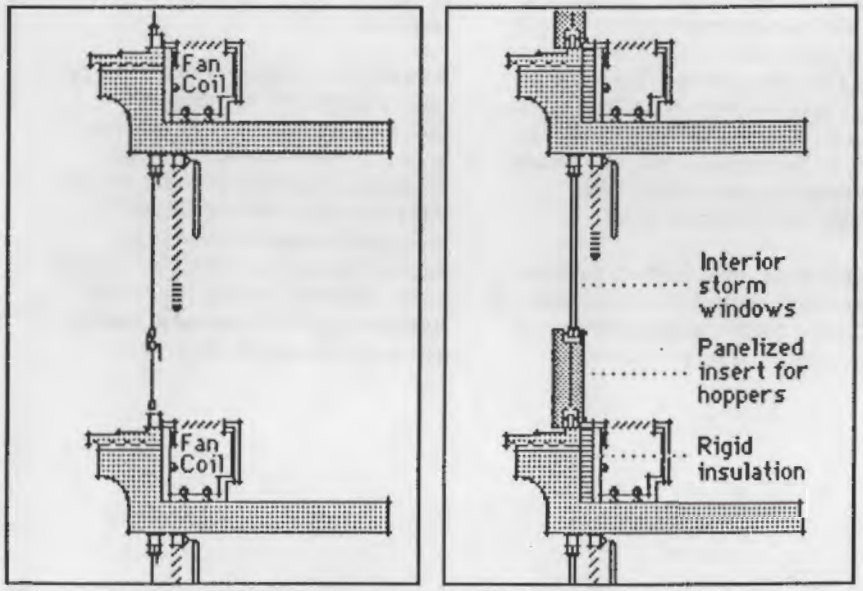
Single pane interior storm windows were recommended for all fixed glass (68,080 square feet). Together, these strategies effectively double the R-value of about 70 percent of the building shell.

The cold and high winds coming off Lake Michigan also suggest large potential energy savings by weather-stripping all hopper windows and caulking all fixed glass. Combining the effects of storm windows, caulking, and weatherstripping, heat losses due to infiltration were estimated to be reduced by 50 percent. Altogether, envelope and glazing strategies cost roughly $275,000.

The existing two-pipe hydronic loop that circulates either heated or cooled water to fan coil units in each apartment was split into two zones at each floor. This modification allows east and west zones to receive different water temperatures, which not only increase occupant comfort but also reduce energy costs. The change can be made by adding a new supply and a new return riser at a cost of about $10,000.

With each apartment, fan coil units were modified by adding a thermostat (including an anticipator and an outside temperature sensor) and an hour meter. The thermostat increased tenant control and the potential for conservation. The hour meter creates the potential to

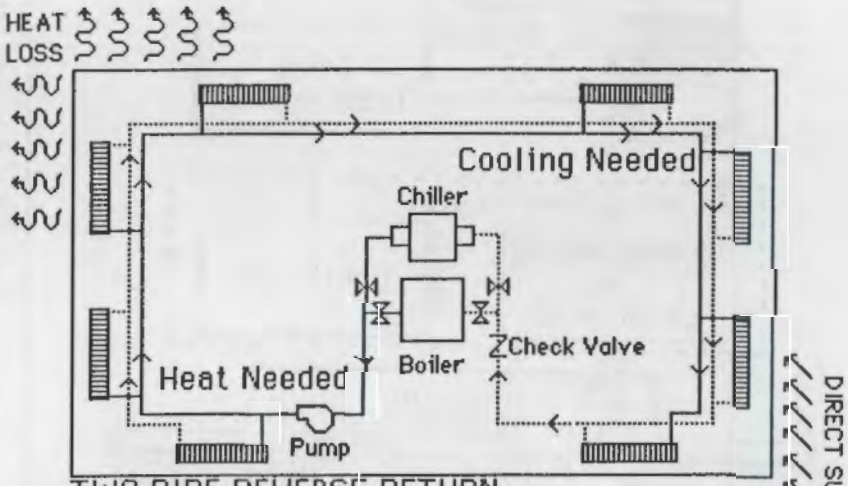
TYPICAL WALL SECTIONS



Before Retrofit

After Retrofit

Large glazed areas create simultaneous heating and cooling loads during the swing seasons



TWO PIPE REVERSE RETURN
PROVIDES ONLY HEATING OR COOLING AT ONE TIME

pass on heating and cooling costs to tenants at some point in the future if the owner wishes. Finally, 1-1/2" of rigid insulation was installed behind each fan coil unit to reduce conduction losses.

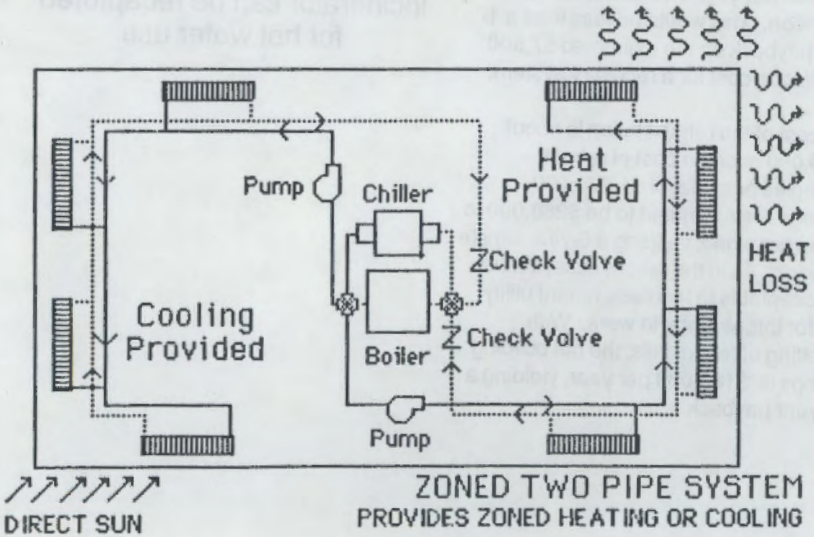
By installing an insulated dropped ceiling to create a heated plenum space, the garage air temperature could be significantly reduced while protecting pipes and maintaining comfort on the first floor. The plenum, insulated to R-11, has a 45° F setpoint and heat to provide freeze protection. The existing sprinkler system was converted from a wet to a dry system. By allowing garage temperatures to drift very low, necessary ventilation could be maintained while cutting heating costs. The minimum garage setpoint would be limited by tenant response to lowered temperatures.

By separating domestic hot water heating from mechanical system boilers the efficiency of both systems could be improved. This change requires installation of a third boiler dedicated to domestic hot water. A flue gas analyzer and DHW pre-heater were recommended for the main boilers.

The team also proposed removing the gas fired incinerator and replacing it with a commercial scale trash compactor for gas fuel savings of 30,000 therms or $15,000 per year not including reduction of water consumption by eliminating the scrubber. This proposal should be compared with the cost of garbage removal to a land fill.

Taken together, these strategies are estimated by computer simulation to reduce total energy use in the building by 37 percent -- a $40 per unit or $177,000 per year savings to the owner and a dollar or so savings per month to each tenant. At an estimated cost of $583,700, simple payback would be achieved in 3.2 years.

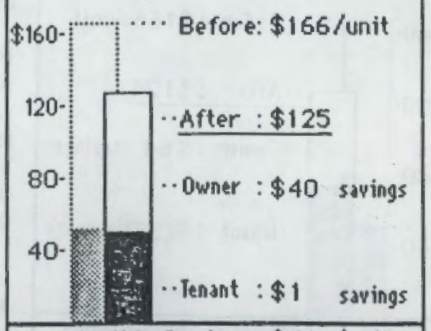
Zoned heating or cooling lowers energy consumption and improves comfort



ZONED TWO PIPE SYSTEM
PROVIDES ZONED HEATING OR COOLING

STRATEGIES & COSTS	
Envelope:	
- Replace13% glazing with R-24 panelized insert	$ 59,300
- Add 1 1/2" insulation @ fan coil	-0-
- Storm windows onafixed glass	153,200
- Caulk window & replace gaskets	65,300
Infiltration/Exhaust:	
- Reduce bath and kitch. exhaust	-0-
HVAC:	
- Add Anticipators and sensors	500
- Add thermostat controll@ units	168,300
- Convert wet garage sprinkler to dry	2,300
- Create heated plenum in ceiling	6,500
- Convert to 2-zone heat system	10,000
- Add hour meter on fan motor	50,500
- Add heat recovery for DHW	7,500
- Add flue gas analyzer	5,000
Lighting/Appliances:	
- Reduce canopy & Soffit lights	-0-
- Add photocell on exterior lighting	1,100
- Remove incinerator	25,100
DHW:	
- Add flow restrictors	4,800
- Use volume reduction in toilets	-0-
- Add dedicated DHW boiler	24,500
- Reduce hot water temperature	-0-
Training:	
- Start tenant education program	-0-
TOTAL COST:	$583,700

UTILITY BILLS



Monthly Savings: $41 /unit

Annual Savings: $180,707

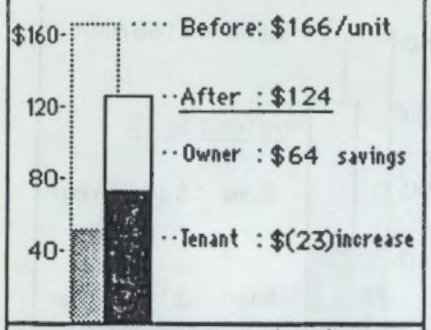
PAYBACK: 3.2 Years

Rehabilitation Team A

CHICAGO, IL

STRATEGIES & COSTS	
Envelope:	
- Repeat Team A retrofit strategies	$ 313,100
Infiltration/Exhaust:	
- Repeat Team A retrofit strategies	290,600
HVAC:	
- Reduce corridor temperature to 60F	-0-
- Install individual hydronic heat pumps/run-around loop system with H/C setback thermostats, reduce water temperature to fan coil	953,700
Lighting/Appliances:	
- Repeat Team A retrofit strategies	79,800
- Install incinerator heat recovery	7,500
DHW:	
- Repeat Team A retrofit strategies	22,000
TOTAL COST:	$1,666,700

UTILITY BILLS



Monthly Savings: $41/unit

Annual Savings: $182,522

PAYBACK: 9.1 Years

The focus of Team A's rehabilitation strategy is to replace fan coil units in each apartment with hydronic heat pumps. This would take advantage of the existing hydronic loop in the building while increasing tenant comfort and control. The team also proposed adding heat recovery on the existing incinerator instead of going to a compactor.

With double glazing at 23 to 36 percent of floor area, these apartments are very sensitive to sunlight. On a clear winter day, south facing units will be receiving more sunlight (and heat) than they can use while north units require heating. The most efficient system for simultaneously offering heating and cooling in a building like this is a hydronic "runaround" loop with heat pumps. Its main advantage is the ability to transfer heat from one side of the building to the other via the water loop. The tenant amenity of optional heating or cooling during the spring and fall is gained, and each tenant is billed directly for the electrical portion of their heating and cooling.

In this arrangement Btu flow meters are not used. It is presumed that the owner will pay for heat added to the hydronic loop by the main boiler. This amount of heat is significantly reduced, however, by taking advantage of solar gains on the building.

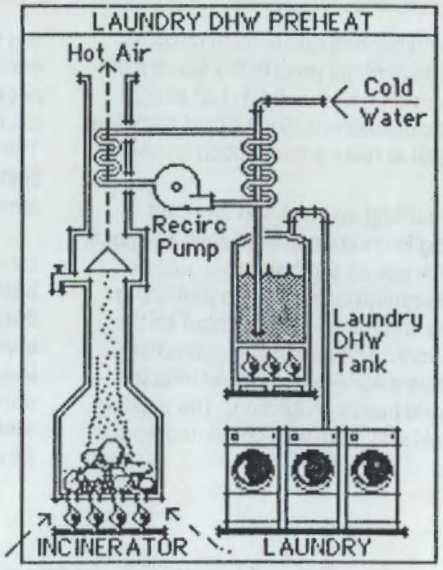
In comparing this solution to the retrofit solution, note that the owner's bill is not reduced as much. The owner still pays for boiler operation. The tenant's bill still increases by about $23 on average.

Even though much of the heating cost is paid by the owner, heat pumps add to the tenant's electric bill. However, tenant comfort is significantly increased. Tenants can have heating or cooling whenever they want, unlike the existing system which can provide only heating or cooling seasonally on a system wide basis.

Team A also looked at using heat recovery from the existing incinerator instead of going to a compactor system. The team noted that while the incinerator "wastes" about 340,000 Btu's, the laundry requires about the same amount for domestic hot water heating. If incinerator flue gasses could be used to preheat laundry water, savings would be significant.

Preliminary modeling estimates indicate that heat recovery could save up to $10,000 per year on incinerator operation. This would be less than a 1-year payback on the estimated $7,500 installation cost for a recovery system.

Net cost of the rehabilitation is about $350,000 over the cost of retrofit strategies or a total of $1,670,000. Savings are estimated to be $288,000 to the owner alone, yielding a 6-year simple payback. As in the retrofit case, it must be acceptable to increase tenant utility bills for this strategy to work. With offsetting of tenant bills, the net building savings is $183,000 per year, yielding a 9.3 year payback.



Waste heat from the incinerator can be recaptured for hot water use

Rehabilitation Team B

CHICAGO, IL

It is the presumption of Team B that rehabilitation would occur either as part of a major refinancing of the building or at the end of the useful life of the mechanical system -- or both. In addition to recommending the majority of operations and retrofit strategies discussed previously, the team focused on replacing major mechanical equipment.

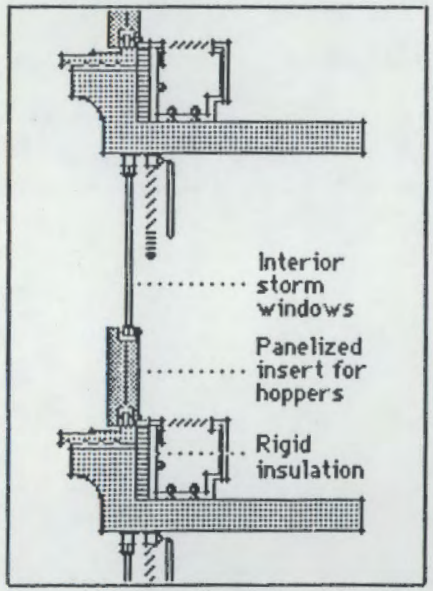
Replacing both hot water boilers with new 8,000 MBH gas boilers improved the overall heating system efficiency to 75 percent. The absorption chiller was also targeted for conversion by installing a new 650-ton chiller with a higher energy efficiency ratio (EER) of 11. Replacing the chiller would be reasonable because of the age of the system regardless of energy cost savings potential.

Instead of using 1 1/2" rigid insulation behind each fan coil unit, dividers were installed to protect the fan coil, all remaining space in the cabinet and all raceways were filled with loose cellular perlite insulation (roughly R-43). This strategy demonstrates an alternative way to reduce wall heat losses. The R-43 insulation level is simply the result of filling the fan coil housings and should not be taken as an optimum or engineered value.

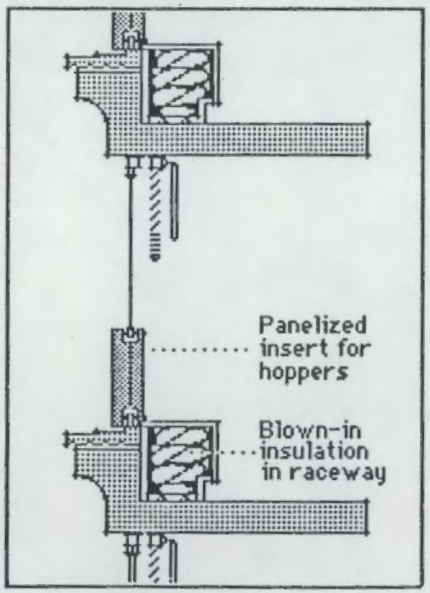
As in the retrofit solution, insulated panels (R-24) replaced one hopper in three window units and two hoppers in four window units (13 percent of glass area). When the design team computed the improved U-value from both insulated panels and highly insulated fan coil units, it was decided that storm windows did not sufficiently increase the overall wall U-value to merit the cost so they were omitted from the rehabilitation strategy set. If panels are not used, the interior storm windows should be installed.

The cost of adding the hot water boilers and high efficiency electric chiller ($305,000 total) is roughly equal to deducts from the retrofit strategy set ($153,000 for storm windows and $168,000 for individual thermostat control). Net cost for this strategy set is $586,000. Annual savings of $40 per unit per month to the owner ($177,000 per year) and $5 to the tenant give a payback of 2.4 years.

TYPICAL WALL SECTIONS



After Retroit

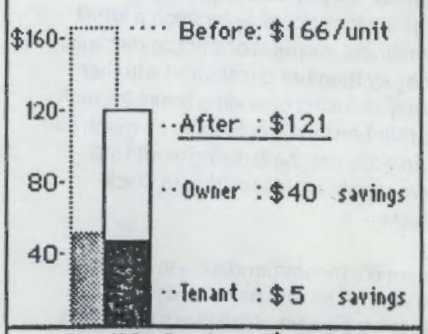


After Rehabilitation

STRATEGIES & COSTS

Envelope:	
- Glazing-replace 13% with R-24 panelized insert	$ 59,300
- "Blown-in" insulation in boxed-in extensions of fan coil units, R-43	18,600
Infiltration/Caulk:	
- Repeat Team B Retrofit Strategies	65,800
HVAC:	
- Repeat Team B retrofit strategies but delete individual thermostats	81,800
- Increase hot water boiler system efficiency to = 0.75 8000 MBH (gas)	150,000
- Electric chiller conversion (EER = 11) 650 ton	155,000
Lighting/Appliances:	
- Repeat retrofit strategies	26,200
DHW:	
- Repeat retrofit strategies	24,300
Training:	
- Education program (3% - cooling season only	-0-
TOTAL COST:	$586,000

UTILITY BILLS



Monthly Savings: $45/unit

Annual Savings: $198,286

PAYBACK: 3.0 Years

Jury Comments

In reviewing the solutions offered by Team A, one jury member questioned the use of charcoal filter units instead of providing bath and kitchen ventilation to the outside. Team members responded that building codes are increasingly allowing this conversion and that it is typically acceptable to tenants. The question of indoor air quality was raised. No information was available to answer this point, but it was said that electric ranges were likely to cause less problems along this line than gas stoves.

Another jury member commented that heat pumps would be especially attractive if the building were to be converted to condominium ownership. Individual unit control would be increased and costs allocated more fairly. Allocating individual costs would also give much greater incentive for conservation.

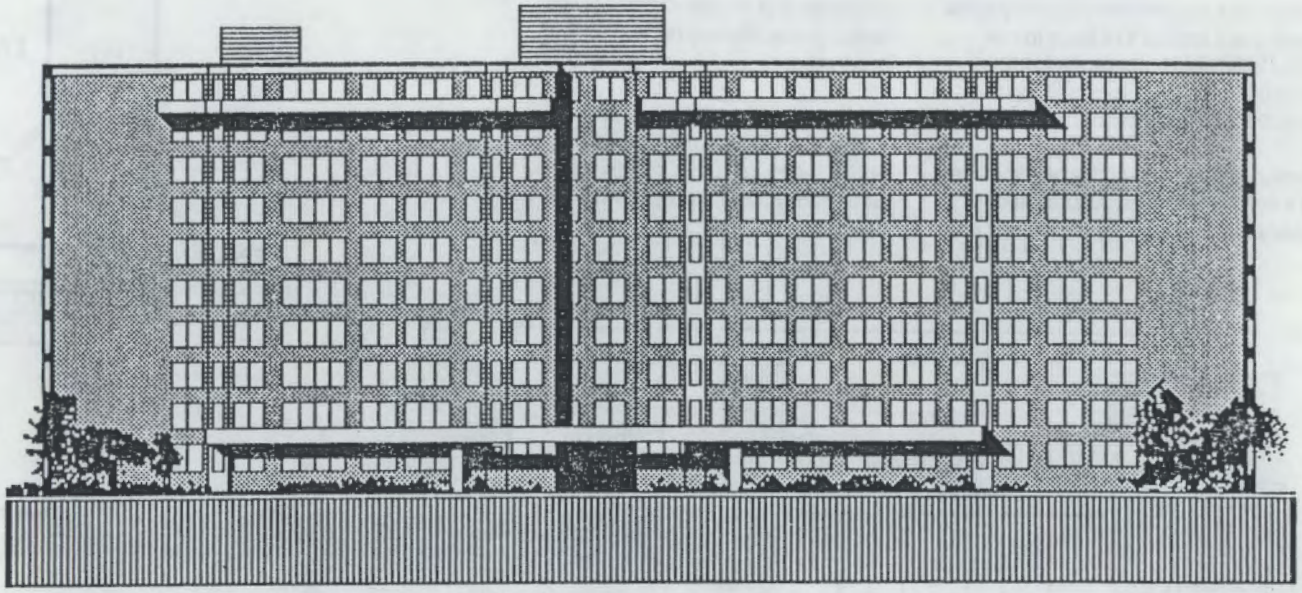
In reviewing the solutions offered by Team B, the jury was impressed with the large savings possible for such a small investment in operations improvements. One jury member questioned whether simply reducing operating hours for bath and kitchen fans would save as much as claimed, since the building would still have significant losses due to stack effects.

Team B's recommendation to cover existing glass with panelized insulation (up to 13 percent of the glass area) was somewhat controversial. It was questioned whether this solution could be made to look good from the outside and whether it would be acceptable to tenants to reduce views.

Team B also identified the exposed spandrel as a significant source of heat loss but could not come up with a solution for covering the spandrel that was acceptable to the jury.

The jury noted that neither team addressed the issue of reducing garage ventilation which could reduce heating costs while maintaining warmer temperatures than recommended by the teams.

Washington, D.C. Highrise



A Capitol Solution

This 10-story luxury apartment building located in Washington, D.C., includes efficiency, one-bedroom, and two-bedroom units with a 25,000 square foot underground garage.

Completed in 1981, the original building design incorporates many energy-saving features, including double-glazed window units, heat pumps and individual metering of apartment energy use. Through our evaluation of this building, the design teams concluded, however, that some of these features could lead to increased energy consumption if not understood and used properly by the tenants. Therefore one of our recommended priorities for improving energy consumption is tenant education.

Each tenant pays for his or her own electricity use, while the landlord pays for natural gas, and electricity used in common areas and exterior to the building. The tenant's average monthly electric bill is approximately $58 per month. The owner's share of the utilities is approximately $40 per month.

Heating and cooling are the largest energy end-use categories in this building. Together they account for over 60% of annual energy costs. The air conditioning tonnage required for cooling the building is extremely high, at between 220 and 240 square feet per ton. Much of the energy use is caused by high levels of infiltration into individual apartments, due to the interaction of an inefficient HVAC system in the corridors and an overused kitchen and bathroom exhaust system.

Changes to building operations alone, while requiring an initial investment of approximately $20,000 to $50,000, could produce savings of $50,000 to $75,000 per year; a simple payback of less than six months. The retrofit measures recommended by the design teams would produce savings of approximately $100,000 per year, with simple paybacks of less than two years.

The teams also studied a full-scale rehabilitation of the building to further increase energy savings while adding to the amenities of the building.

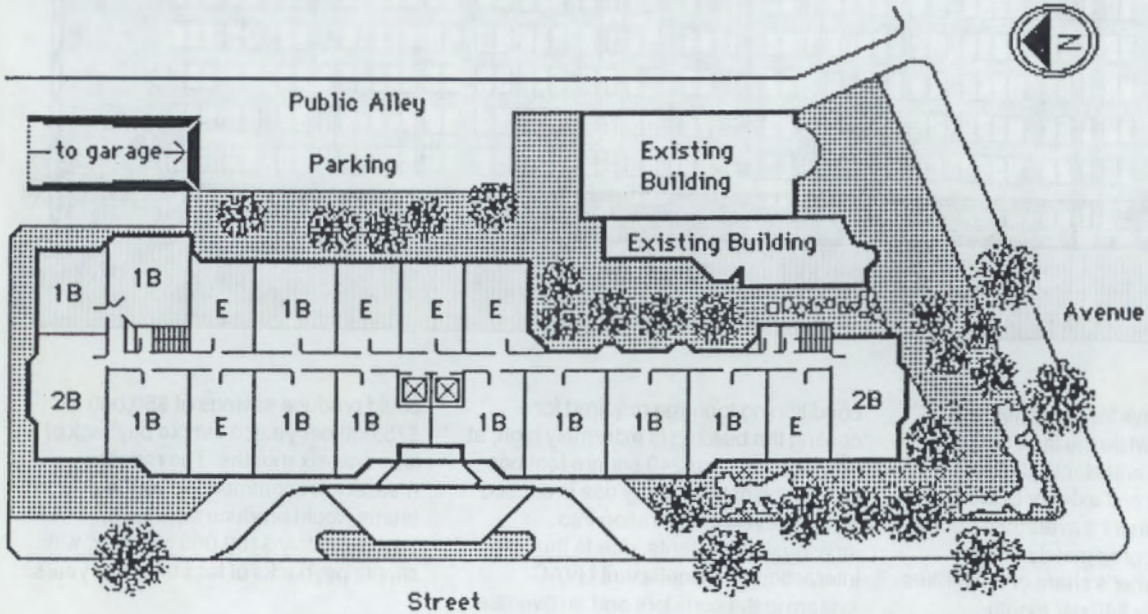
Building Layout

A typical floor plan and apartment floor plans are shown in the sketches below. Each floor has two 820 square foot two-bedroom apartments, ten one-bedroom apartments averaging 602 square feet each, of which there are two models, and six 491 square foot efficiency units. There are a total of 176 units in the entire building. Rents range from $508.00 for an efficiency unit, up to $965.00 for a two-bedroom apartment.

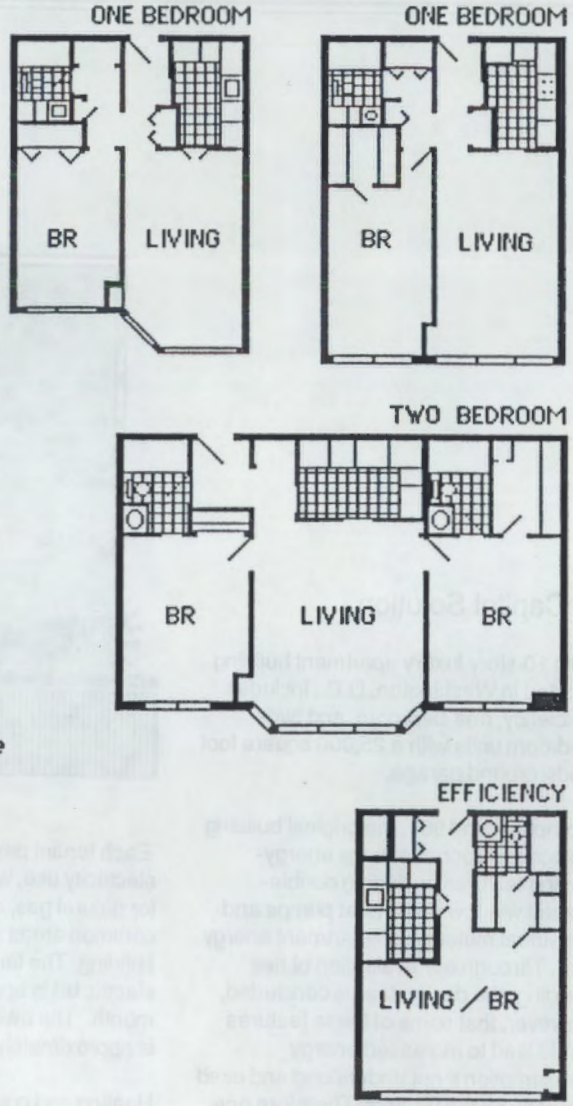
The long dimension of the building lies on a north-south axis. All units face either east or west. Approximately 45 percent of the exterior envelope is glazed.

The ground floor (not shown) houses the lobby and the rental office. An airlock entry gives access to the street and a single level of enclosed parking lies below grade, directly beneath the ground floor.

Two elevators provide vertical transportation and are flanked at each end of the main corridor by fire stairs. Each floor has a laundry room with washer and dryer.



SITE & BUILDING PLAN



TYPICAL UNIT PLANS

Building Specifications & Operations

WASHINGTON, D.C.

Built in 1978, this is a luxury high-rise with approximately 300 tenants at full occupancy.

The quality of the building is expressed in the fairly large size of the units, the standard furnishings and appliances provided with each unit, and the large amount of exterior glass, arranged as bay windows in the larger apartments. Some units also save a private balcony or patio. A sauna and sun deck are located on the roof of the building.

Building specifications include a number of features intended to reduce energy consumption, including insulated glass windows, individually controlled hydronic heat pump heating and cooling systems and individual electric meters for each apartment. Each apartment also has its own electric-resistance hot-water heater.

The building has adequate roof insulation (R-20), but relatively low thermal resistance in the uninsulated exterior walls (R-4). Thermal breaks are not provided between balconies and the interiors of the apartments.

Space conditioning is provided to each apartment by an individual hydronic heat pump drawing from a common runaround loop. A thermostat is located in each apartment. Supplementary heating is provided by in-line electric-resistance heaters located upstream of each heat pump. A cooling tower is used to reject heat from the runaround loop when the units are operating in the cooling mode. The heat pump units are sized to provide one ton of cooling capacity to approximately each 230 square feet of apartment floor area. A supplementary 38-ton capacity DX unit provides conditioning to the common spaces.

Mechanical exhaust of kitchens and bathrooms introduces greater amounts of outside air than would occur due to uncontrolled infiltration.

BUILDING SPECS

ENVELOPE:

- Exterior Wall
  4" CMU faced with 4" brick. No insulation. Gypsum wallboard interior finish. Similar to ASHRAE Wall Type C, weight 50#/s.f. R=3.67/U=0.28. Surface medium dark color
- Window
  Clear, double-pane glass in horizontal aluminum sliding frames R=1.82/U=0.55 including frame. Shading coefficient 0.64 with light-colored venetian blind
- Roof
  Membrane roofing, 2" of polyurethane insulation, 8" of light-weight concrete. Similar to ASHRAE Roof Type #12, weight 75#/s.f. R=20/U=0.05. Surface medium color

INTERNAL LOADS

- Lights: 0.5 Watts/s.f.
- Appliances: 0.4 Watts/s.f.
- Cooking: 6000 Btu/day (40% latent)
- Elevators: 2 @ 22kW
- Infiltration: 0.7 Air Change/hr.

VENTILATION/EXHAUST

Kitchen & Bathrooms	2-Br.	1-Br.	Efficiency
	160 cfm	80cfm	80 cfm

SYSTEM SPECS

HVAC
Hydronic Heat Pump System with Supplemental Electric Resistance Heaters

TEMPERATURE SETPOINTS
Heating: 70°F
Cooling: 78°F

CENTRAL PLANT
Central Plant for common areas can provide heating or cooling in any month
1-38 Ton roof-mounted DX Cooling unit with COP=3.03 (EER=10.3)
Electric reheat coils: 130 kW
Air handling unit: 5750 CFM

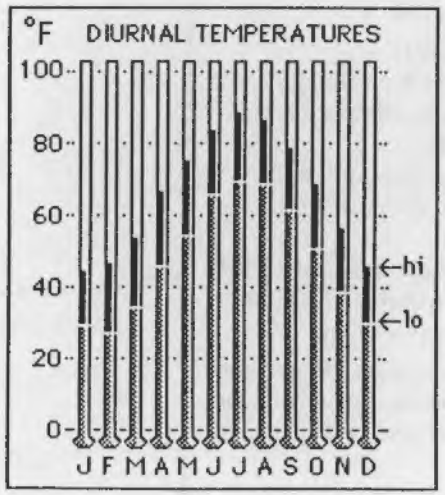
DOMESTIC HOT WATER
2000 Btuh usage rate assumed during weekday occupied hours w/80% assumed efficiency

Energy Analysis

Washington, D.C., temperatures fall between 30° and 80° F approximately 85 percent of the time. These hours are almost evenly distributed across this temperature range.

In general, residential buildings in this climate require some amount of heating energy during 8 months out of the year. Moderate levels of solar radiation make passive-solar heating possible during approximately 3,600 hours. Cooling is required an average of 800 hours per year. Except during midsummer periods of extreme humidity, the climate permits a variety of passive and low-energy cooling strategies.

The Washington climate is both hot and cold, creating significant heating and cooling loads



Energy consumption in the spring and fall is lower in this building than in typical buildings for the area due to the double glazing and the runaround hydronic heat-pump system. The hydronic heat-pump system allows heat gains on one side of the building to address heat losses on the opposite side of the building. However, the envelope construction, inefficient HVAC systems, high auxiliary electric loads, and a domestic water-heating system that consumes far more energy than necessary, offer opportunities for significant energy cost savings.

Over 80 percent of the glazing in this building faces either due west or east. This orientation results in net heat loss in the winter and excessive solar gains, requiring additional mechanical cooling, during the summer.

When auxiliary heating is required, electric-resistance coils, placed up-stream of an apartment's heat pump, raise the temperature of the runaround loop. The heat pump then extracts this energy from the loop to heat the apartment, an extremely inefficient form of electric-resistance heating during cold weather.

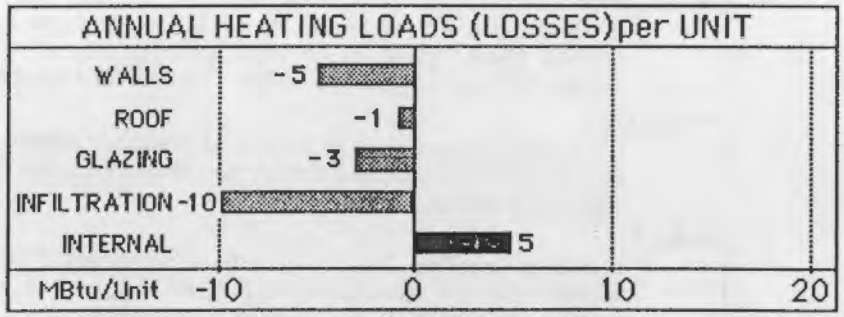
In summer, the high cooling loads caused by the east and west glazing require one ton of air-conditioning per 220 to 240 square feet of apartment. This condition highlights the significance of proper glazing orientation and/or external shading.

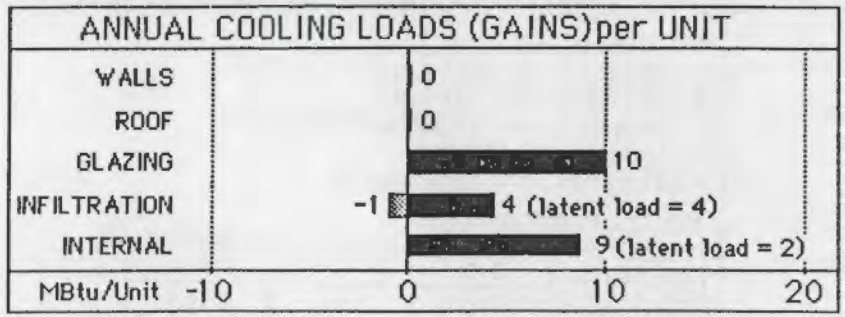
The centralized exhaust system for kitchens and baths is assumed to raise apartment infiltration loads to 1.33 ACH when in use. The negative pressure created by the exhaust system draws air from both the corridors and the exterior.

Although corridors have significant uninsulated exterior wall area, the primary load in these areas is conditioning makeup air. The roof-mounted, constant-volume terminal reheat unit that serves all corridors operates using 100 percent outside air with no recirculation. Some supplementary heating and cooling in the corridors is provided by the owner, but all apartment heating and cooling costs, except for energy to operate the cooling tower and hydronic loop pumps are borne by the tenant.

The heating of domestic hot water also requires significant amounts of energy. The tenant pays for the use of an undercounter electric-resistance tank, located in the kitchen of each apartment. Each laundry has its own 120-gallon DHW tanks, whose operation is paid for by the owner.

Major lighting loads are caused by incandescent apartment unit lighting systems, fluorescent corridor and lobby lighting, and approximately 2 kW of garage and exterior lighting.





It would cost roughly $3.8 million to replace this building,assuming a 1985 construction cost of $60 per square foot. This price excludes the wall insulation that should have been included in the original design.

The rents charged in this building are, on average,$0.56 per square foot per month higher than the median for Washington, D.C., according to IREM.

The owner's average annual energy bill is $84,245 per year or $1.32 per square foot per year. His largest cost is heating the corridors and lobby, followed by water heating, cooling of the corridors and lobby and vertical transportation. Heating accounts for 67 percent of the owner's bill. Together, these four categories account for 91 percent of the owner's bill.

The owner's annual utility bill is slightly above the IREM median for the Washington, D.C. area. Energy-related utility costs are roughly 9 percent of the rental income for an average apartment.

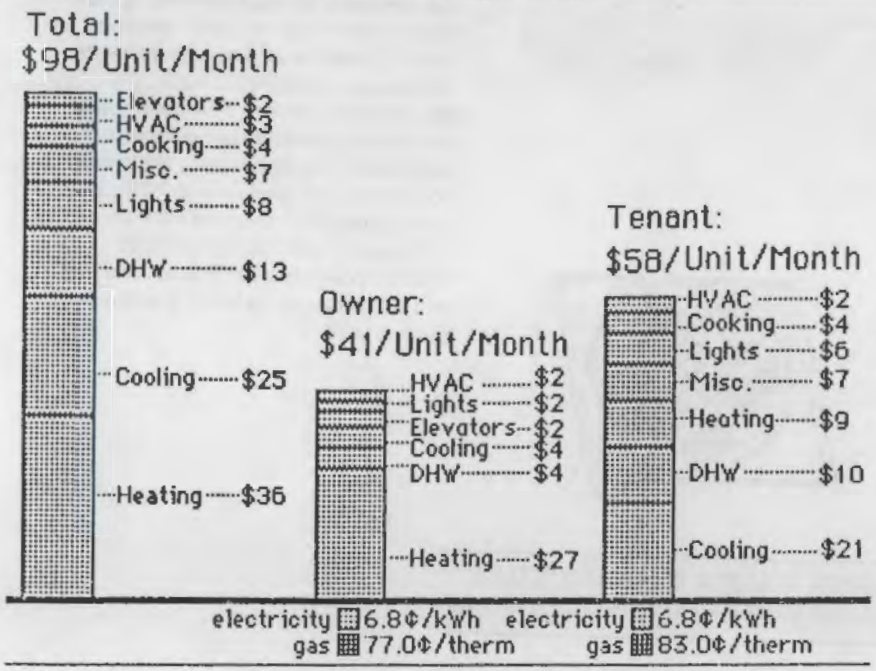
The tenant's average monthly utility bill varies with the size of the apartment: efficiency units run $40 per month or $480 per year; one-bedroom units run $54 per month or $648 per year; two-bedroom units run $78 per month or $936 per year. The average of these ($58 per unit per month) was used for this study.

The largest area of energy use for the tenant is space cooling, followed by water heating, space heating, miscellaneous appliance loads and lighting. Together, these five categories account for 91 percent of the tenant's bill.

A typical two-bedroom unit in this building rents for $850 per month. After adding average utility costs of $58 per month, the shelter cost is $908 per month. Assuming that shelter cost cannot exceed 35 percent of gross income, it would take an annual income of over $31,000 per year to qualify for this apartment. Reducing utility costs by 50 percent would reduce income to qualify by roughly $1,000. A factor of significant interest in a very competitive market.

The following six pages illustrate approaches to reducing energy costs taken by two separate design teams. They focus on changes to operating strategies, the retrofit of the existing building, and its complete rehabilitation. In some cases, utility costs are reduced by more than 50 percent.

Washington, D.C. Highrise Utility costs



Energy and Rent Analysis

(Typical Two-Bedroom Unit)

Net Rent to Owner	$809
Owner's Monthly Energy Cost/Unit	$ 41
TOTAL RENT	$850
Tenant's Monthly Energy Cost/Unit	$ 58
SHELTER COST	$908

INCOME TO QUALIFY: $31,131

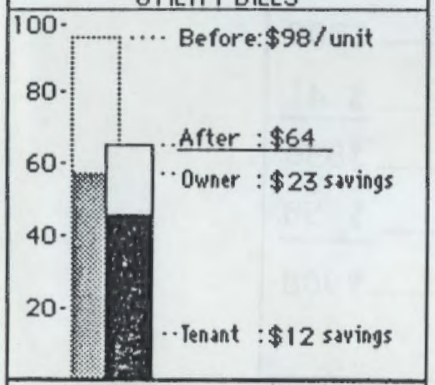
WASHINGTON, D.C.

Operations Team A

STRATEGIES & COSTS

Infiltration/Exhaust:	
- Caulk windows	6,790
- Weatherstrip unit doors	6,635
- Reduce kitchen & Bath exhaust-fan timer from 16 to 8 hrs.	-0-
HVAC:	
- Install time clock on corridor vent. supply	175
- Revise corridor setpoints to 60° F (heat) and 80° F (Cool)	-0-
- Install programmable t-stats	19,360
Lighting/Appliances:	
- Relamp garage w/watt miser lamps - (at normal replacement schedule)	-0-
- Add photocell control for ext. lights	225
- Add time switches for storage area and laundry	250
- Add high efficiency ext. lights	16,000
DHW:	
- Add insulating jackets for all DHW heaters	3,162
- Fow restrictors on all DHW	1320
- Reduce DHW water temp. to 115°F	-0-
- Install high efficiency laundry equip	-0-
- Use plastic "chits" for laundry	-0-
Training	
- Prepare tenant education program	-0-
TOTAL COST:	$53,917

UTILITY BILLS



Monthly Savings: $35/unit

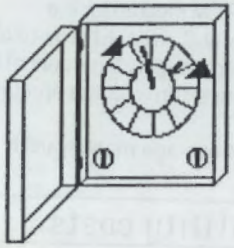
Annual Savings: $73,054

PAYBACK: 9 Months

Team A felt a cost effective way to lower energy bills is through proper use of the existing equipment. Because tenants currently pay their own energy bills, they are already motivated to reduce energy costs. A memo from the manager could be sent to tenants advising them of seasonal energy savings operations. These operations would include: opening blinds on winter days and closing blinds on summer days to reduce solar heat gains; setting back thermostats at night in the winter and setting up during unoccupied hours on summer days to cut heating and cooling costs; and using operable windows for natural ventilation instead of air conditioning. Although sure to save energy, no credit was taken for energy savings due to the uncertain nature of the human response to these requests.

To reduce domestic hot water costs the team recommended: insulating all water tanks; installing flow restrictors on all showers and sinks; and reducing the DHW temperature to 115° F. Additional DHW savings can be achieved by the owner if he requires the laundry equipment vendor to replace the equipment with units that are more energy efficient.

Several concepts were used to reduce heat losses due to infiltration. Exhaust of apartment baths and kitchens was rescheduled to morning and early evening hours only (totaling eight hours). In order to maintain the negative pressure in the apartments (so that odors don't invade the corridor) the exhaust air from the corridor was reduced to code minimum. To further isolate the units from infiltration, weatherstripping was installed on each apartment entry door and windows were properly recaulked.



TIMER SWITCH TO CONTROL STORAGE AREA LIGHTS

Lighting concepts proposed included: putting timed key switches on storage areas; switching to high efficiency fluorescent lamps and ballasts in the garage; relamping the exterior incandescent bulbs; and using a photocell control for the exterior lighting.

The largest operations change recommended by the team was to the HVAC control system, which controls about 60% of the total operations costs. The team recommended that digital programmable thermostats be installed in each unit to provide better control of both the heating and cooling systems. For heating, set points are at 70° F, 8 hours a day with a daytime set back of 60° F and a night setback of 55° F. Summer points are 78° F, 8 hours a day with a daytime set up to 85° F and a night setback to 75° F.

LARGER PULLEYS INSTALLED REDUCE CORRIDOR VENTILATION TO CODE MINIMUM

Operations Team B

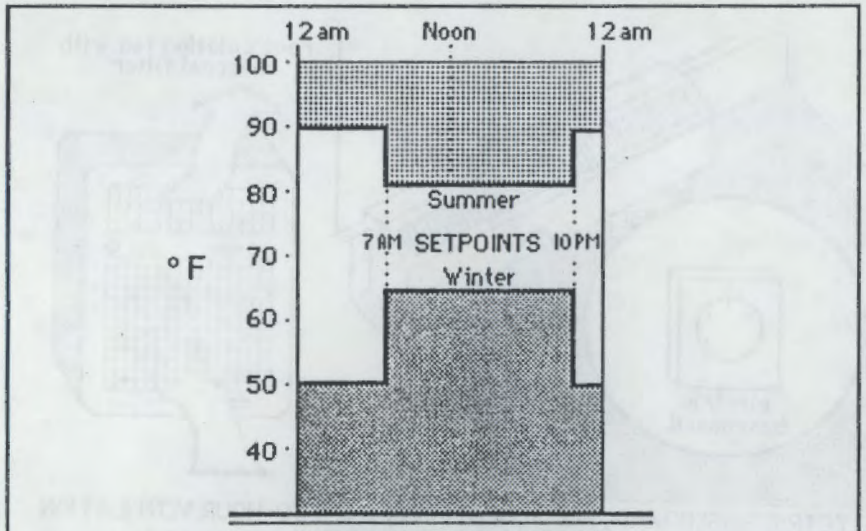
WASHINGTON, D.C.

Team B operations and maintenance strategies principally address the large heating and cooling loads in the building, with some attention given to domestic hot water and lighting strategies.

As with Team A, the recommendation was made that the owner/manager send monthly memos advising tenants to close all blinds and draperies during the day to avoid direct solar gains in the summer and heat loss through conduction in the winter. An inexpensive approach, and one which could have a substantial impact.

To reduce the amount of electric resistance energy required to condition corridors, the team proposed setting thermostats at 65° F in winter and 80° F in summer from 7AM through 10PM. Thermostats would be set at 50° F in winter and 89° F in summer from 10PM through 7AM.

Another strategy is to disable the reheat coil in the corridor and in the public space HVAC system from mid-May through the first of October, to avoid any unscheduled or unnecessary delivery of heat.



THERMOSTAT SETTINGS IN PUBLIC CORRIDORS

The following strategies were proposed to reduce infiltration, and thereby reduce heating and cooling costs for both the owner and tenant: 1.) Schedule the central kitchen exhaust system to operate at full capacity from 6AM through 10AM, 11:30AM through 1:30PM, and 5:30PM through 10:30PM; 100 percent off at all other times, reducing fan energy requirements by 55 percent; 2.) Schedule the central bath exhaust system to operate at full capacity from 6AM through 9AM and 6PM through 11PM; 100 percent off at all other times, reducing bath fan energy; 3.) Completely seal off corridor gravity feed relief vents during the heating season to avoid loss through these vents; 4.) Weatherstrip all corridor apartment unit doors, laundry room doors, and stairwell doors to reduce infiltration by 600 CFM per floor. Several of these strategies may require special approval or a code variance.

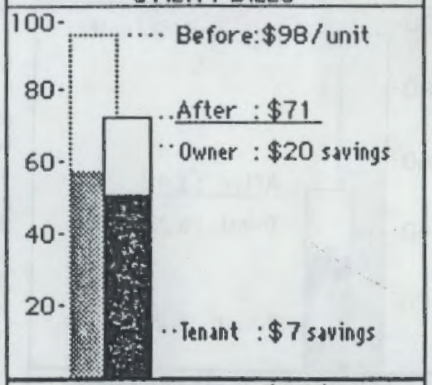
Team B recommended the installation of flow restrictors at all sinks and showers; that all DHW tanks be insulated; and that water temperature settings be reduced from 140° to 115° F.

The cost of implementing these strategies is minimal and depreciable. Utility rebates may be available for a number of the strategies. Even without rebates, however, all strategies can be paid for with the first four and one-half months of energy cost savings.

STRATEGIES & COSTS

Infiltration/Exhaust:	
- Caulk exterior windows	6,790
- Weatherstrip all doors (unit, corridor, stairwell, etc.)	9,387
- Revise kitchen ventilation schedule	-0-
- Revise bathroom ventilation sched.	-0-
- Turn off corridor ventilation: reheat coil in summer	-0-
HVAC:	
- Revise corridor setpoints	-0-
Lighting/Appliances:	
- Add photocell control ext. lights	225
DHW:	
- Add insulating jackets all DHW heaters	3,162
- Install flow restrictors	1,320
- Reduce DHW water temp. from 140° to 115° F	-0-
Training:	
- Prepare tenant education program on window management	-0-
TOTAL COST:	$20,884

UTILITY BILLS



Monthly Savings: $27/unit

Annual Savings: $56,179

PAYBACK: 5 Months

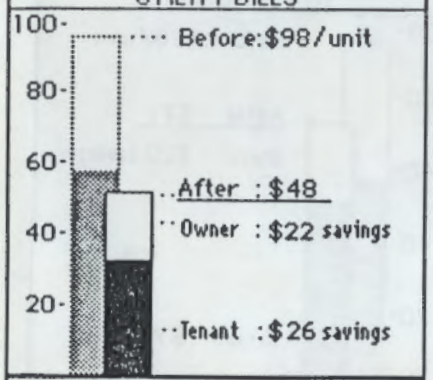
WASHINGTON, D.C.

Retrofit Team A

STRATEGIES & COSTS

Envelope:	
- Install ext. storm windows w/tinted glazing	47,000
Infiltration/Exhaust	
- Repeat Operations Strategies	13,425
- Cap kitchen & bath exhaust install recirculating fans	59,136
- Install activated charcoal recirculating fans in corridor	4,900
HVAC:	
- Repeat Operations Strategies	19,535
- Convert 40 ton roof top re-heat unit to vent only	290
- Add 60 LF of strip baseboard electric heaters in each corridor	9,600
Lighting/Appliances:	
- Repeat Operations Strategies	16,475
DHW:	
- Repeat Operations Strategies	4,482
- Convert laundry DHW and dryers to gas	4,520
Training:	
- Repeat Operations Strategies	-0-
TOTAL COST:	$179,363

UTILITY BILLS



Monthly Savings: $48/unit

Annual Savings: $101,165

PAYBACK: 1.8 Years

Retrofit features repeated operations strategies recommended by Team A, but with a more comprehensive approach to reducing ventilation air requirements.

All bathroom and kitchen exhaust ducts were capped and replaced with recirculating activated charcoal filters, now commonly used in new construction. By recirculating the air through filters, heat is captured within the apartment unit. However, this "simple" strategy costs almost 40 percent of total retrofit costs to implement.

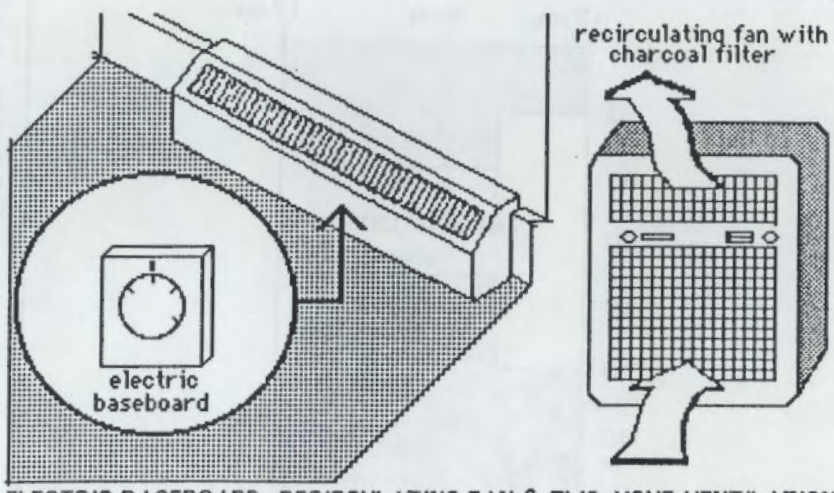
The corridor ventilation system was substantially modified. The 40-ton constant air volume terminal reheat system was converted to a ventilation system only and rescheduled to run one hour in the morning and one at night to "flush" the corridors with outdoor air. Code requirements for outdoor air were met by replacing fixed corridor windows with operable windows.

Electric resistance "strip" heaters were installed for corridor heating. At reduced ventilation rates, the corridors will be heated somewhat by "borrowing" heat from the apartment units. It was judged by the team to be less costly for the owner to bring partially heated air up to temperature with baseboard heaters than to bring 100 percent outside air up to temperature with the existing terminal reheat system.

Activated charcoal recirculating filters were installed to keep the corridor air fresh at lower air change rates. The corridor thermostats were set at a constant 60° F.

Glazing is a major source of heating and cooling loads. Tinted exterior storm windows were added to cut infiltration, reduce glazing conduction loads and decrease the amount of solar heat entering the units. Storm windows makeup about 25 percent of the total retrofit cost. The building laundry system was also targeted to lower energy costs. Team A recommended replacing electric hot water heaters with high efficiency gas units with insulating jackets. Also included in that strategy were the installation of efficient gas dryers with electronic ignition. The cost of venting through the wall to the outside was not excessive.

The concept of switching from electricity to gas will save energy costs as gas costs about one-third that of electricity for the same amount of energy in the Washington, D.C. area.



ELECTRIC BASEBOARD, RECIRCULATING FAN & TWO-HOUR VENTILATION "FLUSHING" REPLACE 40-TON, CONSTANT VOLUME CORRIDOR HVAC

Retrofit Team B

WASHINGTON, D.C.

Team B chose to include all operations strategies in the retrofit strategy set. In addition, they added the following: 1.) install exterior operable Bahaman louvered shades made of dark, anodized aluminum; 2.) install through-wall fresh air intakes at each laundry room; 3.) replace existing thermostats with programmable thermostats. The team also recommended further study of converting the laundry hot water heating system from electric to gas fuel heat, but did not include this strategy in the proposed set.

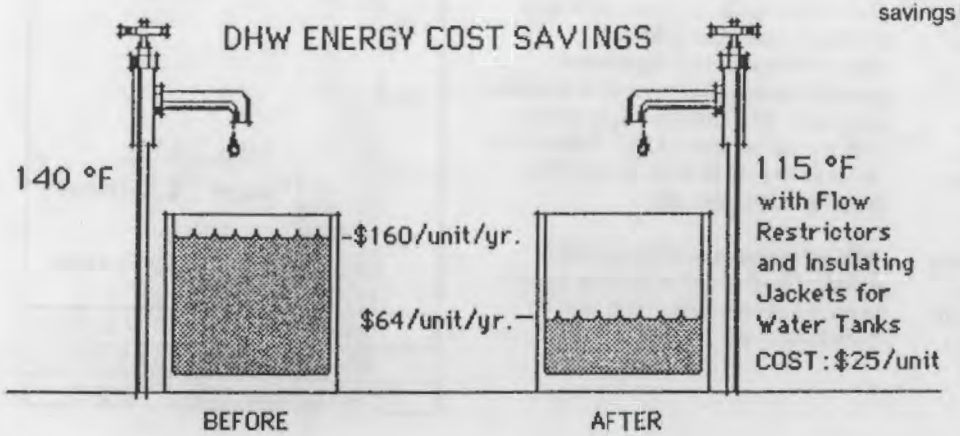
During the summer, direct solar gains are very high due to the direct east-west exposure of 74 percent of apartment unit windows. To reduce direct solar gain, Team B recommended installing exterior, operable, anodized aluminum shades on all east/west glazing. When fully deployed, the shading coefficient of the glazing is reduced from 0.64 to 0.15. The operable exterior shades also have insulating qualities in addition to their shading value. They can be closed tight to the window unit during the heating season to reduce convection losses.

Laundry dryers currently pull conditioned makeup air from the corridors. To eliminate this loss, Team B recommended installing fresh air intakes, through the exterior wall, in each laundry room and sealing the existing air intakes from the corridors.

It is to the advantage of both the owner and tenant to get more efficient operation of the runaround heat pump system. Team B recommended replacing all existing "dead-band" thermostats with programmable thermostats. After discussing the wide variation possible in programmable thermostats (98 models are now available) the team recommended that all programmable thermostats in the building be of the same type and that building personnel assist the tenants with the initial programming of each unit.

Natural gas is available at the street and it was assumed that the gas company would bring natural gas lines to the building perimeter at no cost. For this reason Team B recommended analyzing the energy cost savings potential of converting the laundry hot water system from electric to natural gas. The heat-pump booster tanks could also be converted to gas. The success of converting to gas would depend on the cost implicationqK$Y6ectric rates, demand charges, conversion costs and natural gas rates.

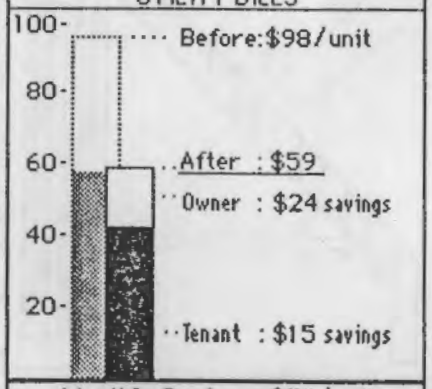
Including the relatively high cost of new shades on the building, the strategy set can still pay for itself in the energy cost savings in about a year and one-half.



STRATEGIES & COSTS

Envelope:	
- Install dark exterior anodized aluminum shades	06,097
Infiltration/Exhaust:	
- Repeat Operations Strategies	16,177
- Install fresh air intake at each laundry	650
HVAC:	
- Repeat Operations Strategies	-0-
- Install programmable thermostats	9,360
Lighting/Appliances:	
- Repeat Operations Strategies	225
DHW:	
- Repeat Operations Strategies	4,482
Training:	
- Prepare tenant education program on window management	-0-
TOTAL COST:	$116,991

UTILITY BILLS



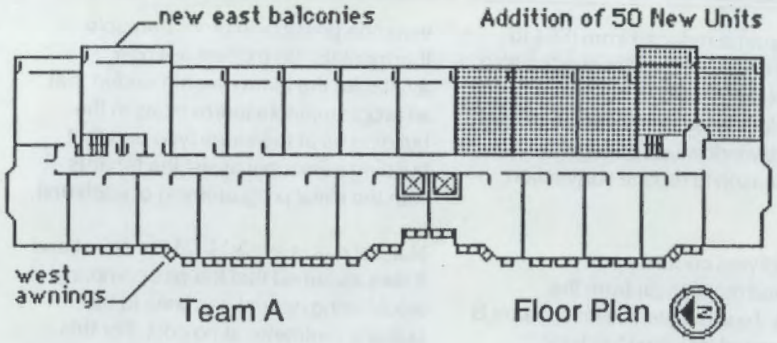
Monthly Savings: $39/unit

Annual Savings: $82,875

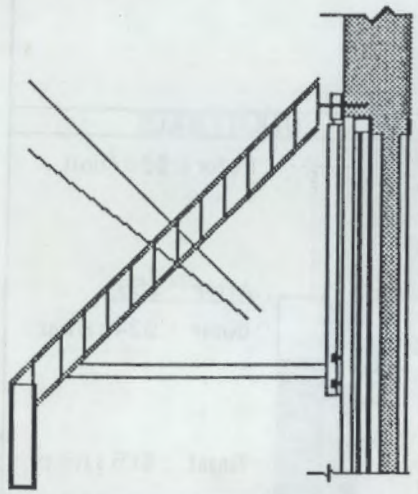
PAYBACK: 1.5 Years

Rehabilitation Team A

Team A chose to add 50 new apartment units (with balconies) to the existing building. This would improve building efficiency by adding rentable space without increasing common area, elevators, or other services. The neighboring two-story buildings must be purchased and removed to make room for the additional units and added surface parking. The team argued that a major rehabilitation is worth considering because the building is approaching its normal cycle for refinancing and the neighborhood is described as rapidly improving and a good location for young professionals.



The new building addition offers the opportunity to provide balconies on the east-side as an added amenity. These balconies shade the double glazed windows and have hinged doors (rather than sliding doors) which can be better sealed to decrease infiltration rates. West glazing is shaded with anodized aluminum louvers mounted vertically (see drawings) to block the lower sun angles. The awning bottom was set at 5'8" to allow a full standing view of the horizon from within the apartment. Energy savings would be greater if the awning dropped further down, but the owner would likely oppose this for aesthetic reasons. A balcony was considered for the west side, but the "bay window" protrusion of the upper floors already encroaches on the three foot setback.



ANODIZED ALUMINUM LOUVERED AWNINGS FOR WEST GLAZING; vertical louvers block low-angle sun

Heat loss through the exterior walls was reduced by furring out the interior face with 2"x 4" studs and filling the void with batt insulation. This construction is the cheaper way to add insulation but uses 2" more rentable space along the exterior wall than would be the case if 2"x 2" furring and 1-1/2" rigid insulation were used. The same R-values are achievable with either approach, therefore the selection depends on the initial cost of the strategy and the value of lost rentable space.

Rehabilitation strategies also include changing over from individual supplemental electric resistance heating (for the heat pumps) to a central gas boiler. The change to gas would cost the owner about $15,000 annually, but is estimated to save the tenants about $45,000 annually.

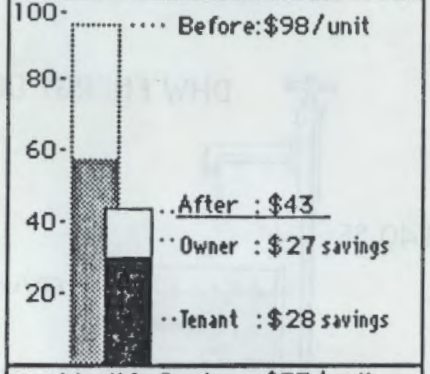
BTU flow meters would have to be installed in all units if the owner wished to pass this new cost of gas heating back to tenants.

STRATEGIES & COSTS

Envelope:	
- Repeat Retrofit Strategies	47,000
Infiltration/Exhaust:	
- Repeat Retrofit Strategies	79,534
HVAC:	
- Repeat Retrofit Strategies	19,535
- Install boiler for run-around hydronic loop heat/cool system	79,456
- Install heating coil (water) in duct for corridor air, disconnect chiller	5,531
- Install Btu flow meters in all units for third party billing	39, 550
Lighting/Appliances:	
- Repeat Retrofit Strategies	16,475
DHW:	
- Repeat Retrofit Strategies	9,052
Building Site & Solar:	
- Add anodized aluminum awnings on west facing glazing	54,752
Training:	
- Repeat Retrofit Strategies	-0-
TOTAL COST:	$350,885

Note: Added cost for 50 new units on east side and 60 new units on east facing units (not paid for with energy savings alone) $1,804,007 for units and $613,440 for balconies

UTILITY BILLS



Monthly Savings: $55/ unit

Annual Savings: $115,716

PAYBACK: 3.0 Years

Rehabilitation Team B

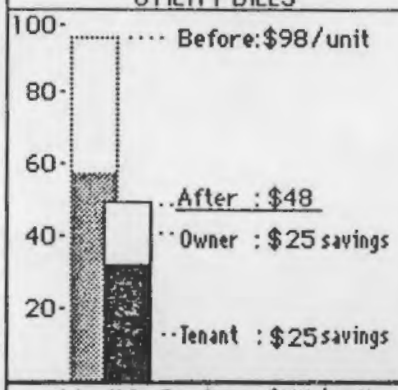
WASHINGTON, D.C.

STRATEGIES & COSTS

Envelope:	
- Add balcony/overhang to exposed corridor wall area on each floor	See: Note
Infiltration/Exhaust:	
- Repeat Retrofit Strategies	16,827
HVAC:	
- Repeat Retrofit Strategies	19,360
- Install solar assist heat pump for each unit	150,000
Lighting/Appliances:	
- Repeat Retrofit Strategies	225
DHW:	
- Repeat Retrofit Strategies	4,482
Training:	
- Repeat Retrofit Strategies	-0-
TOTAL COST:	$244,894

Note: Amenity, balconies on all east/west facing units (not paid for with energy savings alone) $1,226,680

UTILITY BILLS



Monthly Savings: $50/unit

Annual Savings: $105,304

PAYBACK: 2.3 Years

Three major changes were recommended by Team B as rehabilitation strategies. These strategies were chosen not only on the basis of energy savings, but also as marketable amenities:

1.) Add balconies to 15 units per floor;

2.) Install roof mounted solar collectors to supplement laundry and heat pump hot water needs.

The rehabilitation strategy set includes all operation strategies and two retrofit strategies: installing fresh-air intakes at each laundry room and installing programmable thermostats throughout the building.

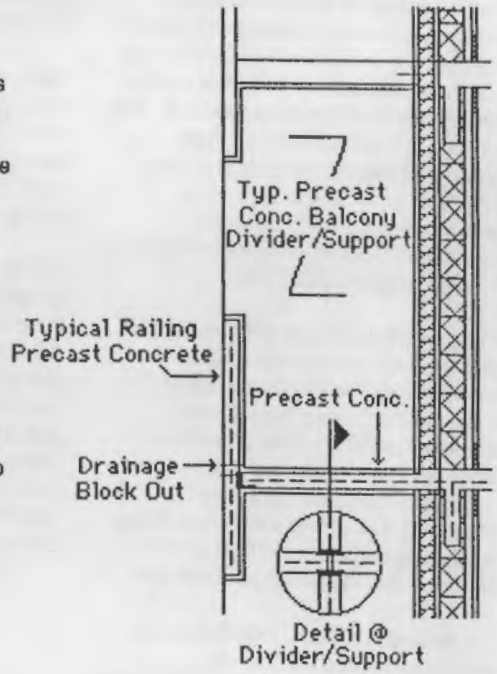
Each floor has 18 apartment units. Of these, nine have west exposure and six have east exposure. In an attempt to improve both the marketability of the units and the thermal performance of the building, Team B recommended building balconies at all east and west facing units.

This approach added approximately 20 percent to the floor area of each apartment. It was assumed that the balconies would be used regularly since the Washington area has a large number of pleasant days with comfortable temperatures suitable for outdoor living.

The balcony design effectively reduces the direct solar gain on the east and west surfaces by 80 percent. This reduces both direct solar gain through the glazing and heat build up and retention in the mass of the building.

The flat roof and available chase access to each floor led Team B to recommend installing solar collectors on the roof to supplement hot water demands. All nine laundry rooms are stacked vertically and are adjacent to a vertical plumbing chase with adequate space to enclose additional plumbing. In addition, the solar system could be used to boost water temperatures supplying heat pumps.

Excluding the new balconies, this strategy set is estimated to pay for itself with energy cost savings in just over two years. It is interesting to note that energy savings alone could pay for the new balconies (and the rest of the strategy set) in just 14 years.



TYPICAL BALCONY SECTION

WASHINGTON, D.C.

Jury Comments

The jury agreed with Team A that it was correct in focusing its operation strategies on reducing ventilation. It is questionable, however, how much ventilation can be reduced without violating code requirements. The idea of isolating the units from the corridors is a good one and works whether or not the corridor ventilation can be reduced. The jury questioned the installation of programmable thermostats. It is the most costly item in the set and its returns are not clear. The jury recommended a much closer analysis of this item before installation.

The jury felt that Team B's approach of altering bath and kitchen ventilation rates is more likely to be acceptable in most building codes than altering corridor ventilation rates. Specifications differ among codes and, in some cases, codes in this matter are changing. Designers must consult the applicable codes for each jurisdiction before applying strategies of this type.

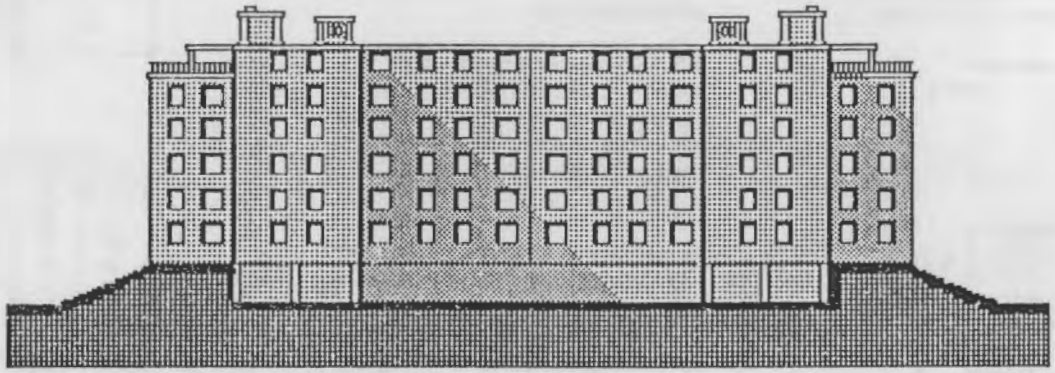
Regarding retrofit strategies, the jury again questioned the use of recirculating activated charcoal filters in kitchen and bathroom vents. The energy saving potential of this strategy is very impressive if the solution can be made acceptable to tenants. The owner may wish to experiment by altering a few units as recommended and judging the results before committing to changing all units.

The jury was impressed with Team B's approach to adding exterior shading to the building. If it can be made accpetable to the owner, it could have a major effect not only on the building's appearance but also on annual energy costs. As the most costly retrofit item proposed, this strategy merits special analysis.

The jury was interested in Team A's rehabilitation focusing on adding new units. They pointed out, however, that the acceptability of this stratey would depend on costs and economic factors that go far beyond energy use.

Finally, the jury discussed at great length Team B's proposal to add insulation to the exterior of the building. Although this application of insulation has a major effect on both conduction and air infiltration, it is still highly questionable whether an owner would cover up brick with a substance requiring increased maintenance and one that changes the overall aesthetic of the building.

Boston Midrise



Public Housing for the Elderly

This Boston midrise, with 7 stories and 82 units, is owned by the Boston Public Housing Authority and is used entirely for elderly tenants. The building was offered for analysis because it had the poorest energy consumption record of the 20 buildings currently owned by the Authority. The total annual energy bill is $87,600.

Monthly rents are limited to 30 percent of income, and average about $125 per unit. However, management fees plus an $89 per unit energy bill add up to $198 per month -- a net monthly loss of about $73 per unit. For this building, conservation is seen as a means to cut losses while increasing comfort for elderly occupants.

Although Boston's cold northern climate is moderated somewhat by the sea, the building's main energy problem is still heating (about 55 percent of the annual energy bill). Heating loads are caused by high infiltration rates through drafty windows, and by conduction losses through uninsulated walls and single pane glass.

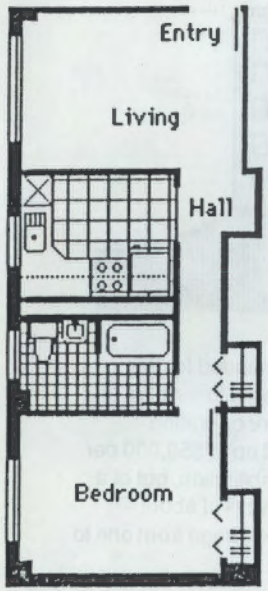
Strategies recommended for this building are estimated to save up to $11,000 per year for operation improvements and up to $50,000 per year for major rehabilitation, out of a total annual energy bill of about $87,000. Paybacks range from one to five years.

Building Layout

BOSTON, MA

This building has a long east-west axis, the entrances to this building face just slightly west of south, with large covered canopies over each of the two main doors. The majority of the building is comprised of one-bedroom units (72), the rest being two-bedroom units (10). One-bedroom units average 490 square feet; two-bedroom units are 610 square feet.

Organization of the building around two central elevator cores gives the building an inherent inefficiency. Large lobbies, extra stairs, and extra elevators reduce the net-to-gross for this building from 80 percent, which would be typical, to no more than 65 to 70 percent.



TYPICAL ONE BEDRROM UNIT

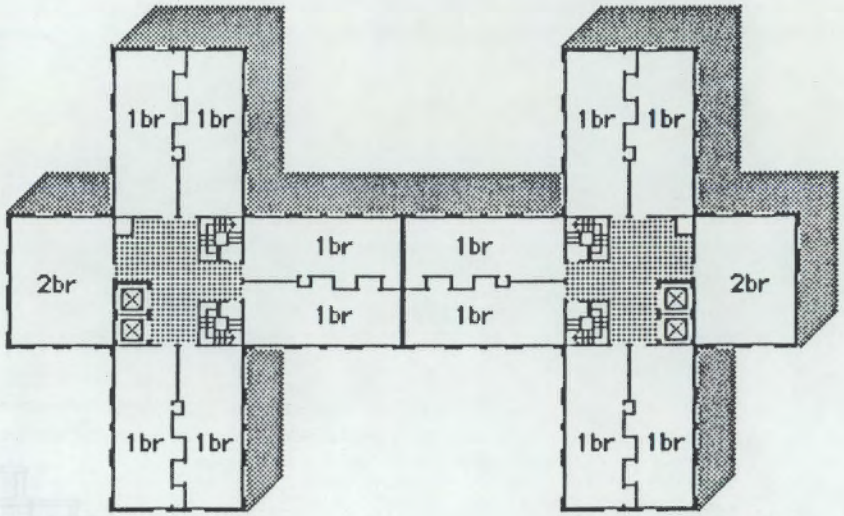
The building has only five parking spaces -- located in the rear -- but sits on a generous site with many trees. There is a central laundry, with all hot water supplied from the steam boilers.

As can be seen on the ground floor plan, there are several generous storage areas and large service areas including a maintenance room, incinerator, machine room, and large boiler room. In addition, there is a large community room.

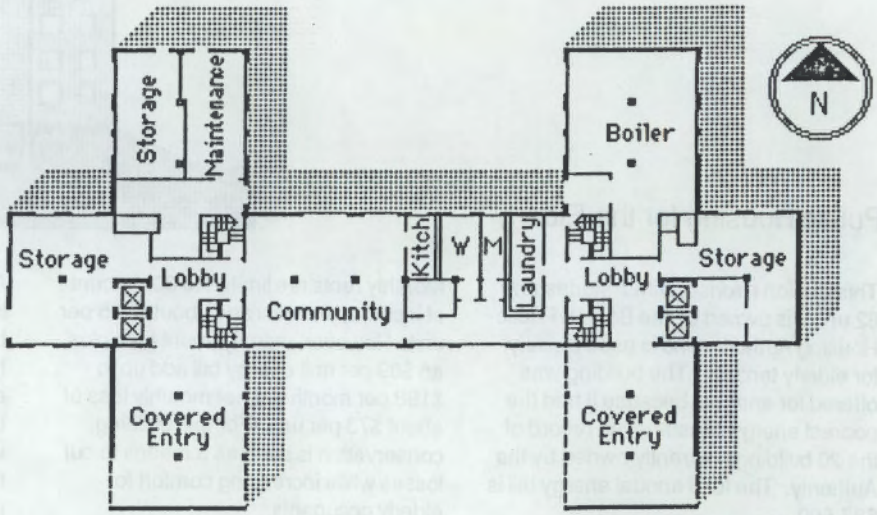
The one-bedroom unit (shown at left) is modestly inefficient because of the long interior hall connecting the living room and the bedroom.

Although all units are individually metered, the incentive for energy conservation is lost because all bills are turned over to the management for payment. These bills are, in turn, passed on to the Housing Authority.

All units are supplied with a refrigerator and electric stove. The stove is known to be used as an auxiliary heat source when tenants feel the building is too cold. The building is not centrally air conditioned and there are no window air conditioning units in use.



TYPICAL FLOOR



GROUND FLOOR

Building Specifications & Operations

The specifications for this building clearly indicate that it is a pre-1970 design. The exterior walls are uninsulated and all glass is single pane. Heating is supplied from a large central steam system. There is no thermostatic regulation in the individual units. Although the apartments are individually metered for electric use, tenants are not responsible for individual electric bills.

Given this type of wall and window construction, it is not surprising that tenants say the building is "drafty" and that it "feels cold." This situation is aggravated by the fact that the building is occupied entirely by elderly people who normally require higher temperatures.

Also, given the age of the steam heating system, it is likely that there is virtually no control of heat in the units. Manually operated valve stems have long since frozen open, so apartment temperatures are controlled by opening the window when it is too hot and turning on the electric stove when it is too cold. Both strategies, of course, aggravate an already high building energy bill.

Domestic hot water is supplied to the units and to the central laundry from the central steam boilers. This requires that at least one boiler be operated twelve months of the year. Nominal efficiency drops significantly in the summertime when hot water is the only load on a very large boiler.

Lighting, as originally specified for this building, is generous in both number of fixtures and wattage. Incandescent lights are specified throughout.

In a previous energy study, the Housing Authority had been advised that boiler modifications, conversion to flourescent lights, and installation of additional glazing would be economic. From discussions with the building operators, it was clear that these improvements had not yet taken place. Therefore, for this study, we assumed the building in its original specified condition and noted the economic impact of all recommendations from our design teams whether previously discussed or not.

BUILDING SPECS

ENVELOPE:

- Exterior Wall
  - 4" face brick, 1" air space
  - 4" cinder clock, 1/2" plaster (ASHRAE type D, R=3.83)
- Window
  - Metal frame, single pane glass, sliding windows
  - U overall = 1.35, shading coefficient = 0.64 with blinds
- Roof
  - Tar & Gravel on Built Up Roofing
  - 1-1/2" insulation with 6" concrete, light-weight
  - (ASHRAE type 12, R=13.2)

INTERNAL LOADS

- Lights: 0.5 Watts/s.f.
- Appliances: 0.4 Watts/s.f.
- Cooking: 6000 Btu/day (40% latent)
- Infiltration: 1.0 Air Change/hr.

OTHER LOADS:

- Lighting in common areas: 1.2 W/sq. ft.
- Elevators: 15 kW
- Exterior Lighting: 3 kW operated 12 Hours/day

SYSTEM SPECS

HVAC

Steam convectors
No cooling provided
No range exhaust
No bath exhaust
No corridor exhaust

TEMPERATURE SETPOINTS

Heating: 76°F
Cooling: none provided

CENTRAL PLANT

No. 6 Oil-fired boiler,
Efficiency = 65%,
Boilers available for heating and DHW on demand throughout year

DOMESTIC HOT WATER

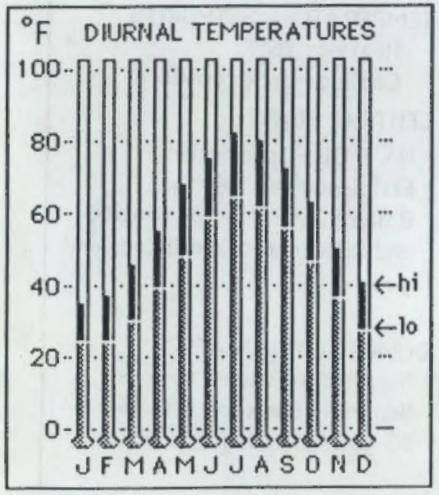
Supplied off steam boilers
Nominal efficiency = 60%
35 gal./unit/day @125°F

Energy Analysis

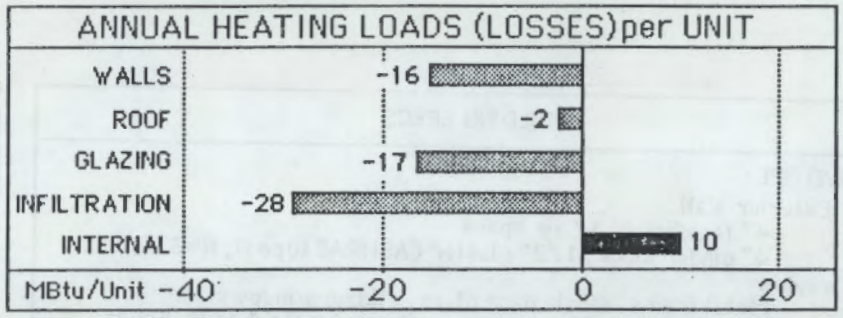
Since it is situated in a cold northern climate, heating is the main energy problem for this building, accounting for roughly 55 percent of the annual energy cost. At over 150,000 Btu's per gross square foot per year total energy use, this building is clearly consuming an excessive amount of energy.

Although as northern in latitude as Chicago, the Boston area is actually 10° to 15° F warmer in winter because of its location near the sea, and has significantly smaller daily temperature swings in summer.

To illustrate the magnitude of the heating problem in this building, net heating losses for typical units range from 12 to 17 Btu's per square foot per degree day. By comparison, a reasonably well built single family residence today would be expected to lose no more than 5 to 8 Btu's per square foot per degree day. There are at least five compounding problems causing this high heating cost.



Heating loads are dominated by infiltration, but most heating is caused by conductive heat loss through the walls and windows



The bar graph of annual heating loads illustrates three of these problems. First, and largest, is the problem of infiltration. Windows makeup a rather high portion of exterior walls in this building, about 17 percent, and are single pane aluminum sliders with no weatherstripping. There is no question but that they leak air badly.

Second, because the glass is only single pane, there are high conduction losses. As most of the building glass does not face south, solar gains do not greatly offset these high conduction losses. Third, there are significant losses through the uninsulated wall, which consists of 4" cinder block and 4" face brick.

These three problems create a fourth, the fact that tenants often "feel cold" in their apartments. Because exterior walls are cold due to conduction losses, they easily absorb radiant heat from occupants, making them feel colder in spite of the ambient air temperature. On two occasions, when management installed temperature recorders in "problem" units, tenants still complained of "feeling cold" when recorders never registered below 77° F for three days. When tenants feel cold, they call for more heat whether or not air temperatures are in a reasonable range.

Finally, the mechanical system that supplies heat is inefficient. Due to the age of the boilers, they are probably operating poorly. Worse, however, is the fact that the system is likely to be completely out of control. Valve stems at individual radiators are almost certainly "frozen open" by corrosion. The only tenant option is to open windows when it is too hot, thus wasting tremendous amounts of energy.

Electric lighting is the second highest energy cost in this building. It is caused by a relatively high number of fixtures in the building all made for incandescent lamps.

Miscellaneous loads are the third highest cost in this building. This load includes receptacle use and no doubt is high because of the use of auxiliary electric space heaters.

The fourth cause for high costs is domestic hot water. Although use in this elderly occupied building is probably below average, the cost is above average due to an inefficient system. DHW is produced by a heat exchanger from the main boilers. This requires at least one functioning boiler over the summer at a great loss of efficiency -- similar to keeping a large locomotive up to steam for an occasional blow of the whistle.

In this building, the owner pays all of the energy costs. The management firm tracks these costs with well kept monthly logs, enabling us to compute very accurate energy costs.

With an annual energy bill of $87,000 and net rentable area of about 50,000 square feet (out of 74,000 gross), annual energy costs are $1.75 per net square foot. This compares with an average cost for the Boston area of $1.18 (according to an IREM survey of 65 buildings) and a "high" cost for the area of $1.54 per net square foot.

These high energy costs aggravate an already existing operating cost problem as illustrated in the "Energy and Rent Analysis" below. Because this is subsidized elderly housing, tenants pay none of their monthly energy bills. The owner, the Boston Housing Authority, pays the entire $89 per unit per month bill. In addition, the Authority pays a monthly management fee of $109 per unit ($2.34 per square foot) which is average for the Boston area excluding insurance costs.

Rents are limited to 30 percent of each tenant's income. The average monthly rent is $125 per unit, compared to a median IREM rent for the area of $354 per month. Net operating loss per unit is $73 per month, or an annual building operating loss of $70,000, excluding any mortgage payment. Any savings due to conservation would likely go to reduce operating losses.

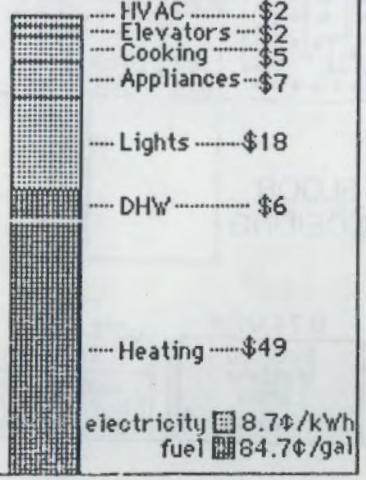
With all energy costs being passed from tenant to management and then to the Housing Authority, there is little incentive for conservation. Most conservation improvements proposed would have the attractive advantage of simultaneously reducing operating costs while increasing tenant comfort.

Our recommendations, which follow, show that incremental operating improvements are possible, but that major retrofitting or rehabilitation is more likely to produce significant savings. The question is, of course, how these improvements would be financed. One possible scenario is shown in the box to the right.

It is presumed, for the sake of argument, that annual energy savings could be used to fund state backed bonds which would pay for conservation improvements. The analysis illustrates, based on some very simple assumptions, that if this concept were accepted, significant budget outlays could be justified. In this case, a monthly savings of $40 per unit would support a conservation improve-ment budget of nearly $3,000 per unit or a total project budget of approximately $240,000. These figures include no value for the improved comfort of the elderly occupants.

Owner's Utility costs

$89/Unit/Month



Energy and Rent Analysis

(Typical One-Bedroom Unit)

Tenant's Monthly Energy Cost/Unit	$ -0-
Owner's Monthly Energy Cost/Unit	($ 89)
Monthly Operation &Maintenance Cost	($109)
Total Monthly Cost/Unit*	($198)
Typical Monthly Rent (max: 30% of income)	$125
Net Operating Profit (Loss)/Unit/Month*	($ 73)

*Assumes No Mortgage Payment Cost

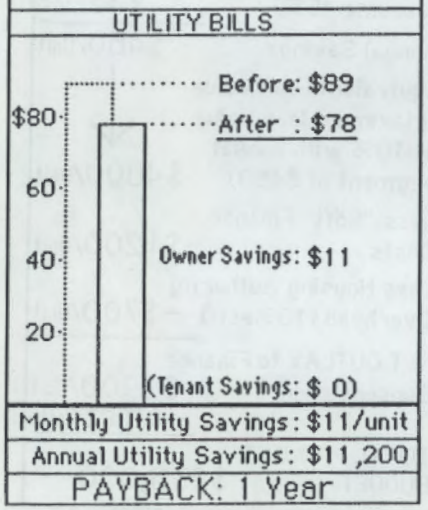
Financing Conservation

A SCENARIO FOR FINANCING CONSERVATION IMPROVEMENTS WITHOUT FEDERAL GRANTS--
Use Utility Savings to Payback State-backed Bonds

Monthly Savings (assume 45%)	$40/Unit X 12Mos
Annual Savings	$480/Unit
Equivalent Loan Value (Maximum loan value at 10% with annual payment of $480)	$4800/Unit
Less "Soft" Finance Costs	-$1200/Unit
Less Housing Authority Overhead (15%est.)	-$700/Unit
NET OUTLAY to Finance Conservation	$2900/Unit X 82 Units
TOTAL PROJECT BUDGET	$238,000

Operations Team A

STRATEGIES & COSTS	
HVAC	
- Clean and paint radiators	8,040
- Check radiator and valve operation	2,000
- Clean boiler; check flue gas; trim boiler	1,752
Lighting/Appliances	
- Delamp (remove 10% of inc. lamps)	-0-
- Relamp with 30% less wattage	-0-
- At repainting, common areas white	-0-
Training/Other:	
- Incentive Program - Owner/Tenant split energy cost savings	-0-
- Convert 2 passenger elevators to freight	-0-
TOTAL COST:	$11,792



Both design teams focused on the mechanical system as a source of low cost operation improvements. This team recommended a major effort to improve radiator function.

First, radiators would be cleaned to improve infrared radiation. Next, both steam traps and radiator valves would be repaired. If steam traps are "frozen" open, steam is wasted. If radiator valves are stuck open, overheating occurs. If stuck closed, heat can't get into the apartment, and other more costly means of heating are used by the tenant -- like the oven or small electric heaters. The team also recommended cleaning the boiler and "tuning up" its operation. The cost for all mechanical system maintenance was estimated to be $12,000.

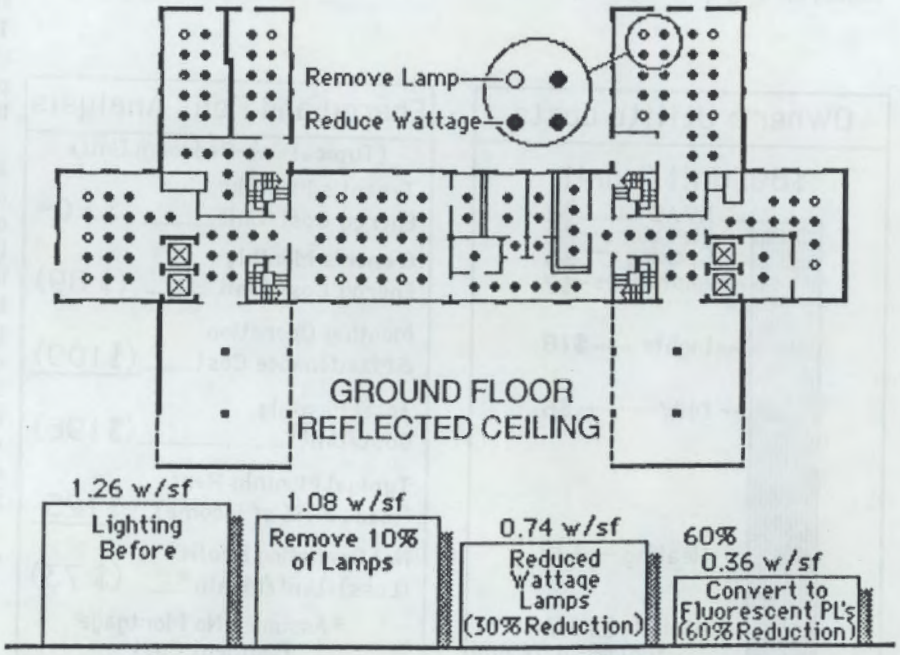
Team A focused on lighting as a source of low-cost savings. The team estimated that at least 10 percent of the existing incandescent lights could be removed without any detrimental effect on the building and probably without notice (note the reflected ceiling plan). The team also recommended that remaining lights be relamped (at burnout) with lamps of 30 percent less wattage. This reduction in wattage could be offset somewhat by painting all common areas white at the next scheduled painting.

In order to reduce the cost of vertical transportation, the team recommended turning off one elevator in each bank, except as needed to haul freight or to assist move-in/move-out. Waiting time and shared rides would increase modestly, but otherwise there would be no "hard" costs.

Finally, Team A recommended an incentive program to encourage occupants to get involved in energy conservation. One proposal put forward was for management and tenants to share electric savings. The problem, of course, with any shared savings scheme is that it is difficult to give up any savings when the building as a whole is operating at such a loss.

Our analysis estimates that this package could reduce the average unit bill by $11 per month or an annual total of $11,200 for the building. This would yield an attractive one-year payback.

Large numbers of incandescent lamps offer numerous opportunities to reduce energy consumption



Operations Team B

BOSTON, MA

Team B focused its attention at the other end of the mechanical system, recommending a thorough look at boiler operations. As illustrated below, its main recommendation was the installation of a flue gas analyzer and combustion efficiency controller. This relatively low cost piece of equipment would allow for continuous testing of flue gases to determine boiler efficiency, and the potential for automatic adjustment to achieve the best balance possible for the system.

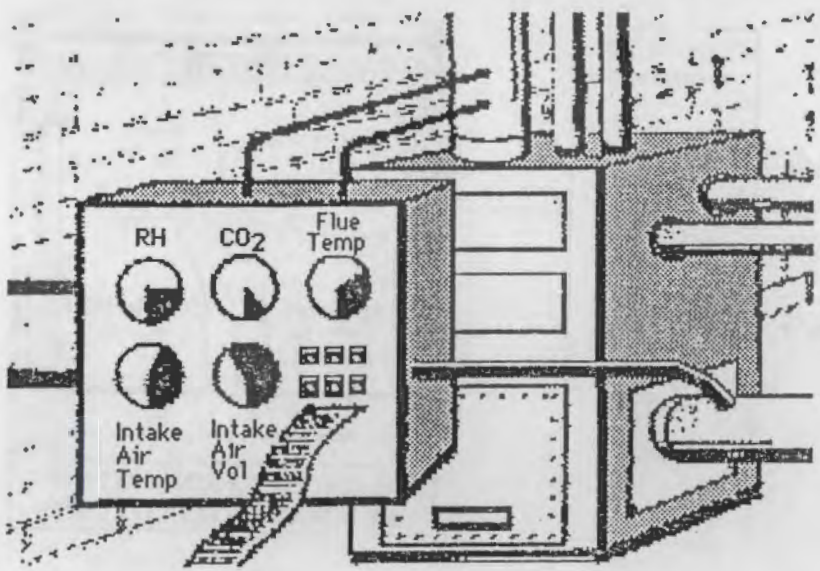
The basic function of this equipment is to measure the mixture of oxygen, carbon dioxide, and carbon monoxide in flue gas and to compare it with the rate of fuel consumption. From these measurements, a micro-processor computes system efficiency and then issues command signals to adjust boiler controls for maximum efficiency.

The team also recommended a close look at boiler operation and domestic hot water needs to determine if one boiler could be turned off in the summer, and to limit its operation in the spring and fall seasons. It was estimated these boiler improvements would cost only a few hundred dollars. Team B also recommended a significant reduction in lighting wattage, as well as the installation of a photocell control for all exterior lighting, to insure that outside lights are off when not needed. This would be especially important for the entrance canopy lights which have a rather high wattage. These controls are estimated to cost a total of $240.

Finally, the team recommended the installation of flow restricting shower heads in all units. To keep costs down, installation would be done by building staff as time permits. It was also recommended that this installation be done at change over of unit occupancy to make the change in shower flow less noticable. The cost of the flow restrictors was estimated to be $650, not including state or utility incentives that may exist.

The total cost of this package was estimated to be roughly $6,300 with projected savings of nearly $7,000 per year. This is a 11 month payback.

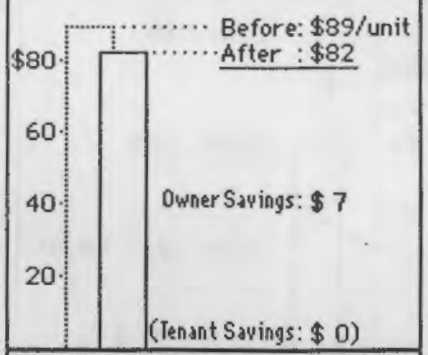
Flue gas analyzer aids optimum operation of boilers



STRATEGIES & COSTS

HVAC:	
- Combustion efficiency controller	400
- Flue gas analyzer	5,000
- Cut off 1 boiler in swing season	-0-
Lighting/Appliances	
- Relamp to lowest wattage possible	-0-
- Photocell on all exterior lighting	240
DHW:	
- Flow restrictors on all showers	650
TOTAL COST:	$6,290

UTILITY BILLS



Monthly Utility Savings: $ 7 /unit

Annual Utility Savings: $6,900

PAYBACK: 11 Months

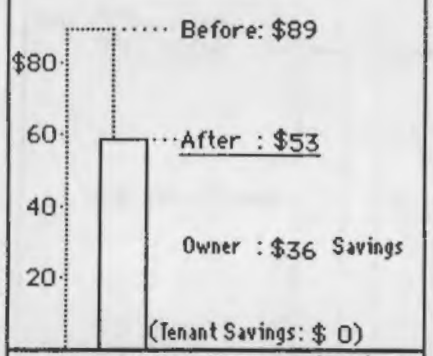
Retrofit Team A

BOSTON, MA

STRATEGIES & COSTS

Envelope:	
- Reinsulate existing roof (R-28)	5,000
- Install exterior storm windows	24,738
Infiltration/Exhaust:	
- Caulk all exterior windows	Included above
- Add entry vestibule	2,592
HVAC:	
- Repeat Operation Strategies	11,792
Lighting/Appliances	
- Repeat Operation Strategies	-0-
- Change incandescen to fluorescent in all public areas	9295
- Time switches in storage & low use areas	470
Training/Other	
- Repeat Operation Strategy	-0-
TOTAL COST:	53,887

UTILITY BILLS



Monthly Utility Savings: $36/unit

Annual Utility Savings: $35,000

PAYBACK: 1.5 Years

The centerpiece of Team A's retrofit strategies is the installation of exterior storm windows. Although a costly item (about $25,000) it attacks the two major causes of heating problems in the building -- infiltration and conduction losses through glass. Installation of the storm windows also creates an opportunity to caulk exterior windows to further reduce infiltration.

The team also recommended reinsulation of the existing roof up to R-28 at the next regular roof maintenance. Incremental cost for the insulation would be a modest $5,000.

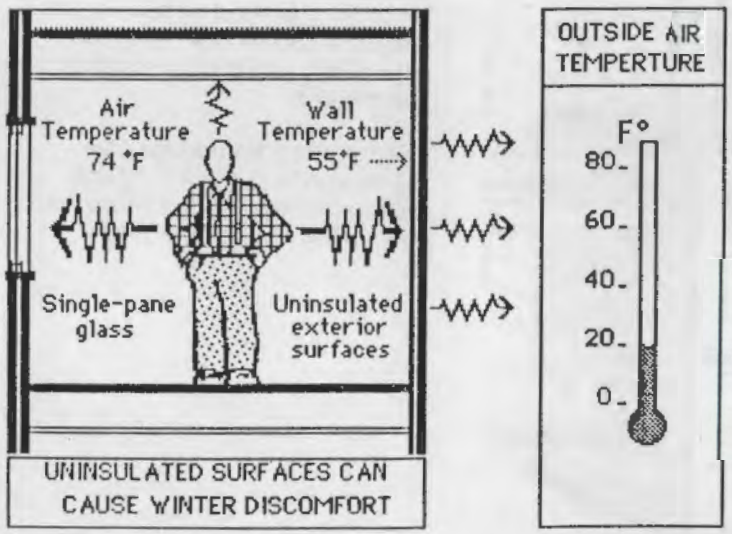
The team also considered means to insulate exterior wall surfaces. However, because of the cost and disruption involved in the alternatives, the team elected to consider exterior wall insulation only in a rehabilitation situation.

The team also recommended the addition of vestibules at each entry. This would further reduce unwanted air infiltration.

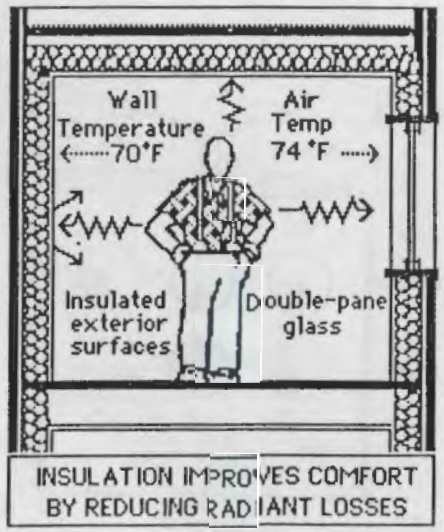
Finally, the team recommended that all incandescent lights in common areas be replaced with "screw-in" fluorescent lamps. This would reduce electricity consumed in public areas by about two-thirds. All storage areas and low-usage areas should be put on time switches to eliminate the possibility of lights accidently being left on for long periods of time.

When combined with the operation strategies discussed previously, this strategy set costs about $54,000 and is estimated to save up to $36 per unit per month or a total of $35,000 per year. Simple payback is still very attractive at only a year and one-half.

Effects of Mean Radiat Temperature on Human Comfort



UNINSULATED SURFACES CAN CAUSE WINTER DISCOMFORT



INSULATION IMPROVES COMFORT BY REDUCING RADIANT LOSSES

Retrofit Team B

BOSTON, MA

Team B also added exterior storm windows and more insulation in the roof, but took a much more aggressive approach to improving both the HVAC system and lighting.

As shown in the diagrams below, Team B's main recommendation was to improve control of the heating system by replacing valves at each radiator. Assuming that old valves would be "frozen" and needing replacement anyway, the team recommended replacement rather than repair. Replacement would allow the addition of thermostats which would not only increase occupant comfort but also reduce overall heating in the building -- it would no longer be necessary to heat the whole building to the highest temperature needed in only a few units. Although a costly strategy at $27,000, payback for the entire set appears to easily justify this cost. One problem, however, is that corrosion inherent with steam systems will cause even these new valves to "freeze up" again within 5 to 10 years.

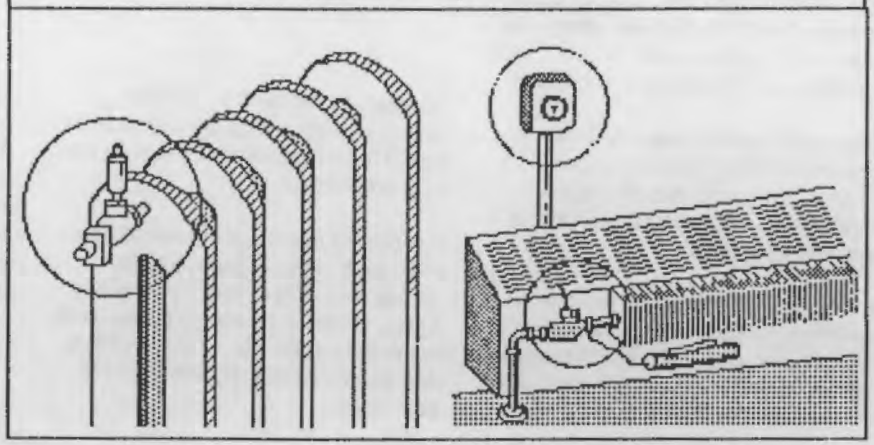
Team B also recommended conversion from #6 to #4 fuel oil. Although the boilers were originally specified for #4 oil, the team believes that lower cost #6 is actually in use. If this is the case, higher maintenance costs and poorer performance of the boilers may, in fact, be costing more than the savings in fuel. This should be investigated closely.

The other main strategy of Team B was to convert as much of the building lighting as possible from incandescent to more efficient alternatives. They recommended changing all bath and kitchen fixtures in the units to fluorescent fixtures and a similar change in all public areas. Outside lights should be changed to high pressure sodium and should be controlled with photocells.

Altogether, the lighting strategies cost $20,000, but should reduce electric consumption for lighting by 30 percent. Team B also recommended installation of a separate domestic water heating system. This would eliminate the need for any boiler use in the summer and would yield a significant increase in overall system efficiency. The team recommended using gas already at the site for fuel. At $6,500, savings due to lower energy use and lower fuel cost should pay back in 5 years or less.

Although the total cost of this package of strategies approaches $100,000, estimated savings of $36,000 per year (about $37 per unit per month) would give an excellent payback of about 2-1/2 years. From the Housing Authority's point of view, operating losses for this building could be cut in half.

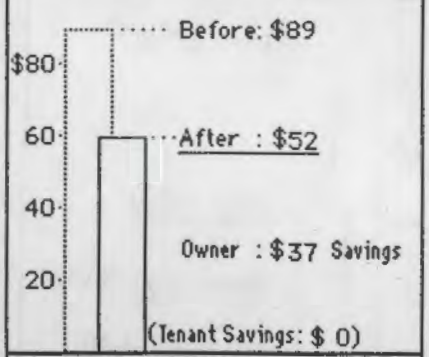
Thermostatic valves can be installed either directly on radiators or on adjacent walls



STRATEGIES & COSTS

Envelope:	
- Rigid roof insulation (R-33)	7,500
- Exterior storm windows	24,738
Infiltration/Exhaust:	
- Caulk all exterior windows	in above
HVAC:	
- Cut off 1 boiler in swing season	-0-
- Upgrade boilers/convert fuels	
°modify boiler burners	4,000
°replace boiler tubes	5,000
°hydrolic testing	300
°use #4 fuel oil	-0-
- Thermostat control, all radiators	26,800
Lighting/Appliances	
- Repeat Operation Strategies	240
- Fuorescent in kitchens, baths, & common areas	16,099
- High pressure sodium on exterior	3,480
DHW:	
- Repeat Operation Strategies	650
- Separate gas DHW system	6,500
TOTAL COST:	95,307

UTILITY BILLS



Monthly Utility Savings: $37/unit

Annual Utility Savings: $36,000

PAYBACK: 2.6 Years

Rehabilitation Team A

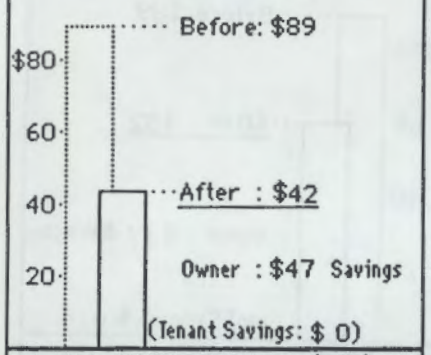
BOSTON, MA

STRATEGIES & COSTS

Envelope:	
- Install wall insulation (R-6)	87,536
- Install exterior storm windows	24,738
Infiltration/Exhaust:	
- Repeat Retrofit Strategies	2,592
HVAC:	
- Repeat Retrofit Strategies	11,792
- Thermostatic radiator valves	26,800
Lighting/Appliances	
- Repeat Retrofit Strategies	9,765
- High efficiency appliances upon Replacement	20,500
DHW:	
- Separate gas DHW system	6,500
Training:	
- Repeat Retrofit Strategy	-0-
TOTAL	$190,223

Note: Added cost for 8th floor w/ 16 units & sprinkler sys. (not paid for with energy savings alone) $570,000

UTILITY BILLS



Monthly Utility Savings: $47/unit

Annual Utility Savings: $46,000

PAYBACK: 4.1 Years

Turning to rehabilitation, Team A made a radical departure from its previous thinking. It was presumed that this would be a major rehabilitation and that everything but the structure of the building could be changed. They kept previous ideas, such as adding storm windows and converting to lower wattage fluorescent fixtures, but added several totally new concepts: new wall insulation, thermostatic valves at all radiators, high efficiency appliances, and a separate DHW system to eliminate summertime boiler use.

Their most radical recommendation, however, was the addition of 16 more units as a new eighth floor. They argued as follows: since the building would be torn to pieces for the rehabilitation anyway, why not look at new construction on the top floor? Preliminary analysis showed that the structure of the building could hold another floor. By taking advantage of the existing building structure and other building systems, it was estimated that the new floor could be added for $25 to $30 per square foot or about $25,000 per unit. This is roughly half the cost of new units in the area.

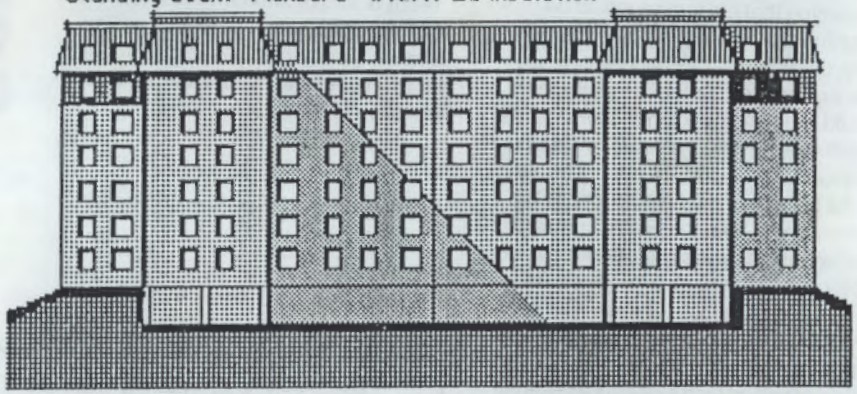
This would make sense only if the Housing Authority were in need of additional housing units. If it is, this approach could deliver 16 new units at a very attractive price.

In this case, energy needs (such as a new roof) could be included as part of an overall building revitalization. However, payback calculations are not applicable. Energy savings alone will not pay for new dwelling units. Nevertheless, energy considerations are important as one of the driving forces for making the improvements at all.

It should be noted that the overall cost estimate for this package includes adding sprinklers to the entire building. Again, this is not an energy related cost but would be considered reasonable to add at the time of a renovation of this magnitude.

Cost of this package, excluding sprinklers and the new floor, is $190,000. Projected energy savings of over $48 per unit per month or $46,000 per year would yield a payback of just over 4 years. Energy savings alone could pay for the whole package, including the new floor, over $700,000, in 16 years.

REHAB ADDS 16 NEW UNITS
2 Seventh Floor Terrace Units
14 Units on New Eighth Floor
Standing Seam "Mansard" with R-28 Insulation



Rehabilitation Team B

As did Team A, Team B improved the basic building shell by adding wall insulation, storm windows, and additional roof insulation. In an effort to keep costs down, this team recommended interior storm windows, but found the total job cost only $3,000 less than exterior units -- hardly worth the distinction.

The nucleus of Team B's approach was a major upgrade of the heating system from a steam system to a hot water system. The major problem with control in this building is that radiator valves "freeze up" every 5 or 10 years. It is better to replace the steam system with a hot water system which can be maintained in good condition with hydronic additives for 20 years.

This renovation would add control at each apartment by installing thermostatic control valves at each radiator. System efficiency would improve by adding sophisticated controls on the boiler.

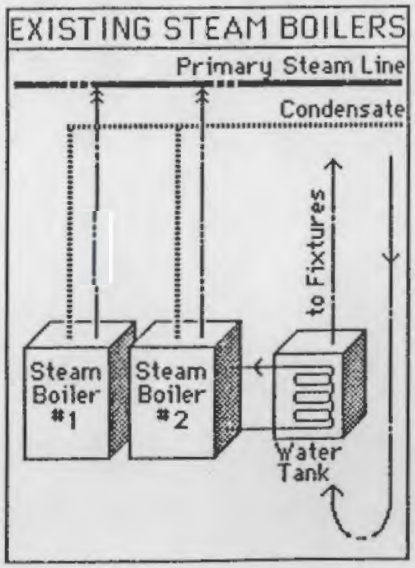
As illustrated in the diagrams below, existing boilers can be converted from steam to water but a new hot water supply and return line must be installed in place of the old steam supply and condensate line. At the time of conversion, the DHW system will be removed from the boilers and a separate DHW system installed.

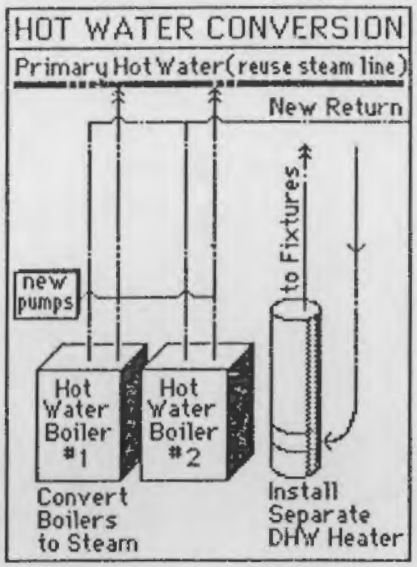
This rehabilitation is estimated to cost over $180,000, but annual energy bills are reduced by 50 percent. With estimated savings of $46,000 per year, simple payback is achieved in about 4 years.

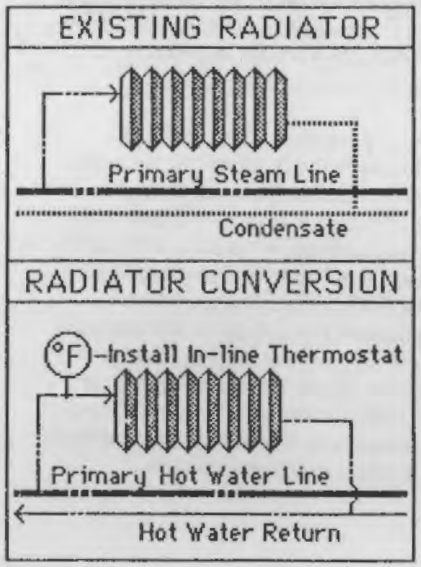
The team investigated the possibility of applying an exterior synthetic stucco finish as a low cost option to interior furring and batt insulation. This, however, proved to be nearly twice as expensive. This approach would be attractive only where it was desirable not to disturb tenants during construction.

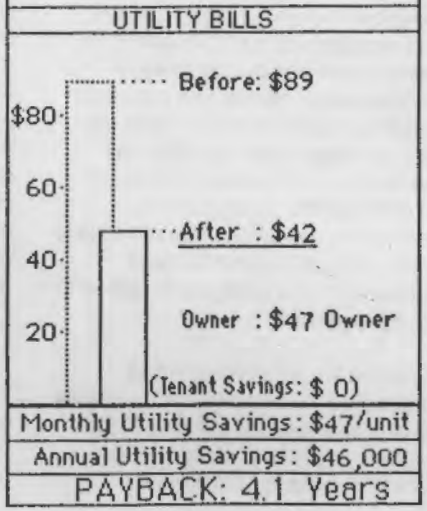
STRATEGIES & COSTS

Envelope	
- Repeat Retrofit Strategies (except use interior storm windows)	29,445
- Install wall insulation (R-11)	83,811
Infiltration/Exhaust:	
- Repeat Retrofit Strategies	
HVAC:	
- Repeat Retrofit Strategies	36,100
- New 2-pipe hydronic system:	
° 2 zone pumps and 2 zone control	1,200
° use steam supply for hot water supply	-0-
° replace condensate line	10,250
Lighting/Appliances:	
- Repeat Retrofit Strategies	19,819
DHW:	
- Repeat Retrofit Strategies	7,150
TOTAL COST:	$187,775









Jury Comments

The jury questioned Team A's incentive program. Would the Housing Authority really want to give away any possible savings considering the amount of loss on the building already?

One engineer on the jury complimented both teams for sticking with both the radiators and the oil fuel of the existing system. He noted that because there is no need for cooling, radiators alone are very good heaters. He also noted that the Housing Authority's ability to buy oil at virtually wholesale prices is well below the price of natural gas.

One reviewer strongly objected to the concept of turning off or limiting the use of one or two elevators. However, it was pointed out that this building was not designed for low-income tenants, as demonstrated by the generous common-space, stair, and elevator configuration, but was purchased by the city for use as subsidized housing. FHA minimums require 2 cars with a maximum of 120 bedrooms per car, but then only for buildings over 7 stories, with potentially long response times, which this is not. Team members responded that the conditions would not be unsafe given the design of the building and that modest concessions were reasonable to ask of the tenants given the large amount of money being lost in operating this building annually.

Pundits in the group could not be suppressed. They noted that as long as the Housing Authority is losing $73 per unit, how could they "make it up in volume" by adding 16 more units?

Both teams were questioned about the quality of lighting that would result by going to screw-in fluorescents and high pressure sodium on the exterior of the building. It was noted that several of the new Japanese screw-in fluorescents have improved color correction but that high pressure sodium was still likely to be less attractive than the current situation.
The question of exterior insulation was also discussed. In addition to questionable economics, there was considerable skepticism by the jury that a synthetic stucco product would stand up over the years as well as the existing brick. New finishes inside would be significantly more attractive to tenants. As to the conversion to a hot water system, using the existing supply line for hot water heat was questioned. It was also questioned whether the potential for downsizing boilers was lost by using the existing boilers. Useful life of the existing boilers would be critical in making this choice.

One jury member added that it is unfortunate the Boston Public Housing Authority probably will not be able to take advantage of its very substantial equity in this project in order to raise the capital required to realize these cost-effective savings. The mortgage agreement typically made with the U.S. Department of Housing and Urban Development forbids such additional encumbrances on property, and therefore precludes the normal and business-like financing of improvements.

The Authority's only resource is to petition the City of Boston to advance the required capital for alterations. This will inevitably introduce political consideration into what would otherwise be a straightforward business decision. Since the ultimate savings from this program will go entirely to reduce federal rental subsidies and will bring the City of Boston no pecuniary return, it will be suprising if any action is taken.

Minnesota Midrise

MANKATO, MN

The next building in our series is located in Mankato, MN. Completed in 1959, this 6-story apartment building contains 49,307 square feet, divided between one-bedroom apartments, two-bedroom apartments and public space.

The six-story apartment tower is flanked by a heated parking garage for up to 20 cars, and a heated swimming pool. A large penthouse game room is located on the roof.

Space heating is the largest single cause of energy use, followed by cooling, water-heating, and lighting. The building presents a number of opportunities to significantly reduce energy use and costs for both the owner and the tenants.

The tenant's average utility bill is approximately $20 per month. The owner's share of the utilities is approximately $59 per month.

Changes to building operation and maintenance procedures could produce an average savings of $8,400 per year for an initial investment of between $1,000 and $2,000, providing a simple payback of less than three months. Monthly average energy cost savings to tenant and owner would total approximately $14 per apartment.

The retrofit measures recommended by the design teams would produce average total savings of over $11,500 per year, with a simple payback in three to five years.

Strategies selected for use in full-scale rehabilitation would produce average annual savings of approximately $15,000 with a 15-year payback period.

Building Layout

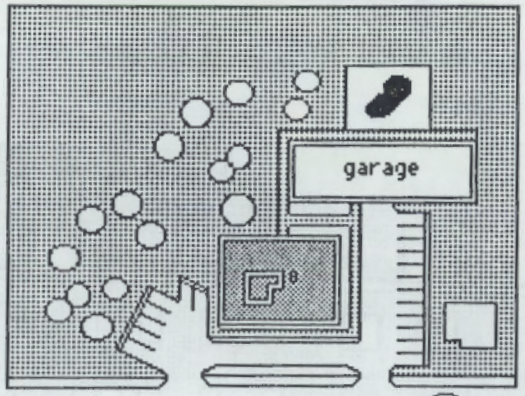
Typical apartment floor plans in the Minnesota midrise are illustrated at right. Each floor has four 689 square foot one-bedroom apartments, and four 945 square foot two-bedroom units. There are a total of 46 units in the entire building. During 1985, rents for a one-bedroom unit ranged from $297 to $340 and from $410 ro $426 for a two-bedroom unit.

The building is cubic in form. All apartments have either east or west exposure and all two-bedroom units are corner apartments. An equivalent of 13 percent of the floor area is glazed.

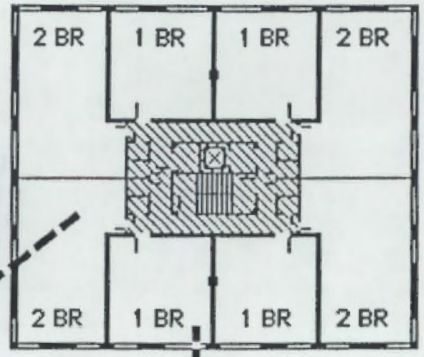
Both entrances to the building are air-locked with swinging doors. The ground floor includes the laundry, work-room and the rental office.

A single elevator and stairs provide vertical transportation, and a covered walkway joins the building to the enclosed parking garage. The heated swimming pool is located adjacent to and east of the parking garage.

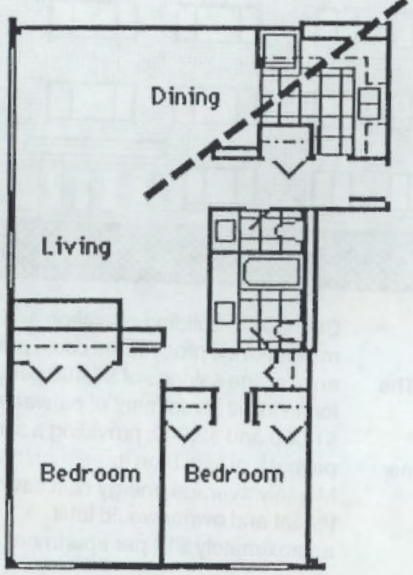
Each tenant pays for the electricity he or she uses for lighting and appliances, while the landlord pays for the natural gas and electricity used to heat and cool the apartments, common areas, garage and swimming pool. The owner also pays for common area and exterior lighting and for all domestic hot water.



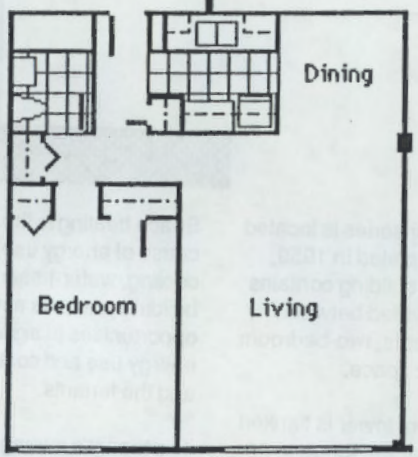
Site



TYPICAL FLOOR



TWO BEDROOM



ONE BEDROOM

Building Specifications & Operations

MANKATO, MN

The Minnesota midrise is consistent in form and quality of construction with many apartment buildings of its era. It houses approximately 115 tenants at maximum occupancy.

The apartment units are fairly large with standard appliances provided for each unit. The amount of exterior glass is larger than on some newer buildings, and can be operated to provide cross-through ventilation in the two-bedroom apartments. Mechanical ventilation of kitchens and bathrooms introduces significant amounts of outside air. The building has three central gas-fired hot water heaters.

Compared to current practice, the building has relatively low thermal resistance in the built-up roof (two inches of rigid insulation) and in the walls (one inch). The windows are double-glazed.

Space conditioning is provided to each apartment by a two-pipe fan coil unit, fed by a central chiller and gas-fired boiler. This equipment is located in a mechanical penthouse on the roof of the apartment building. A separate heating and cooling system using 100 percent outside air is used to condition common areas. A gas-fired furnace, operating at 70 percent efficiency, maintains temperatures above 45° F in the garage. No cooling is provided to this area. A single-zone draw-through unit provides supplementary space conditioning to the mechanical penthouse. The swimming pool is heated for three months a year by a gas heater connected in-line with the filtration system.

BUILDING SPECS

ENVELOPE:

- Exterior Wall
  - 4" face brick, 8" concrete block; 1" styrofoam insulation, 1/2" gypsum board(garage walls not insulated)
- Window
  - Double Pane, R=2.05/U=0.49 including frame
  - Shading coefficient 0.64 with light-colored venetian blind
- Roof
  - Main: Built-up roofing, 1-1/2" roof insulation, metal deck, joist airspace, gypsum plaster ceiling.
  - Garage: Built-up roofing, 2" roof insulation, 3" light-weight conc. deck

INTERNAL LOADS

- Lights: 0.5 Watts/s.f. (1950W, garage)
- Appliances: 0.4 Watts/s.f.
- Cooking: 6000 Btu/day (40% latent)
- Elevator: 1 @ 22kW
- Infiltration: 1.0 Air Change/hr., apartments; 0.5 ACH, common space

VENTILATION/EXHAUST

- Apartments: 40 cfm/apt
- Garage: 10% outdoor air/winter; 50% outdoor air/summer

SYSTEM SPECS

HVAC

Apartments: Two-pipe fan-coil

Laundry & Workshop: Same as apts.

Halls & Lobby: same, 100% outside air

Penthouse : draw- through unit

Garage - Gas-fired furnace; 70% nominal efficiency

TEMPERATURE SETPOINTS

Heating: 70°F, apartments
65°F, common spaces
45°F, garage

Cooling: 78°F (no cooling in garage)

CENTRAL PLANT

1 Boiler 1,200,000 Btus/hr. 75% efficiency

1 Open 60-ton Centrifugal Chiller C.O.P.= 3.33 720,000 Btus/hr.

Cooling Tower

DOMESTIC HOT WATER

3 Gas-fired water Heaters, 67% efficiency, 60,000 Btus/hr. ea.

Energy Analysis

Mankato, Minnesota has approximately 2,000 hours per year below 30° F. The daily average temperature range in December, January, and February is between 30° F and 10° F. The average daily temperature swing in summer is greater than 20° F and temperatures above 95° F occur rarely, with relative humidities of 30 percent to 50 percent common during hot weather.

Space heating in this Minnesota midrise accounts for 70 percent of total energy use and cost. The majority of this cost is due to heating the apartments, which accounts for 70 percent of the floor area. Major causes of heating loads in the apartments are conductive losses through the exterior walls (R-value less than 8), and high infiltration/ventilation loads, induced in part by the forced kitchen and bathroom exhaust systems that have a typical daily operating period of 16 hours. When these systems are turned on, outside air infiltration rates increase from a reasonable range of 3/4 to 1 air change per hour to 2 to 4 air changes per hour.

Because window areas are relatively small, conductive losses through the walls are the major component of envelope loads. Correcting the excessive infiltration due to the exhaust systems is therefore more important than reducing infiltration through the exterior skin of the building. The uninsulated parking garage is heated whenever its interior temperature drops below 45° F and is mechanically ventilated at a rate of 4 air changes per hour to prevent the build-up of car exhaust.

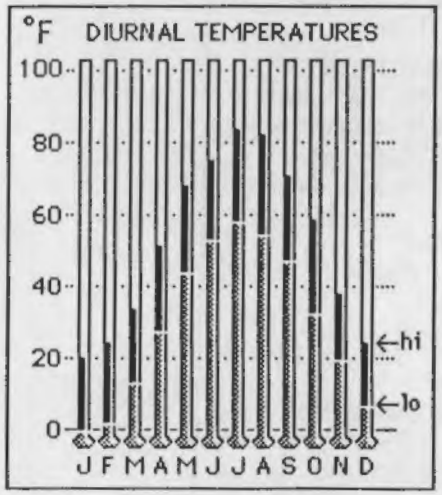
The largest portion of energy cost occurs in heating which is supplied to the apartments from September through May by a two-pipe fan coil system with a gas-fired boiler operating at an efficiency of 70 percent. Cooling is supplied in the remaining months by an electric chiller with an average EER of 11.3. Incandescent lights are used in the apartments and paid for by the tenant, while the owner pays for the higher-efficiency fluorescent and HID lights in the common areas, garage, and on the building exterior.

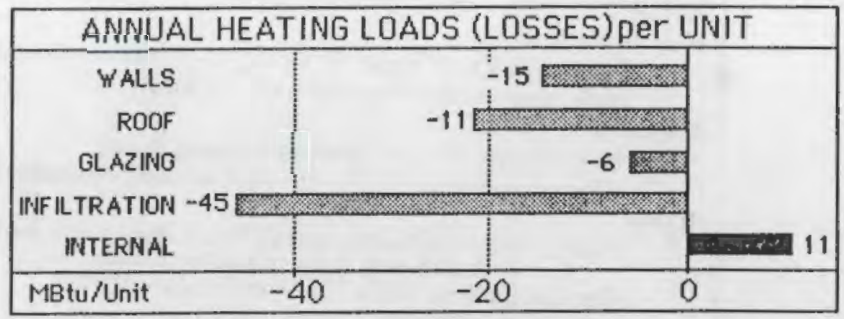
The majority of the appliance energy cost is the responsibility of the tenant, accounting for the largest single component of the tenant's energy bill.

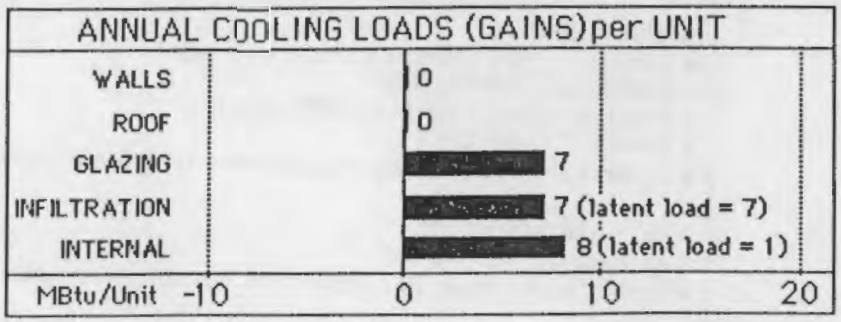
Water is heated centrally in two gas-fired heaters and paid for by the owner; the overall efficiency of the heaters is 67 percent. Approximately 15 percent of the water-heating requirement is generated by laundry equipment.

The space heating, lighting, domestic hot water and appliance energy costs account for approximately 83 percent of the owner's monthly average energy bill per apartment. The remaining 17 percent is made up of: operation of HVAC equipment (7 percent); cooling (7 percent); and vertical transportation (3 percent).

Extreme temperature variations and cold winter temperatures show heating as a major concern







Economics

This building would cost roughly $2.5 million to replace at today's prices of approximately $50 per gross square foot. That price includes added wall, roof, and foundation insulation which would certainly be standard in current design in the Minnesota region.

The average energy costs of approximately $0.10 per square foot per month or $1.20 per year are reasonable for a building constructed in this climate in 1959. An average two-bedroom unit rents for about $418 per month and energy costs represent 22 percent of the average monthly shelter costs. The rent analysis at the lower right corner of the page shows both the owner's and tenant's proportional shares of the energy costs.

Utility rates in Mankato, Minnesota are slightly below the national average. The electric rate is the same for the tenant and the owner and there is no cost penalty when electric use is shifted from the owner to the tenants.

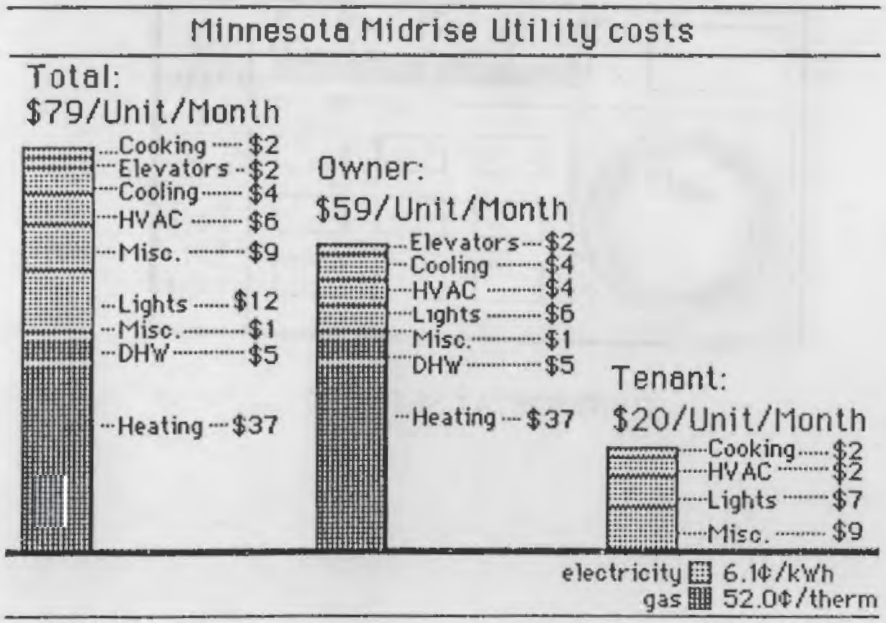
At an annual utility bill of $45,504 total or $79 per month per unit average, the owner pays almost three times per unit what tenants do. As shown in the bar chart, space heating and cooling account for roughly 70 percent of the owner's bill. Of the remaining utility costs, the largest single component is lighting which represents 13 percent of the owner's bill and 16 percent of the total energy costs.

On the tenant's side, appliances (refrigerators, electric ranges, dishwashers, broilers, mixers, etc.) are the highest energy cost items followed closely by thew auxillary fans (used to blow heating and cooling out of the unit heat exchangers) and interior lighting.

According to IREM, the owner's annual utility bill is typical for the region. In this building utility costs (excluding water, sewer, and trash removal) are roughly 16 percent of rental income for an average unit.

As shown in the rent analysis example, when all utility costs are included, the "shelter costs" of a typical two-bedroom unit are $418 per month, and should not exceed 35 percent of a tenant's gross annual income to "QUALIFY" for this apartment.

Assuming utility costs could be cut by one-third (and all savings were passed through to the tenant) shelter cost for a two-bedroom unit could drop to $392 per month and income to qualify would drop to about $13,440. This is likely to be of significance to owners in a competitive market and to renters in general.



Energy and Rent Analysis

(Typical Two-Bedroom Unit)

Net Rent to Owner	$339
Owner's Monthly Energy Cost/Unit	$59
TOTAL RENT	$398
Tenant's Monthly Energy Cost/Unit	$20
SHELTER COST	$418

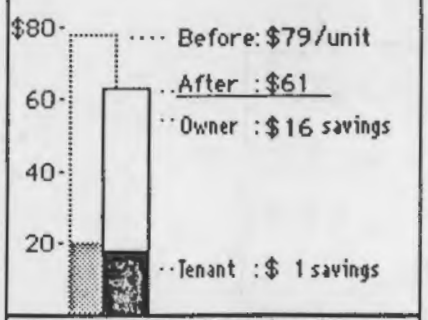
INCOME TO QUALIFY: $14328

MANKATO, MN

Operations Team A

STRATEGIES & COSTS	
Infiltration/Exhaust:	
- Add CO sensor for garage	$750
- Slow fan speed of roof vent motors	750
HVAC:	
- Reduce outside air supply in corridor	25
- Reduce corridor temperature to 58°F	-0-
- Install programmable thermostat in garage	300
DHW:	
- Reduce boiler temp to 115°F	-0-
Training:	
- Shut off space heating boiler pilot in summer	-0-
- Instruct tenants to reduce DHW temp when on vacation	-0-
- Have gas company check flue gas	-0-
TOTAL COST:	$1,075

UTILITY BILLS



Monthly Savings: $17/unit

Annual Savings: $9,367

PAYBACK: 2 Months

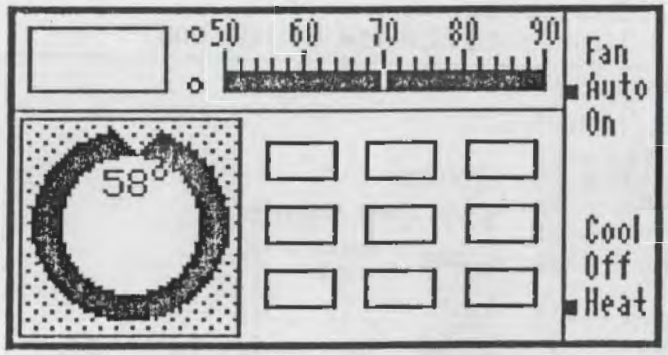
Under Operations, Team A evaluated several low or no cost items. Although none of these strategies saves a large amount of energy, they are simple enough to be implemented immediately by the property manager and the maintenance crew as part of the regular maintenance schedule. The computer analysis of these concepts was not able to identify all of the potential energy savings for all of the strategies.

Temperature setpoints were changed in the corridor, lobby, garage, and in the hot water tank. The heating setpoint of the corridor and lobby areas was reduced from 70° F to 58° F, corresponding to their main use as transient buffer spaces, rather than regularly-occupied areas. In the garage, the heating setpoint was reduced to 34° F from 45° F, on the premise that the lower temperature would still provide for easy starting of the automobiles on winter mornings. Temperatures in the two centralized hot water heaters were lowered from 140° F to 115° F.

Incandescent lamps in the garage were replaced with screw-in fluorescent lamps. These lamps offer both lower power consumption and longer life than incandescent lamps, so their higher initial cost is offset by savings due to less-frequent maintenance, as well as reductions in energy cost. The existing ventilation rate in the garage of four air changes per hour was significantly reduced by adding a carbon-monoxide sensor to the fan-control system. Pending code approval, this device will turn on the ventilation fans only when levels of carbon monoxide reach a predetermined threshold.

The local gas company should be called in, free of charge, to analyze the boiler flue gases. From the results of this test, the maintenance crew was able to adjust the burner air intake to the optimum. This test will be repeated regularly in the future. Since the boiler was already operating at roughly 80 percent efficiency, no credit was taken for energy savings for this strategy. The gas pilot light wcan also be extinguished during the summer, when heating is not needed.

The design team established that informed tenants could reduce their energy consumption by 10 percent to 30 percent. The educational program includes monthly or seasonal mailers with tips for conserving energy for space heating and cooling, and water heating. Because of the current billing structure, however, the tenants are not motivated to conserve energy in the major end-use groups. The Team felt it unlikely that a tenant education program could be effective over the long term unless the tenants pay for their own energy use. For this reason, no savings were credited for this concept.



THERMOSTAT SETBACK

Operations Team B

MANKATO, MN

Team B chose a restricted set of options, all implementable at low cost, and all capable of being maintained by the building manager and maintenance staff.

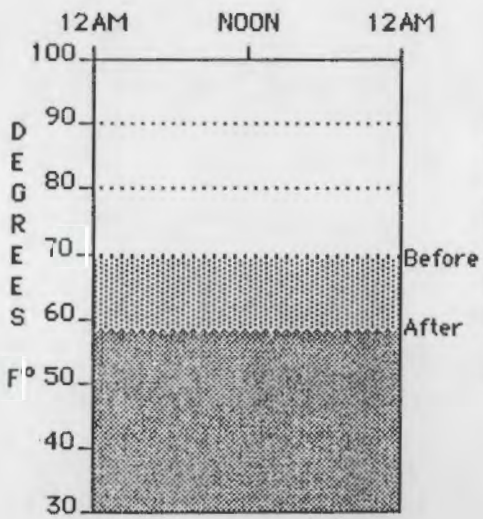
Careful attention was given to reducing operating temperatures in commom areas and in the garage. The temperature in the corridor joining the garage to the apartment building was lowered from 70° F to 58° F. In the garage, a programmable thermostat was installed to raise the building to the desired setpoint temperature of 55° F only between 5 A.M. and 9 A.M. A temperature ramp function raises the temperature to 45° F between Midnight and 5 A.M. The thermostat turns off the heating system the rest of the time.

Quantities of ventilation air in common areas were also reduced. Outdoor air supplied to the corridor was reduced to 10 percent of supply volume. This measure will reduce the amount of supplementary heat needed to maintain the desired interior temperature. A carbon monoxide sensor was added to the garage to reduce fan operation to only those times when carbon monoxide approaches unacceptable levels. In addition to decreasing the heating requirements, this measure will produce some savings in fan energy consumption due to reduced hours of operation.

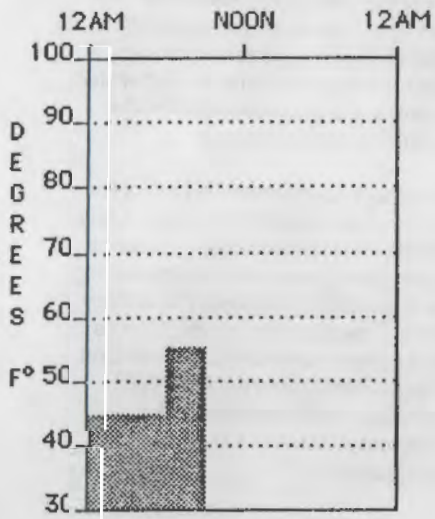
The speed of the roof vent motors was reduced to 50 percent of the current operating rate. This measure will reduce exhaust rates in kitchens and bathrooms in the apartment building. This will, in turn, decrease the amount of outside air drawn into the building through the negative pressure created by the exhaust.

A photocell was specified to reduce the hours of operation of the outside lighting system. At relatively low cost, this measure controls the lighting equipment.

As with Team A's operations strategies, the main asset of these measures is the respectable energy savings that they produce, in return for low implementation cost.



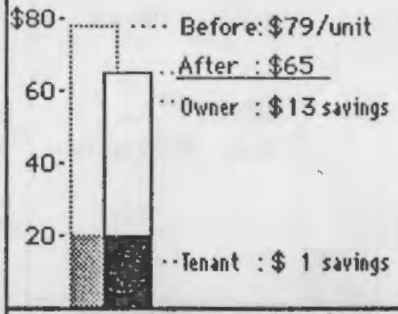
Winter Thermostat Settings in Public Corridors



Thermostat Settings in Garage

STRATEGIES & COSTS	
Infiltration/Exhaust:	
- Add CO sensor for garage	$750
- Slow fan speed of roof vent motors	750
HVAC:	
- Reduce outside air supply in corridor	25
- Reduce corridor temperature to 58° F	-0-
- Install programmable thermostat in garage	300
Lighting/Appoliances:	
- Add photocell control to outdoor lighting	225
TOTAL COST:	$2,050

UTILITY BILLS



Monthly Savings: $14 /unit

Annual Savings: $7,513

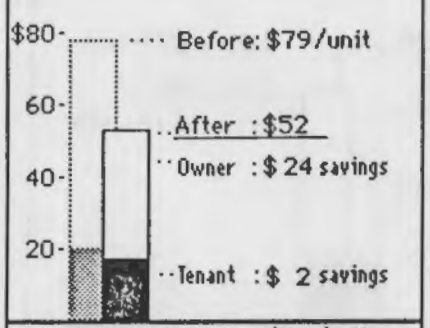
PAYBACK: 3 Months

Team A Retrofit

MANKATO, MN

STRATEGIES & COSTS	
Envelope:	
- Install exterior storm windows	$12,313
- Blow R-40 insulation into roof	7,636
- Insulate garage wall with 2" rigid insulation board	2,000
Infiltration/Exhaust:	
- Repeat Operations Strategy	750
- Install ductless range hood	2,990
- Install 60 CFM switched toilet fan in existing duct	9,180
- Install automatic flue vent damper	1,000
HVAC:	
- Repeat Operations Strategies	325
- Bill tenants for heating by metering fan coils	13,000
- Insulate piping	10,000
- Install programmable thermostats in apartment units	7,590
- Improve boiler efficiency	-0-
DHW:	
- Repeat Operations Strategy	-0-
Building Site Design/Mass & Solar Control:	
- Plant vines on garage wall	-0-
- Plant wind break on north side of pool	-0-
Training::	
- Repeat Operations Strategy	-0-
TOTAL COST:	$66,784

UTILITY BILLS



Monthly Savings: $26/unit

Annual Savings: $14,507

PAYBACK: 4.6 Years

Two main approaches to retrofitting the Minnesota midrise were developed by Team A. While they both involve increasing the insulation of the building envelope, they feature different solutions for the HVAC equipment, involving either improvement in the efficiency of the existing central system, or its replacement by individual heating and air conditioning units located in each apartment.

Insulation was added to the building and to the garage. Fiberglass insulation was blown into the attic joist space of the apartment tower, to bring the insulation level to R-40. This method allows the owner to retain the relatively new surface on the building roof. The exterior walls were insulated on the interior surface, using 2" rigid foam board covered with 1/2" gypsum board, nailed to 2" x 3" furring strips. This approach costs more, but uses less floor area than fiberglass insulation nailed to 2" x 4" furring. The garage was insulated with unfinished foam board glued directly to the interior of the walls and roof.

Exterior storm windows were installed to further reduce envelope conduction and uncontrolled infiltration of outside air. These windows were attached directly to the metal frames of the existing windows, allowing the window sections to remain operable. As the second most expensive retrofit option, after insulation, the cost effectiveness of this measure was evaluated carefully.

Activated charcoal recirculating air fresheners installed in the kitchens and bathrooms, replacing the central exhaust system. These areas are major sources of sensible and latent heat gain. Capping the exhaust systems traps this heat in the apartments, where it reduces the need for auxiliary heating energy.

Improvement in the efficiency of the central HVAC system would involve replacing the current boiler with a new unit one-half its size, with an automatic vent damper and insulated piping.

Greater energy savings could be achieved by the replacement of the existing central HVAC system by individual mechanical units. This was the single most expensive retrofit strategy evaluated, accounting for up to half of the total cost of the retrofit package. This approach would see a split electric air conditioning system, a high-efficiency gas furnance and water heater, and a dead-band thermostat installed in each apartment.

After careful consideration, both of the above strategies were rejected in favor of a substantially less costly approach where savings are produced by shifting the responsibility for paying for energy from the owner to the tenant. Meters were installed on each fancoil unit and programmable thermostats in each apartment so that tenants could individually control the amount of heat being called for.

Additional energy saving concepts recommended included conversion of the incandescent lighting systems to fluorescent lighting in kitchens, lobby, corridors, and common spaces.

Retrofit Team B

MANKATO, MN

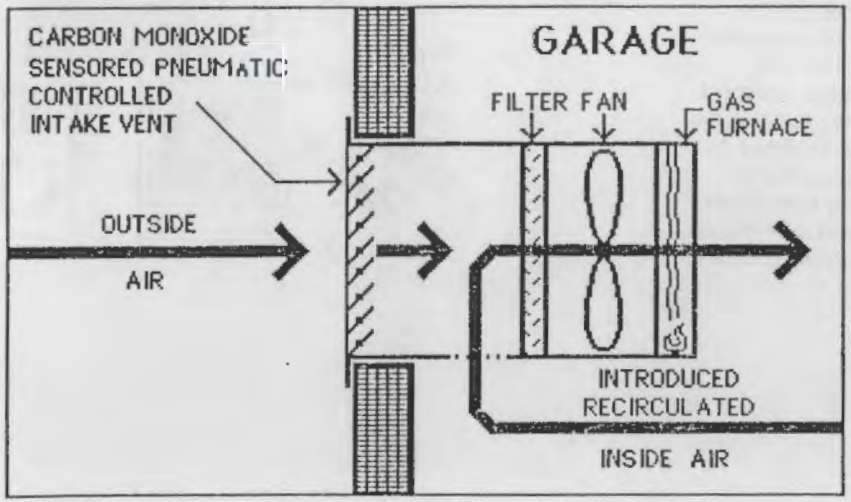
In designing its retrofit measures, Team B focused on improving the building envelope and investigating a variety of HVAC concepts. The most cost-effective approach was found to focus on reducing envelope loads on the existing central HVAC system.

Rigid insulation was recommended for installation on the roof of the apartment building at the time when the roof would normally be reroofed. The insulation value of R-40 was specified.

Additional measures were taken to reduce uncontrolled infiltration and excessive rates of exhaust throughout both the apartment building and the garage. In the garage, the outside air intakes for the gas-fired heaters were modified by installing louvered dampers with pneumatic controls. Carbon monoxide sensors were coupled to the ventilation controls to activate the fan system and draw in fresh air when, if ever, indoor air quality in the garage exceeds prescribed limits. The apartment building ventilation system was redesigned to include individually switch-operated bath fans and range hoods, to replace the roof powered ventilators. By placing operation of these systems under the control of the tenant, hours of operation will be reduced, decreasing in turn both fan energy consumption and rates of infiltration.

In addition to these efforts, to reduce fan induced infiltration, caulking around the joint between metal window frames and the brick exterior finish was recommended to minimize wind induced infiltration. By plugging this infiltration pathway in this very cold climate, heating and cooling loads are significantly reduced.

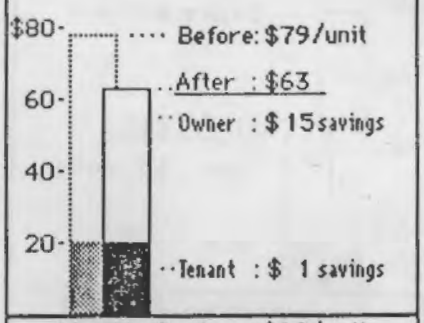
Team B initially considered a series of modifications to the central HVAC system, including replacement of the chiller and cooling tower with new, high-efficiency equipment. Following evaluation of the results of computer analyses of the envelope strategies, it was noticed that the infiltration/exhaust strategies reduced energy costs to such an extent that HVAC system modifications were no longer cost-effective.



STRATEGIES & COSTS

Envelope:	
- Install R-40 rigid roof insulation at replacement	$7500
Infiltration/Exhaust:	
- Repeat Operations Strategy	750
- Remove outside air intake from garage heaters, seal intake vent	320
- Reduce bath and kitchen exhaust: Install 60 CFM in-duct switched bath fan	5,780
- Install 140 CFM in-duct switched range hood	5,060
- Remove powered roof ventilators	700
- Install rooftop goosenecks	1,750
- Caulk exterior windows	4,500
HVAC:	
- Repeat Operations Strategies	325
Lighting/Appliances:	
– Repeat Operations Strategy	225
TOTAL COST:	$26,910

UTILITY BILLS



Monthly Savings: $16/unit

Annual Savings: $8,716

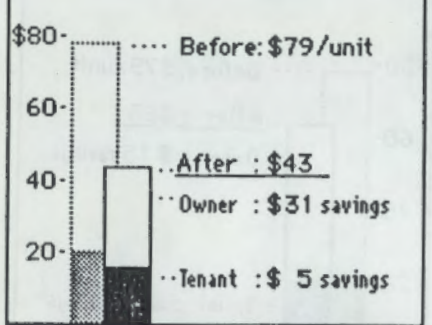
PAYBACK: 3.1 Years

MANKATO, MN

Team A Rehabilitation

STRATEGIES & COSTS	
Envelope:	
- Repeat Retrofit Strategies	$21,949
- Insulate inner face of exter. wall: 2" rigid insul. w/ fur & 1/2" gyp. bd.	9,076
Infiltration/Exhaust:	
- Repeat Retrofit Strategies	13,920
- Caulk windows	6,500
HVAC:	
- Repeat Retrofit Strategies	7,915
- Install high efficiency individual AC with forced air gas heat	97,366
- Install hgh efficiency individual gas fired DHW at replacement	-0-
- Direct utility company billing to tenants	-0-
Lighting/Appliances:	
- Install high efficiency ranges and refrigerators incrementally	10,350
DHW:	
- Repeat Retrofit Strategy	-0-
Building Site Design/Mass & Solar Control:	
- Repeat Retrofit Strategies	-0-
- Add 2-1 BR to 1st floor	22,833
- Add 1-1 BR to penthouse	10,491
- Add gameroom	89,309
Training:	
- Repeat Retorift Strategies	-0-
TOTAL COST:	$329,679

UTILITY BILLS



Monthly Savings: $36/unit

Annual Savings: $20,774

PAYBACK: 15.9 Years

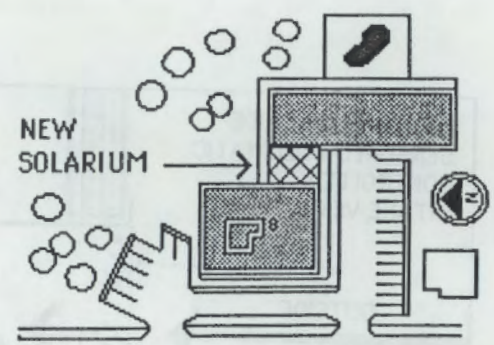
The basic rehabilitation strategy included all of the insulation and ventilation control strategies developed for the retrofit package, as well as the installation of individual high-efficiency gas water heaters and heating and cooling systems, with setback thermostats in each apartment. The tenants would be directly billed for DHW and HVAC, increasing their awareness of the cost of these items, and in turn better controlling their use.

Rehabilitation measures included the upgrade at replacement of existing refrigerators and stoves with high-efficiency models. No salvage value was assumed for the existing appliances.

Major changes were made to the building. Two new one-bedroom apartments were added in part of the space occupied by the laundry/work room/mechanical room, on the ground floor, and a new one-bedroom apartment was created in the penthouse. The game room was moved to a new passive solar solarium on the ground floor between the garage and the apartment building. To accomodate this move, the walkway's north wall was insulated, its flat, built-up roof was removed and replaced with a partially-glazed atrium roof, and its south wall was relocated on new footings parallel to the south face of the building. A new concrete floor slab was poured in this space. The existing walls of the garage and apartment building serve as low-cost thermal mass. Excess heat, generated by occasional solar overheating of this space, will be ducted into the garage.

Three apartment units (2,108 SF) and a solarium game room (1,680 SF) were added, at a total cost of $123,000 ($32 per square foot). Additional strategies were applied to the pool and the garage, in an effort to reduce as many of the owner's remaining energy related costs as possible. The garage and pool strategies are a major part of this cost. Photocell controls were recommeded for the garage, to completely reduce the lighting load during the daytime.

The skylight and photocell system was ultimately rejected by the owner, due to marginal economic performance. The cost of these components was approximately $26,000, versus a total cost of $1,000 per year for all common-space lighting. The pool enclosure was accepted by the owner due to the amenity value of having the pool open for an extended period in the spring and fall. Although this will actually lead to an increase in energy consumption, it is anticipated that this concept will pay for itself through added rent due to increased amenity value.



Rehabilitation Team B

MANKATO, MN

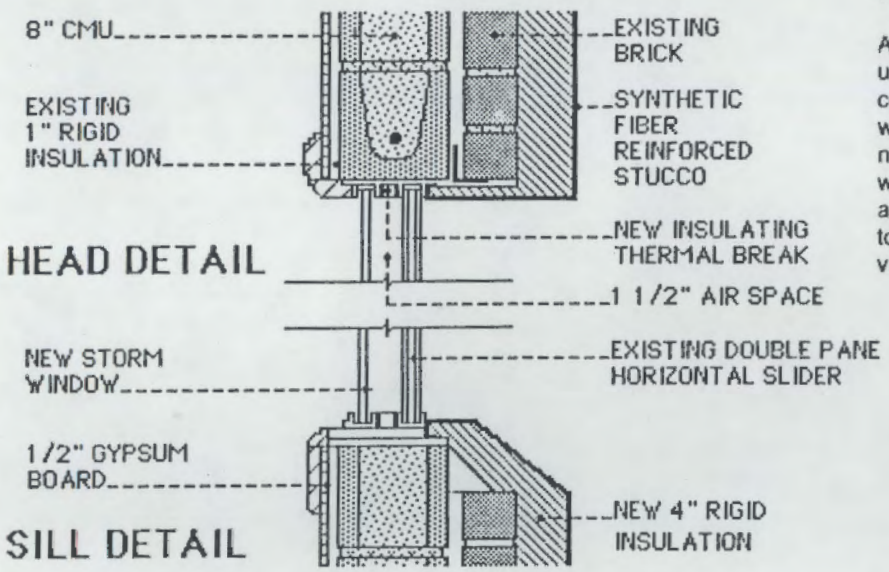
In its rehabilitation strategies, Team B incrementally expanded on the envelope modifications that had proved cost-effective as retrofit options.

Major additions to the earlier options package include the insulation of the outside surface of the exterior concrete block and brick walls with 4" of rigid insulation with a fiberglass reinforced concrete finish or comparable reinforced elastomeric finish. To further tighten the envelope, storm windows were installed supplementing the existing double glazed window units.

The exterior insulation strategy was chosen to exploit the thermal storage capacity of this massive masonry building. This strategy generated considerable debate among team members regarding the magnitude of benefit achievable. No consensus was reached regarding the best way to model the energy implications of the strategy and the various methods used generated significantly different answers. To avoid presenting potentially misleading information, the Team used the most conservative approach in analyzing this strategy. Unfortunately, the results of this analysis showed the exterior insulation strategy to be less beneficial than Team B's retrofit strategies. Optional evaluation methods, however, showed this strategy to be extremely effective in reducing heat loss, the largest single energy cost issue. One analysis method suggested this solution has the R-value of 60 in combination with the internal mass. Several options for the central HVAC system were evaluated and discarded due to their marginal economic performance when considered in context with the extensive envelope solutions including, the replacement of all heating equipment with new high-efficiency equipment. Since the existing boiler operates at approximately 70 percent efficiency, a new boiler would not cost-effectively improve performance and replacement of the cooling equipment was still not determined to be cost-effective.

One strategy that did meet the criteria of the Team and was found viable was heat-recovery from the boiler exhaust as a preheating option for the domestic hot water system.

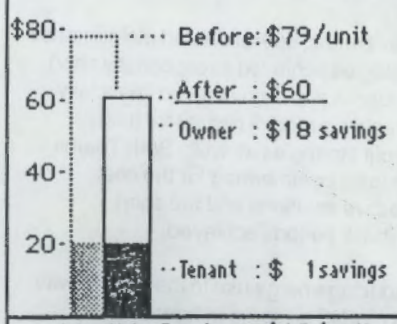
Among the options considered and ultimately rejected were various configurations based on the addition of windows or skylights in the garage for natural lighting and ventilation. The window options considered were neither adequate for sufficient natural lighting, too expensive or failed to comply with ventilation code requirements.



STRATEGIES & COSTS

Envelope:	
- Repeat Retrofit Strategy	$7,500
- Install 4" exterior insulation and finish	102,551
- Install storm windows	12,313
Infiltration/Exhaust:	
- Repeat Retrofit Strategies	18,860
HVAC:	
- Repeat Retrofit Strategies	325
Lighting/Appliances:	
- Repeat Retrofit Strategy	225
DHW:	
- DHW preheat off of gas boiler flue	2020
TOTAL COST:	$142,974

UTILITY BILLS



Monthly Savings: $19/unit

Annual Savings: $10,449

PAYBACK: 13.7 Years

MANKATO, MN

Jury Comments

In reviewing the options for operations the jury felt the control of the infiltration rates caused by the kitchen and bath exhaust system would be one of the least expensive and most effective methods of saving energy cost. The individual control of the exhaust fans in each apartment would certainly lessen the infiltration and energy use. The jury commends the strategy of reducing air infiltration and lowering the temperature in the garage.

With regard to the Team A retrofit strategies, one jury member felt that foam board insulation in the garage would not save enough energy to outweigh the unsightly appearance of the boards after a few years. The fragile nature of foam board makes its use on the garage walls questionable. The addition of storm windows seemed excessive, especially since the windows are already double glazed. By caulking around the existing windows, the infiltration should be lessened enough not to require the addition of storm windows.

Both Teams, operation and maintenance strategies achieved exceptionally short paybacks and both acieved financially attractive payback results for their retrofit strategies as well. Both Teams are to be commended for the cost effective solutions and the short payback periods achieved.

Reducing energy use in the garage was applauded as some indignation was expressed at the use of precious fuel for auto pampering. Carbon monoxide sensors were accepted as a good solution to reducing outside air intake into the garage conditioning system as long as they are maintained properly.

The insulation of the roof seemed sensible.

In reconsidering Team B's rehabilitation strategy of insulating the outside surface of the exterior walls there were two trains of thought. Part of the jury felt that there could be an added cost of maintenance for the new elastomeric skin as compared to the simplicity of caring for the existing brick surface, making this option less feasable. Another jury member, though, felt that the added skin and insulation would create a mass that would stabilize the building in terms of temperature swing and could make major energy savings possible. The jury felt more detailed study was necessary to evaluate the cost effectiveness of this strategy.

It should be noted that in Team A's rehabilitation strategy of adding new units, payback consideration was given only to energy cost savings. The additional rent from these new units was not included in the payback analysis and if included would greatly decrease the payback time.

The probability of over heating in the new solarium was considered insufficient, by one juror, to warrant constructing duct work to the garage.

Albuquerque Midrise

ALBUQUERQUE, NM

Built in 1979, this six-story, 150,000 square foot building is the residential portion of a larger complex serving the elderly. Another building in the complex offers nursing home care. There are common dining facilities for those who want. Only about one-third of apartment tenants eat in the central facility.

The complex is owned and run by a church affiliated group. The owner pays all energy costs for both common spaces and tenant apartments.

The building reflects good energy conscious design of the late 1970's. Walls are reasonably insulated and windows have double glazing. The building has hydronic heat pumps off of a central "California" loop. Supplemental heating is by natural gas. Supplemental cooling is provided by a cooling tower.

Although located in the sunny southwest, Albuquerque has a cold climate (over 4,200 heating degree days). Heating, therefore, is the largest load for the building, although cooling loads are also significant.

The total energy bill for this building is estimated to be about $116,000 per year. Improved operations in this building were estimated to save up to $14,000 per year with a two to four year payback. Retrofit improvements can save up to $28,000 per year with paybacks in the six to eight year range. In the case of rehabilitation, both design teams studying this building recommended enclosing balconies to make them more attractive for elderly tenants and to reduce energy costs.

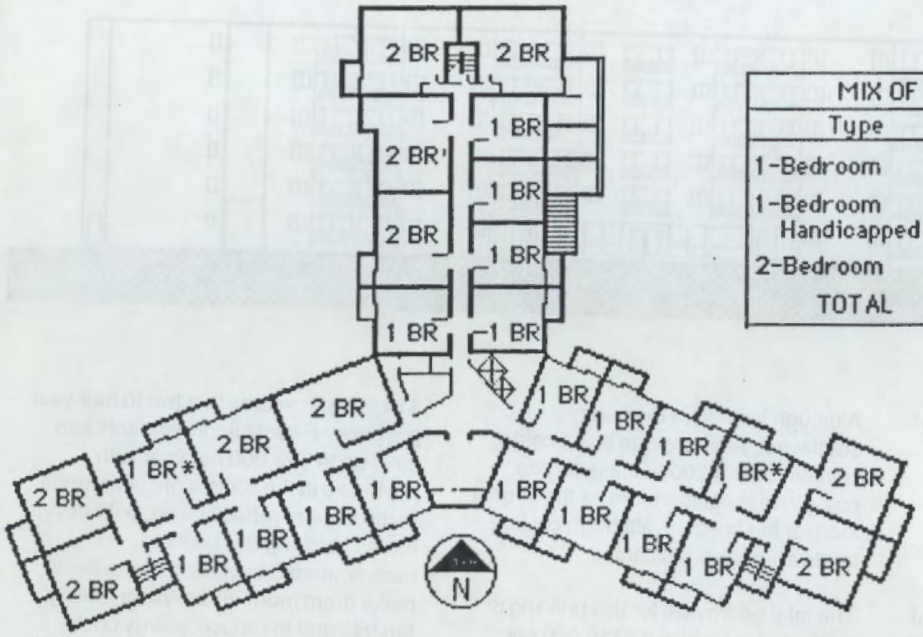
Building Layout

The building is connected to the extended care facility on the ground floor level of the northeast wing. The common dining facility is located at this point to allow easy access from either complex. In order to make this building comparable to other multifamily buildings in this study, the common dining area was not modeled as part of our analysis of this building. As shown on the typical floor plan below, the building is laid out with three double loaded corridors radiating from a central core. In addition to containing elevators, the core has a laundry room, small storage area, and a balcony with patio. Every unit has a balcony. Stairwells for fire exit are located at the far end of each wing of the building.

The ground floor, not shown, has a mix of apartments and common facilities. In addition to a dozen standard one-bedroom and two-bedroom units, there are four handicapped units, the lobby, a gift shop, beauty shop, lounge, library, and manager's office.

As shown in the "Mix of Unit Types" below, the building is designed for elderly occupancy. The majority of units are one-bedroom (65% including handicapped units). In doing computer simulations of this building, it was assumed that two-bedroom units have only two occupants -- unlike other buildings in the study which typically assume families in these units.

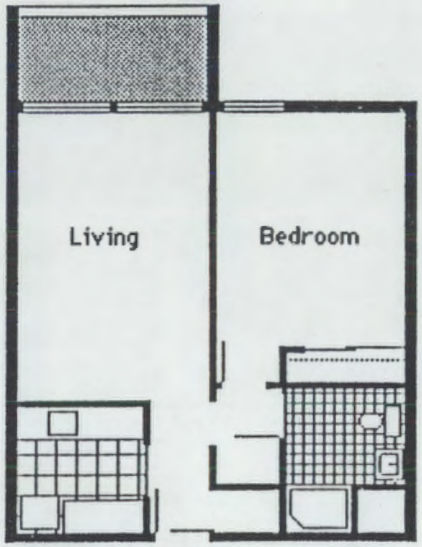
Handicapped units are only thirty-six square feet or 6% larger than standard one-bedroom units yet meet all criteria for handicapped access: including increased door widths and greater interior turning radiuses. Handicapped units need not be significantly larger than standard units to meet necessary specifications.



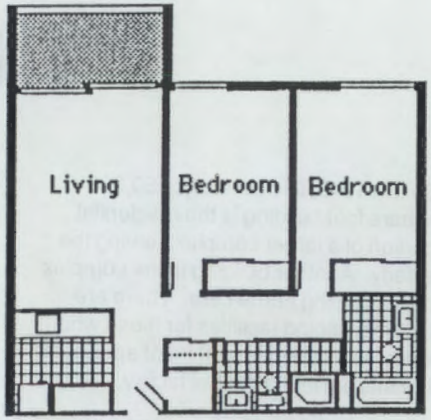
* Handicapped Unit

TYPICAL FLOOR PLAN

MIX OF UNIT TYPES			
Type	Tot.	Mix	Size
1-Bedroom	88	56%	621 SF
1-Bedroom Handicapped	14	9%	657 SF
2-Bedroom	54	35%	821 SF
TOTAL	156	100%	



HANDICAPPED UNIT



TWO BEDROOM TWO BATH

Building Specifications & Operations

This building has a number of energy conscious design features. Walls have a modest but reasonable amount of insulation. Windows use double pane insulated glass.

Because of added glazing and improved construction practices to caulk and seal buildings, it is presumed that infiltration into the apartment units is about 0.6 air changes per hour -- significantly lower than the older buildings in the study. Because of large balcony doors in the common area of each floor and multiple entries on the ground floor, the lobby and corridors are estimated at 1.0 air changes per hour.

The mechanical system is a hydronic loop with a central gas boiler for supplemental heating, a cooling tower for cooling, and hydronic heat pumps (plenum mounted) for distribution of heating and cooling to the apartments, lobby, corridors, and common spaces.

Individual 50 cfm fans provide ventilation from all unit bathrooms to a central duct with a single rooftop fan operating 24-hours a day. Range hoods are recirculating. As with other midrise and highrise projects in this study, it is presumed that "stack effects" with this type of ventilation system can be a significant but relatively hidden cause of added infiltration losses in the building.

Domestic hot water is supplied to all apartments and laundries from a central gas boiler. There is a significant amount of storage (2,000 gallons) and the tank is moderately insulated.

All units have an electric stove and refrigerator. It is presumed that use of these appliances is somewhat below normal given the elderly occupancy of the building.

This building is virtually all-electric. (A modest amount of natural gas is used for water heating and to supplement heat required in the hydronic loop.)

However, individual meters were not installed. It appears to have been a policy decision from the beginning that all utility bills would be paid by the owner.

BUILDING SPECS

ENVELOPE:

- Exterior Wall
  Stucco on 8" semi-solid CMU, 1-1/2"Z furring with 1-1/2" thermofiber batt insulation, 5/8" gyp. bd.
- Window
  Aluminum sliders, insulated glass U=0.57
  shading coefficient=0.64; white blinds partially closed
- Roof
  Ballasted built-up roof, tapered expanded polystyrene (5" thick average), 2-1/2" concrete on metal deck, bar joists, 1/2" suspended gyp. bd. ceiling

INTERNAL LOADS

- Lights: 0.5 Watts/s.f.
- Appliances: 0.4 Watts/s.f.
- Cooking: 6000 Btu/day (40% latent)
- Infiltration: 0.6 Air Change/hr. (0.4 ACH in common spaces)

OTHER LOADS:

- Lighting in Corridors: 3.68 kW/floor (24 hrs./day)
- Lighting in Lobby: 2.64 kW/floor (16 hrs./day)
- Lighting in Lobby: 3.28 kW(16 hrs./day)
- Elevators: 40 kW
- Exterior Lighting: 4 kW Metal Halide & HPS on clock timer 12 Hours/day

VENTILATION/EXHAUST

- 50 cfm bath exhaust to central duct with fan operating 24 hrs./day
- recirculating range hood.

SYSTEM SPECS

HVAC

Plenum mounted hydronic heat pump (cooling EER=10.3; heating COP=2.4) with central gas boiler and cooling tower supplementing hydronic loop

TEMPERATURE SETPOINTS

Heating: 72°F(storage, 55°F)
Cooling: 78°F(storage, none)

CENTRAL PLANT

Tube type natural gas boiler (capacity 4.6 MBTU's);

DOMESTIC HOT WATER

Central gas boiler, with time clock; 125° F hot water supply; 25 gallon/day/unit domestic use 10 gallon/day/unit laundry; 2000 gallon storage tank with 1-1/2" fiber batt insulation

Energy Analysis

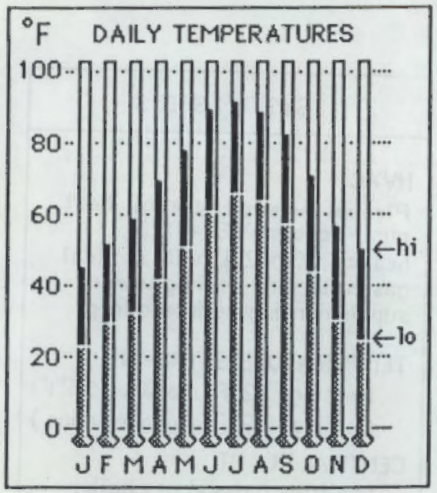
In reviewing the Albuquerque climate, it is interesting to compare it to the climate of Phoenix (just 300 miles away and the location of another building in this study). Although both cities are located in the sunny southwest, Albuquerque has a much different climate due to its 4,000 foot elevation. Albuquerque has three times more heating degree days than Phoenix, but one-third the cooling degree days. In terms of daily temperatures and degree days, Albuquerque is more like Washington, D.C. than its neighbor across the border.

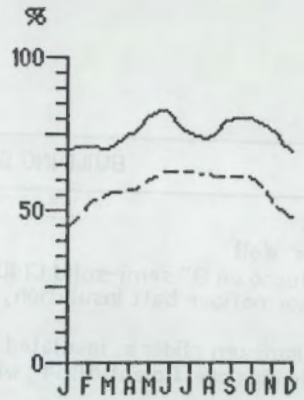
Unlike Washington, the humidity in Albuquerque is very low. There is a 94% probability that the relative humidity will be below 50% at 3:00 p.m. on any summer day. Albuquerque is also much sunnier than Washington. As shown on the diagrams (at right), Albuquerque is not only twice as likely to be sunny as Washington, but horizontal solar radiation also causes a greater heat load per square foot in Albuquerque. This strong sun is a good source of solar heat in the winter but a different problem to protect against in summer.

The cost of heating and cooling is about equal, as illustrated on the bar chart of utility costs on the next page.

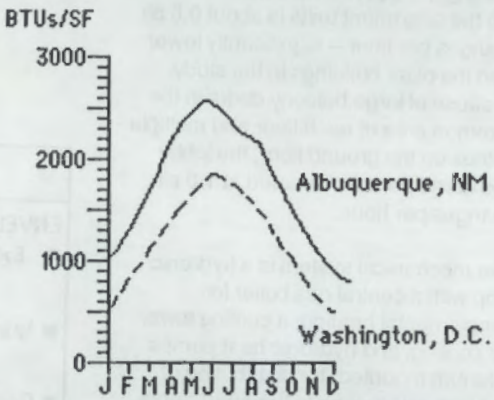
As shown on the bar charts of loads, infiltration is the principal cause of heating loads, followed by roughly equal losses through glazing and walls.

In spite of the strong sun, internal gains are still the principal cause of cooling loads. This is true in part because it is assumed that all internal heat gains from people, lights, and equipment are removed mechanically from the building. In fact, conscientious use of windows to naturally ventilate apartments when they overheat is a better solution but one which cannot be assumed to occur with certainty. It is not surprising that solar gains through glazing are the second highest cause of cooling loads.

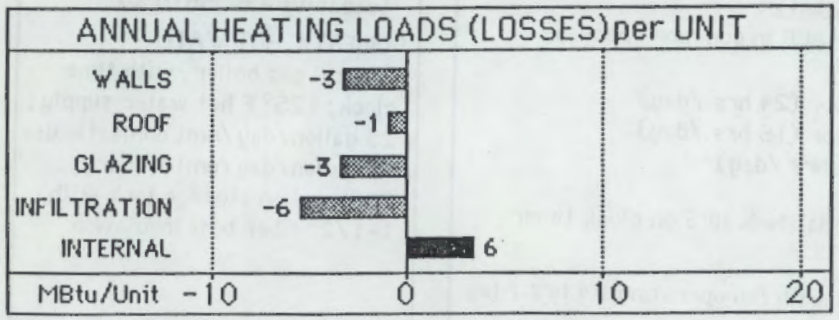


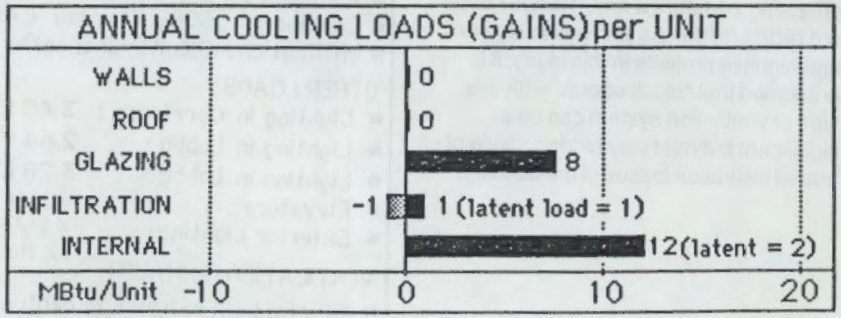


MEAN PERCENTAGE OF POSSIBLE SUNSHINE MONTHLY



HORIZONTAL SOLAR RADIATION





The owner pays for all energy costs in this building. At $61 per unit per month average for the residential portion of the complex, this is an annual energy bill of over $116,000. With costs of this size, and lacking individual tenant meters, the owner has all the incentive to look for energy cost reductions.

Heating is the largest single annual energy cost, followed closely by cooling. The cost of lights, for both tenant apartments and common spaces together, ranks third. Appliance receptacle loads are fourth, and domestic hot water heating is a distant fifth. These five categories together account for 85% of the total bill.

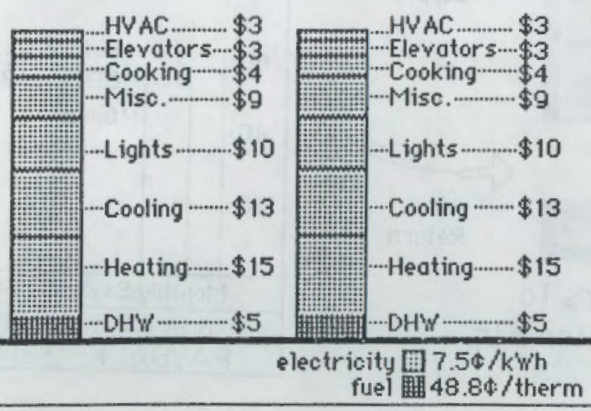
Use of hydronic loop in this building means that excess heat from solar gains can be captured from the warmer side of the building and used elsewhere in the building as needed. This feature is well adapted to the climate and serves to reduce heating costs from what they would have been without this supplement from the sun.

Because heating and cooling costs are modest, lighting becomes proportionately more significant in this building. After reviewing the drawings for this midrise, the design teams felt that more incandescent lighting was in use than necessary. This can be expensive from a long term perspective as illustrated in the chart below.

Although incandescent lamps are considerably less expensive per unit than screw-in fluorescent lamps, recent declines in the cost of fluorescents have made them more competitive especially after accounting for their longer life. It takes roughly nine incandescent lamps with a life of about 1,000 hours each to equal the 9,000-hour life of one fluorescent. Because fluorescents give roughly the same amount of light at one-third the wattage, the cost of operating a fluorescent for 9,000 hours is one- third that of incandescents.

For owners, like those in the Albuquerque project who intend to hold their buildings for the long term, the higher first cost of the screw-in fluorescent lamps is likely to be less of a stumbling block when compared to their long-term savings.

Albuquerque Midrise Utility costs



Screw-in fluorescent lamps cut operating and replacement costs for incandescent fixtures

LAMP		First Cost 9,000 hrs	Operating Cost 9,000 hrs @ 7¢/KWh	Total Cost 9,000 hrs
INCANDESCENT Std Type A	60 W	$6.75 (9 bulbs)	$37.80	$44.80
SCREW IN FLUORESCENT	PL Twin Tube 13 W	$6.00 (1 bulb)	$8.19	$14.17
	18 W SL LAMP	$20.00 (1 bulb)	$11.34	$31.34
	15 W MARATHON	$7-15.00 (1 bulb)	$9.45	$16.45 - 24.45

Operations Team A &Team B

Team A focused its recommendations on reducing heating and lighting costs. Judging that the building was now seven years old, the team believed that a careful job of recaulking could reduce infiltration and thus reduce heating costs. They recommended reducing the rate of bath ventilation by down-sizing the fan and reducing fan speed. As shown in the diagram below, they recommended adjusting dampers to reduce the amount of outside air to the corridors as well.

After reviewing the comparative economics of screw-in fluorescent lamps, the team also recommended replacing as many incandescent bulbs as possible. Relamping incandescent light bulbs to fluorescent also saved on cooling energy costs.

With total savings over $14,000, the team achieved a two-year payback on the set of strategies costing just over $30,000.

Team B recommended a more aggressive strategy to reduce infiltration. In addition to caulking, Team B also recommended weather-stripping all stairway and common area doors and reducing bath ventilation by installing a time clock to limit central ventilation fan operation. Team B also recommended installing programmable thermostats to allow better setback strategies.

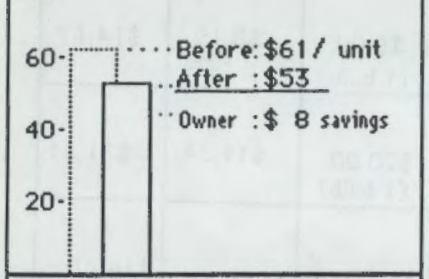
Team B was also more aggressive in reducing lighting costs. They recommended actually replacing common area lighting with more efficient fixtures including higher efficiency ballasts. They also added photocell control for all exterior lights.

Team B's strategy set is more costly than Team A's, but its payback is still under four years.

STRATEGIES & COSTS

Infiltration/Exhaust:	
- Reduce bath vent. by down-sizing fan and reducing pulley	1,200
- Recaulk as required	21,000
- Adjust dampers to reduce outside air supply to corridor	-0-
Lighting/Appliances:	
- Relamp common areas with screw-in fluor.	9,000
HVAC:	
- Raise corridor cooling setpoint	-0-
Training:	
- Educational Program: open windows when units overheat	-0-
TOTAL COST:	$31,200

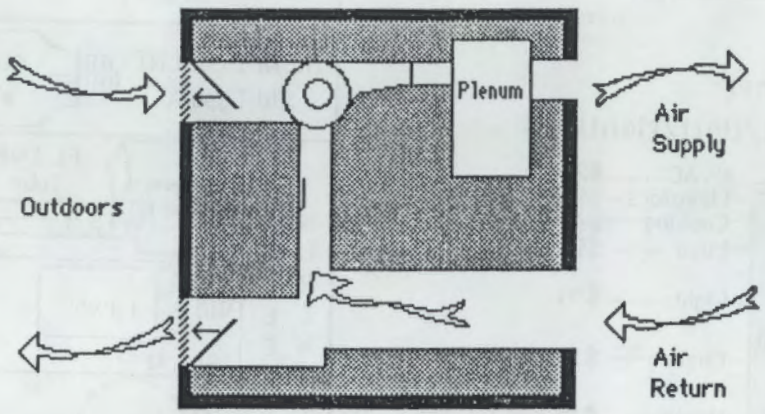
UTILITY BILLS



Monthly Savings: $8/ unit

Annual Savings: $14,826

PAYBACK: 2.1 Years

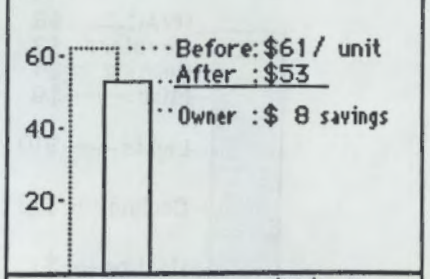


Adjust Outdoor Dampers to Reduce Corridor Ventilation Air

STRATEGIES & COSTS

Infiltration/Exhaust:	
- Disconnect outdoor air supply to corridor	200
- Weatherstrip stair and common area ext. doors	1,000
- Caulk exterior doors & windows	21,000
- Install time clocks on cent. bath exhaust	2,000
HVAC:	
- Install programmable thermostats throughout	6,000
Lighting/Appliances:	
- Install high eff. lamps and ballasts in common areas	9,000
- Add photocell control on exterior lighting	1,400
DHW:	
- Install high eff. laundry equip.	-0-
- Install flow restrictors on showers	2,300
- Increase insul. jacket on central DHW	500
Tenant Education:	
- Provide training on window management & thermostat operation	-0-
TOTAL COST:	$53,400

UTILITY BILLS



Monthly Savings: $8/unit

Annual Savings: $14,227

PAYBACK: 3.8 Years

Retrofit Team A &Team B

ALBUQUERQUE, NM

Turning to retrofit strategies, Team A recommended capping bathroom vents altogether, and installing recirculating charcoal filters instead. As in other buildings in the study, the elimination of "stack effects" by this change reduces infiltration significantly.

Given the dry climate, the team proposed installing two evaporative or "swamp" coolers to cool corridor ventilation air. The team felt that these units could operate more cheaply than the existing chiller.

To reduce unwanted solar gain and thus reduce cooling loads, the team proposed tinted storm windows on east and west facing units. On a job of this size, the Team believed tinted glazing could be custom built if required and still be cost effective.

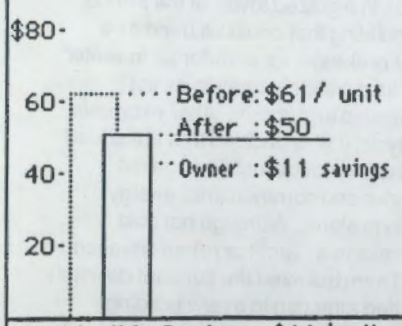
As shown on the drawing below, Team B suggested even more changes to the envelope of the building. In addition to adding tinted glass on the east and west, Team B also added it on the north to protect from diffuse sunlight in this climate. On the south face of the building, Team B recommended improving the R-value of the wall by increasing insulation on the non-glazed portion of the wall. Although the existing CMU block can be effective in delaying conducted heat to the space, added insulation would help reduce the gain altogether. The team also added a storm door for the sliding glass doors on each unit and louvered overhangs on all south glass.

Although nearly twice the cost of Team A's solution, this strategy set increases energy cost savings to nearly $29,000 per year with a payback of 7-1/2 years.

STRATEGIES & COSTS

Infiltration/Exhaust:	
- Repeat operations strategies	21,000
- Cap bath vents & install recirc. charcoal filters	38,000
HVAC:	
- Repeat operations strategies	-0-
- Add 2 evaporative coolers for corridor	10,000
Lighting/Appliances:	
- Repeat Operations strategy	9,000
- Install high eff. refrig. on replacement	12,000
Building and Site:	
- Add tinted storm windows on east and west facing units	32,000
Training:	
- Repeat operation strategy	-0-
TOTAL COST:	$122,000

UTILITY BILLS

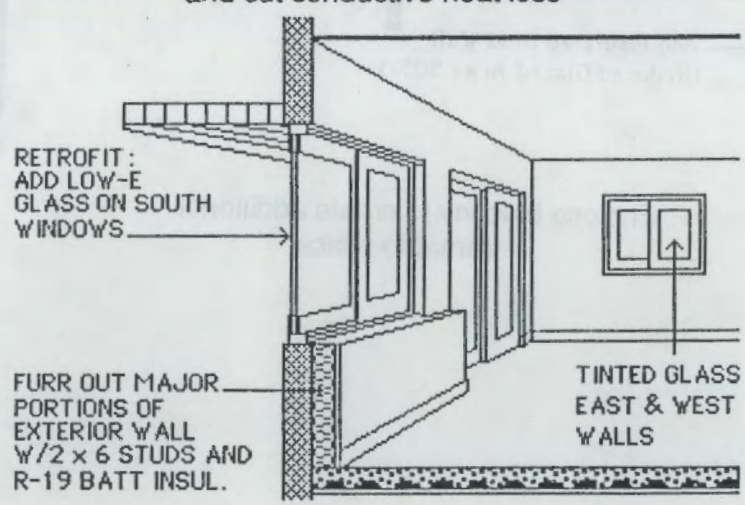


Monthly Savings: $11/unit

Annual Savings: $20,498

PAYBACK: 6.0 Years

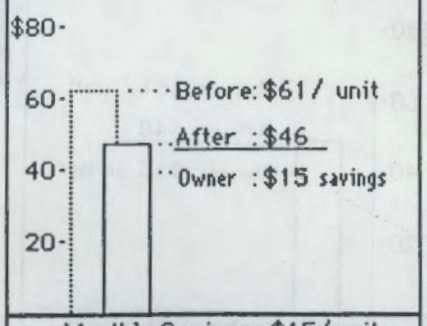
Retrofit concepts control unwanted solar gains and cut conductive heat loss



STRATEGIES & COSTS

Envelope:	
- Install storm windows; tinted glass on east and west; low E hard cast on south	50,000
- Furr out ext. wall with 2x6 studs; add R-19 batt insul., and 1/2" gypsum bd.	36,000
- Add storm door on sliding glass doors	35,280
Infiltration/Exhaust:	
- Repeat operation strategies	24,200
HVAC:	
- Repeat operation strategy	16,000
- Add one ceiling fan per apt.	21,000
Lighting/Appliances:	
- Repeat operations strategies	10,400
- Replace 12 $ft.^3$ refrig. with 8 $ft.^3$ high eff. model	12,000
DHW:	
- Repeat operation strategies	2,800
Building and Site Design:	
- Add alum.louvered overhangs on south	7,500
Tenant Education:	
- Repeat operations strategies	-0-
TOTAL COST:	215,180

UTILITY BILLS



Monthly Savings: $15/unit

Annual Savings: $28,773

PAYBACK: 7.5 Years

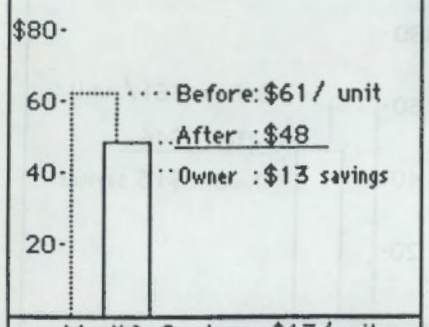
Rehabilitation Team A

ALBUQUERQUE, NM

STRATEGIES & COSTS	
Infiltration/Exhaust:	
- Repeat retrofit strategies	59,000
HVAC:	
- Repeat retrofit strategies	10,000
Lighting/Appliances:	
- Repeat retrofit strategies	21,000
Building and Site:	
- Repeat retrofit strategies	32,000
Training:	
- Repeat retrofit strategy	-0-
TOTAL COST:	$122,000

NOTE: Cost of enclosing balconies (not paid for by energy costs alone) is $150,000

UTILITY BILLS



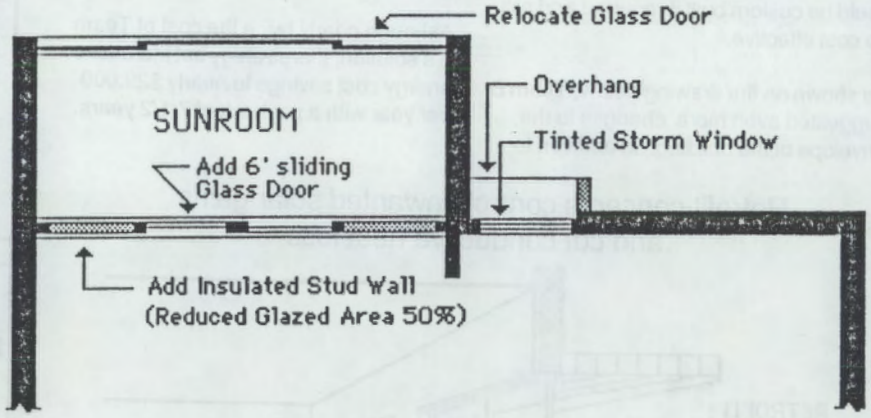
Monthly Savings: $13/unit

Annual Savings: $24,373

PAYBACK: 5.0 Years

Team A chose to repeat all of their retrofit strategies and focus attention in rehabilitation on converting existing balconies into "sunrooms." The team argued that sunrooms would probably be more attractive for use by the elderly tenants than the more exposed existing balconies. From an energy point of view, the sunrooms would not be conditioned but would serve as "buffer spaces," mitigating the effects of climate on the conditioned living spaces.

As shown on the diagram below, the team relocated the existing set of glass doors to the exterior edge of the balcony. The living room wall is then replaced with an insulated stud wall and a much smaller sliding glass door. With these two improvements, both the shading and the R-value of the living room wall is increased -- thus cutting both heating and cooling costs. On the glass not protected by the balcony, the team added a tinted storm window with an overhang.



Enclose balcony to create additional rentable space

Because of the amount of new construction, this renovation is costly -- estimated at about $150,000. If this were a normal for-profit building, these added costs could be paid for out of additional rents while simultaneously increasing the value of the building -- as illustrated in the Oakland case study. In the case of this church operated building, the comfort of tenants would have to become a larger factor in the economic decision to improve the balconies.

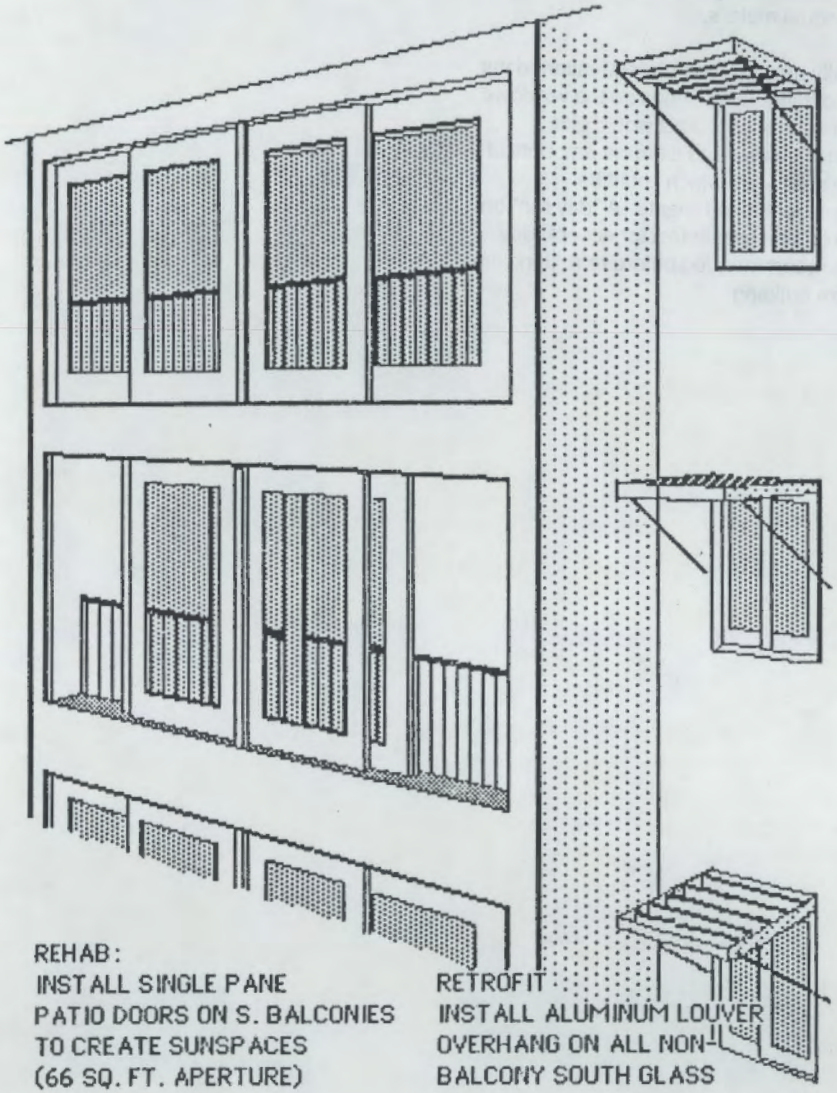
Because of the southwest location of this building, the team spent a great deal of time looking for a passive solar solution that could be added to this building cost effectively. The team considered enclosing the common area patios in a glazed tower at the front of the building that could be used as a solar preheater for corridor air in winter and as a solar chimney to assist ventilation in summer. After extensive analysis, it was decided that the added cost could not be justified against corridor and common area energy savings alone. Although not cost effective in a retrofit or rehab situation, the Team believed the concept definitely merited attention in a new building design.

Rehabilitation Team B

Team B also focused on remodeling existing balconies into living spaces but took a much simpler approach than Team A. This team moved existing glass doors to the front of the balcony and reused existing railings for protection. This approach cost only about $28,000. As shown on a sketch of the proposed solution, the result can be quite attractive even at lower cost.

This team also spent considerable time designing a low cost louver that could be installed to shade all glass on the south face of the building. As shown in the sketch, the team settled on a simple rigid design which could be easily attached to existing window frames. In the opinion of the cost estimators, a rigid design made out of aluminum would be less costly to both build and install than a fabric alternative. The design shown cost only about $125 each including installation. A louvered design was recommended to allow air flow around and up the face of the building so as not to "trap" hot air at the windows.

If the $28,000 estimated cost of the enclosed balconies were added to the cost of the entire package of proposed strategies, it would only increase the payback from 7.2 years to 8.1 years.

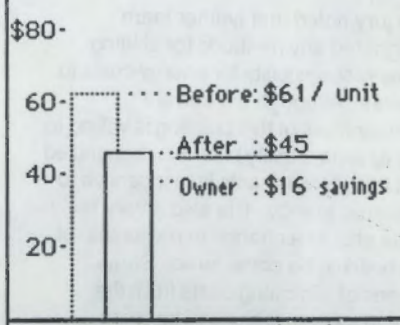


STRATEGIES & COSTS

Envelope:	
- Repeat retrofit strategies	121,280
Infiltration/Exhaust:	
- Repeat retrofit strategies	24,200
HVAC:	
- Repeat retrofit strategies	37,000
Lighting/Appliances:	
- Repeat retrofit strategies	22,400
DHW:	
- Repeat retrofit strategies	2,800
Building and Site Design:	
- Repeat retrofit strategy	7,500
Tenant Education:	
- Repeat retrofit strategy	-0-
TOTAL COST:	$215,180

NOTE: Cost of moving sliding doors to enclose balcony (not to be paid for by energy savings alone) is $28,000

UTILITY BILLS



Monthly Savings: $16/unit

Annual Savings: $30,083

PAYBACK: 7.2 Years

ALBUQUERQUE, NM

Jury Comments

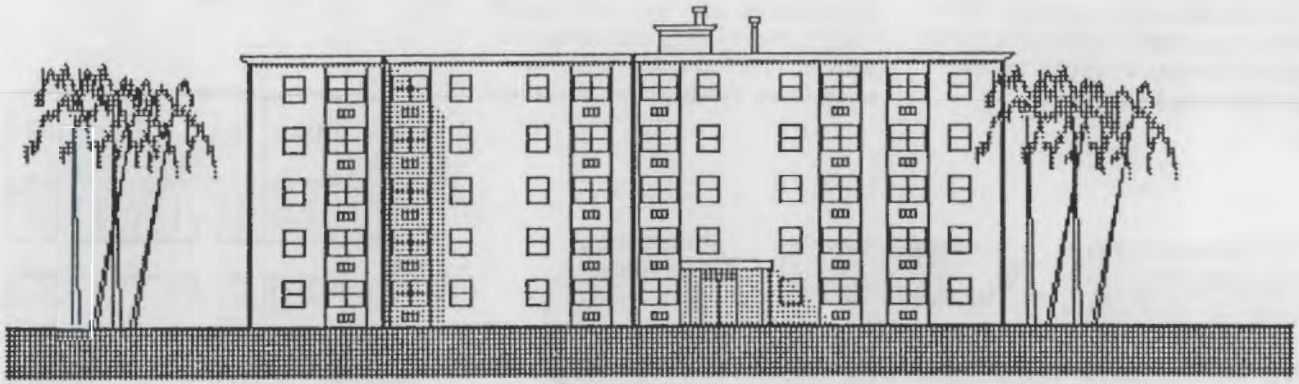
In reviewing the sunrooms proposed by Team A, the jury noted how these spaces would function differently, depending on their location around the building. The sunrooms on the south would truly be "sun" rooms and would benefit from solar heat gains in winter. On the other three sides of the building, these spaces would serve as "buffer zones" and reduce conduction losses.

The jury lamented the lack of Team A's success in finding a passive solar solution for this building but agreed that the only way to get savings sufficient to pay for a renovation of this scale would be to significantly reduce heating and cooling costs in units as well as in common areas.

In reviewing Team B's strategies, the jury questioned whether programmable thermostats would be effective for elderly tenants who tend to occupy their apartments more hours per day (because they are not working).

The jury noted that neither team suggested any methods for shifting some responsibility for energy costs to tenants. Although the current management of this building is willing to pay all tenant utility bills, it is recognized that this gives tenants little incentive to conserve energy. It is also a very likely issue should a change in ownership of the building be considered. Some means of allocating costs from the central system is likely to be more attractive than a complete replacement of the existing system in favor of individual meters.

Finally, one jury member questioned the use of different glazings on the windows of the same unit. This would give different views and different amounts of light in a room, which could be objectionable to tenants. A "day run" on one or two units to test for acceptibility was recommended before retrofitting the entire building.



COOL SOLUTIONS FOR A HOT CLIMATE

This five-story midrise in Miami was planned as elderly housing under the HUD Section 8 Program. Completed in 1979, all 51 units have single bedrooms. Nine units are specially designed for handicapped occupants.

Miami is the warmest and most humid climate in this study. Although the maximum daily temperature almost never goes above 90° F, Miami has more cooling degree days than Phoenix, where temperatures reach into the 100's daily in the summer. Miami has virtually no heating load -- about 200 heating degree days annually -- distinguishing it from all other buildings in the study.

Given the warm climate and high humidity, air conditioning is clearly the leading energy cost in this building. Taking owner and tenant bills together, cooling accounts for over 40 percent of the annual energy bill.

The owner's energy bill is large enough (nearly $12,000 annually) so that energy conservation measures can produce significant savings. Tenant bills total $22,500 collectively or about $36 per unit per month. Although each tenant is responsible for his or her own bill -- based on individual meters -- the bill is subsidized by a "utility allowance" as part of the Section-8 program.

The design teams were able to reduce annual energy bills up to $1,800 by altering building operations (with a 6-month payback) and up to $12,000 per year with a major rehabilitation (with a 6 to 8 year payback).

Because this is Section-8 housing, it is difficult for the owner to alter rents in order to capture a portion of the benefit of lowering tenant energy costs. For this reason, it is questionable how many energy conservation improvements the owner will be willing to finance. If all conservation improvements must be paid for out of owner savings alone, it is likely that the operations strategies for this building will be applied, but less likely that the retrofit and rehabilitation strategies will be done. Paybacks for the more capital intensive changes become too long when based on owner savings alone.

Building Layout

MIAMI, FL

The building is sited to minimize the visual and acoustic impact of I-95 to the east. By having the long east/west axis of the building perpendicular to the highway, only the end wall (which has no windows) faces traffic. Windows are oriented north and south, providing good exposure for units.

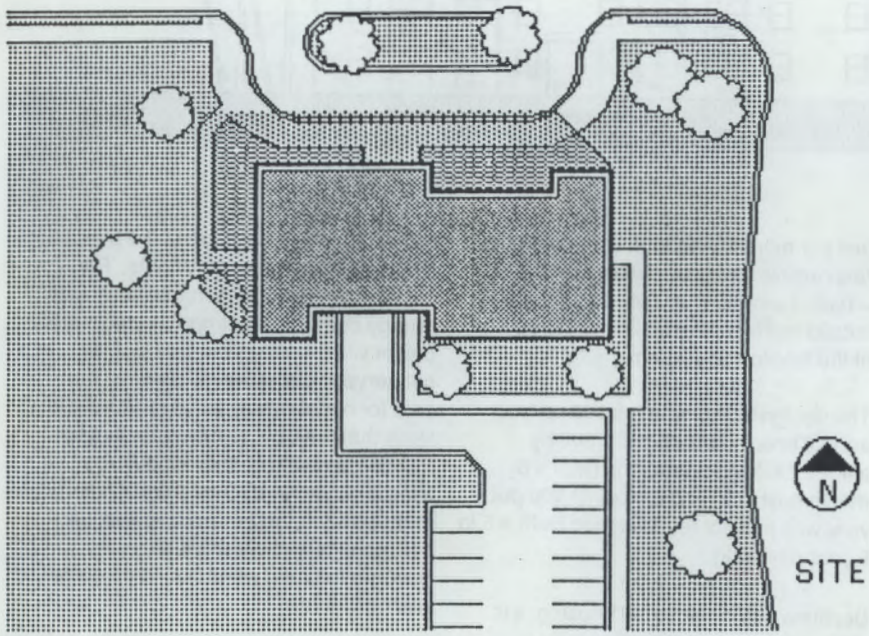
Parking and services are to the rear of the building -- an area that could later be used for expansion if necessary. The front entrance has a covered canopy so residents coming or going by car are protected from the elements.

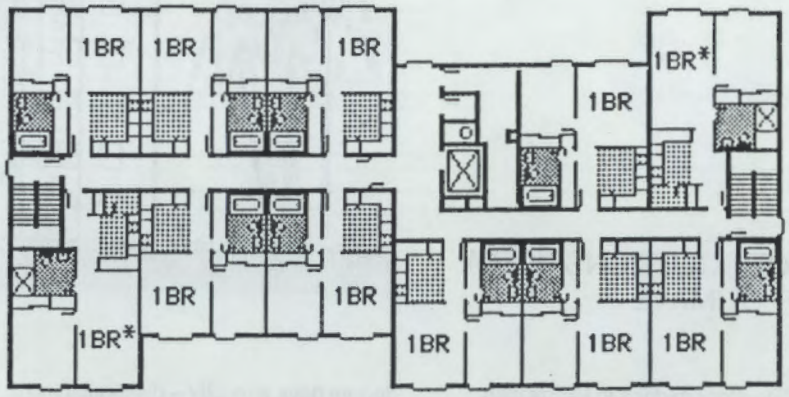
The building itself, which was completed in 1979, is designed specifically for elderly occupants. Of the 51 units in the building, all are one-bedroom. Nine units are designed for handicapped occupants. The building has a compact geometry to minimize corridor lengths from the one centrally located elevator.

As shown on the unit plans, one the next page, handicapped units are 17 percent larger than the other one-bedroom units. The entryway of these units is larger to allow for a five-foot turning radius for wheelchairs. The bathroom and living room spaces also contain more square footage than in standard units. Kitchen and bedroom floor areas are the same as standard units.

Half of the ground floor accommodates the office, lobby, reception area, resident manager's apartment, mechanical room, trash room, and a large community room.

The community room is a very popular space with residents and is estimated to be occupied 16 hours a day. High use of this space and the resulting need for conditioning this space turned out to be more of an energy issue than originally thought by the design teams -- as will be apparent in the strategy recommendations to follow.





*Handicapped Unit

TYPICAL FLOOR

UNIT MIX AND SIZES		
42	One-Bedroom	525 SF
9	Handicapped One-Bedroom	614 SF
51	Units Total	27,576 SF

Building Specifications & Operations

MIAMI, FL

ONE BEDROOM

HANDICAPPED UNIT

This building has masonry bearing walls with precast planks for floors and roof. The exterior treatment is stucco to provide an inexpensive facade. Interior partitions are drywall on metal studs with special attention given to sound treatment between units. Floors are carpeted. Baths have ceramic tile floors.

Heating and cooling are done with individual through-wall direct expansion (DX) air conditioning units with electric resistance heating. Existing equipment is not especially energy conserving with an assumed EER of 7.3. Corridors are neither heated nor cooled but do have continuous ventilation with outside air. Although the lobby is not heated or cooled, it is presumed, based on inspection, that the lobby, office, and much of the connecting corridor are cooled off of the community room which is served by four through-wall DX/resistance units.

Domestic hot water is supplied from a central system with gas boilers. There are also two gas dryers in the laundry.

BUILDING SPECS

ENVELOPE:

- Exterior Wall
  1/2" stucco on 8" regular CMU, 1-1/2" Z furring with 1-1/2" batt insulation, 5/8" gypsum board
- Window
  Aluminum frame with insulated glass U=0.57; shading coefficient = 0.64 with blinds
- Roof
  Ballasted built-up roofing, over 2" expanded polystyrene, on 6" concrete deck with sprayed interior finish.

INTERNAL LOADS

- Lights: 0.5 Watts/s.f.
- Appliances: 0.4 Watts/s.f.
- Cooking: 6000 Btu/day (40% latent)
- Infiltration: 0.6 Air Change/hr.(lobby, 0.8 ACH; corridors, 0.5 ACH)

OTHER LOADS:

- Lighting in common areas: corridors, 0.7 W/s.f.
  lobby, 2.7 W/s.f.
  community room, 2.7 W/s.f., 16hrs./day
- Elevator: 10 kW
- Exterior Lighting: 1350W, HPS; 400W, incandescent; 10hrs./day

VENTILATION/EXHAUST:

- 70 cfm bath exhaust and 100 cfm range fan, both individually switched
- Lobby, 2700 cfm; corridors, 400 cfm/floor; continuous
- Community room, 540 cfm, 16 hrs./day

SYSTEM SPECS

HVAC

Individual thru-the-wall DX AC units with electric resistance heating (EER=7.3 cooling)
4 units in community room

TEMPERATURE SETPOINTS

Heating: 72°F
Cooling: 76°F
No heating/cooling provided in corridors or lobby

DOMESTIC HOT WATER

Central gas boilers;
120°F water storage;
25 gal/unit/day domestic use;
10 gal/unit/day laundry;
70% nominal system efficiency

Energy Analysis

The Miami climate is interesting because of the way it is warm. Miami does not have exceptionally high daily temperatures (Phoenix is consistently much warmer in summer), but instead has warm temperatures for many hours of each day and for many days of the year. These consistently warm temperatures add up to over 4,000 cooling degree days per year -- the highest for any climate in this study.

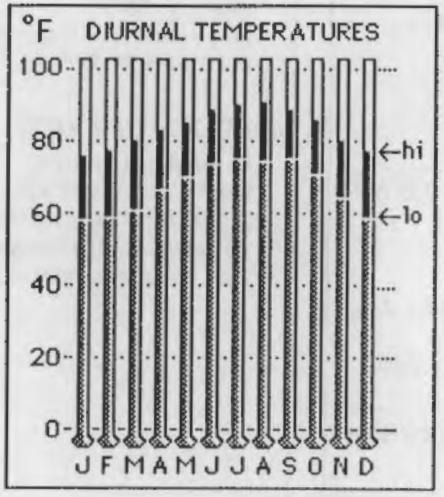
In addition to warm temperatures, Miami also has consistently high relative humidity. With high humidity and warm nighttime, there are many hours per year when mechanical cooling is the only way to achieve occupant comfort. It is not suprising, therefore, that cooling is the largest single energy cost in this building -- about 40 percent of the total energy bill.

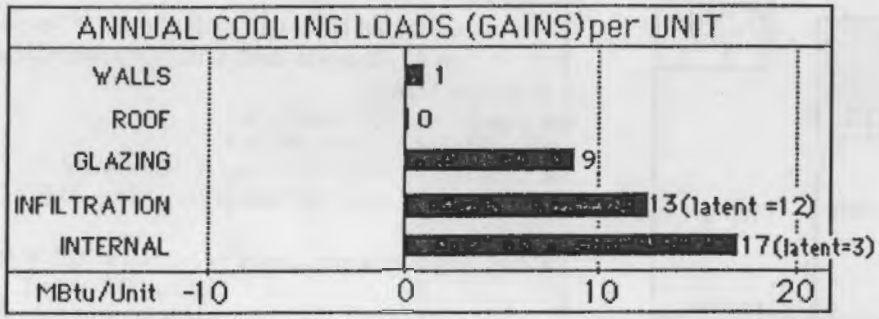
As shown on the bar chart of cooling loads below, internal heat gains, and latent heat gains from infiltration and cooking are the largest single contributor to cooling loads, followed closely by gains from infiltration and glazing. In northern climates, these gains are typically a benefit, offsetting heat losses. In this climate, however, the opposite is true. Because there is so little heating required in this building, internal loads only add to cooling costs.

When the sun climbs high in the summer sky, it is virtually directly overhead -- so that diffuse solar radiation is nearly equal on the north and south sides of the building. In this situation, shading is designed to block direct sunlight (overhangs, etc.) is typically less effective than window films (which can shade out both direct and diffuse radiation).

Because this building is occupied entirely by the elderly, additional energy issues had to be considered. For example, kitchen use is significantly less than in family- type apartments. A local community program picks up most of the tenants daily and takes them to a nearby center for lunch. For most tenants, this is the principal meal of the day and little additional cooking is done in the units.

The summer sun is so high that diffuse/reflected light is a problem on all sides of the building





The total energy bill for this building is about $56 per unit per month or about $34,000 per year. Of this, the owner pays about one-third or $12,000 per year. Tenant's bills range from $30 to $40 per unit per month and are subsidized by HUD.

An example of the interaction between utility bills and subsidies in Section-8 housing is illustrated below (based on average numbers for the Florida Region). By HUD standards, the tenant's contribution toward rent plus an allowance for utility costs typically should not exceed 30 percent of the tenant's adjusted gross income (in our example 30 percent of $550 per month or $165 per month).

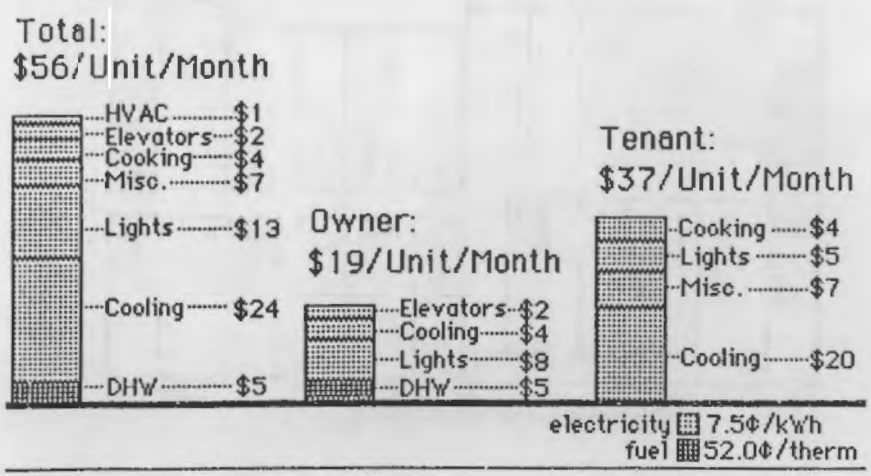
The utility allowance is computed once, typically before the building is occupied. The tenant contribution is computed when he or she qualifies for a subsidized unit. The tenant is responsible to pay the tenant contribution to the owner and to pay the actual utility bill -- whether or not the actual bill matches the "utility allowance" (or credit) which has been computed for the unit.

From the owner's perspective, a "market rent" based on typical rents in the area must be computed and then approved by HUD ($335 per month in our example). The tenant contribution ($128) is subtracted from this figure, and the balance of the market rent ($207) is paid by HUD as a subsidy.

Now, what happens if energy conservation reduces the monthly utility bill? In actual fact, the "utility allowance" is seldom recalculated. So, a reduction in utility bills actually increases the tenant's net income. A good incentive for tenants but little incentive for either HUD or the owner -- the two most likely sources of capital to make energy conserving improvements to the building.

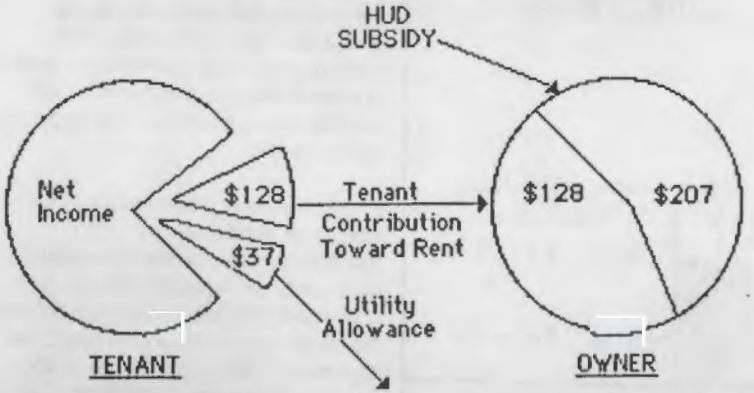
If the utility allowance were adjusted to a new lower figure based on lower actual utility bills, the tenant contribution would have to be increased so the total would again equal 30 percent of adjusted income. The increased tenant contribution would decrease HUD's subsidy. In this case a major incentive for energy conservation is removed from tenants and shifted to HUD. However, this still gives the building owner little incentive to invest in energy conservation improvements for tenants.

Miami Midrise Utility costs



UTILITY COSTS & SUBSIDIES IN SECTION 8 HOUSING

An Example Using Average Figures For The Florida Region



Gross Income = $750/mo.
Adj. Income = $550/mo.
30% of Adj. Inc. = $165/mo.

Utility Company $37/mo.

Typical Market Rent For 1-Br. Unit is $335/mo.

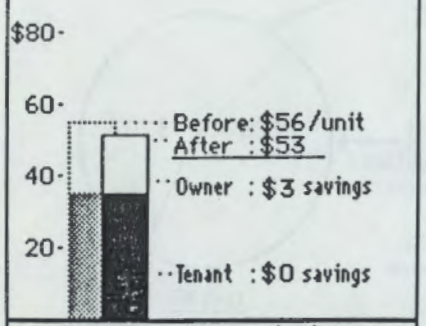
Operations Team A

MIAMI, FL

In terms of operating strategies, Team A focused on reducing the owner's utility bills. Lighting, being the largest owner cost, received the greatest attention. Since all stairwell landings have a window, they should be lit only at night. The design team recommended installing photocell controls -- one for each bank of stairwell lights.

STRATEGIES & COSTS	
Infiltration/Exhaust:	
- Use automatic door closers	-0-
HVAC:	
- Add timer to cut corridor ventilation	165
Lighting/Appliances:	
- Add one photocell on stairwell lights	200
- Add time clock to half corridor lights	350
- Replace hall and lobby lights with screw-in fluorescents	170
Training:	
- Conduct tenant education program on using HVAC units for ventilation only	-0-
TOTAL COST:	$885

UTILITY BILLS



Monthly Savings: $3/ unit

Annual Savings: $1,799

PAYBACK: 6 Months

The team also recommended reducing lamps in the corridors by one-half and installing a time clock to turn off half of the remaining corridor lights during sleeping hours (six to eight hours per night). Screw-in fluorescent lights were recommended for all lobby and corridor lights which had not already been converted to fluorescent fixtures.

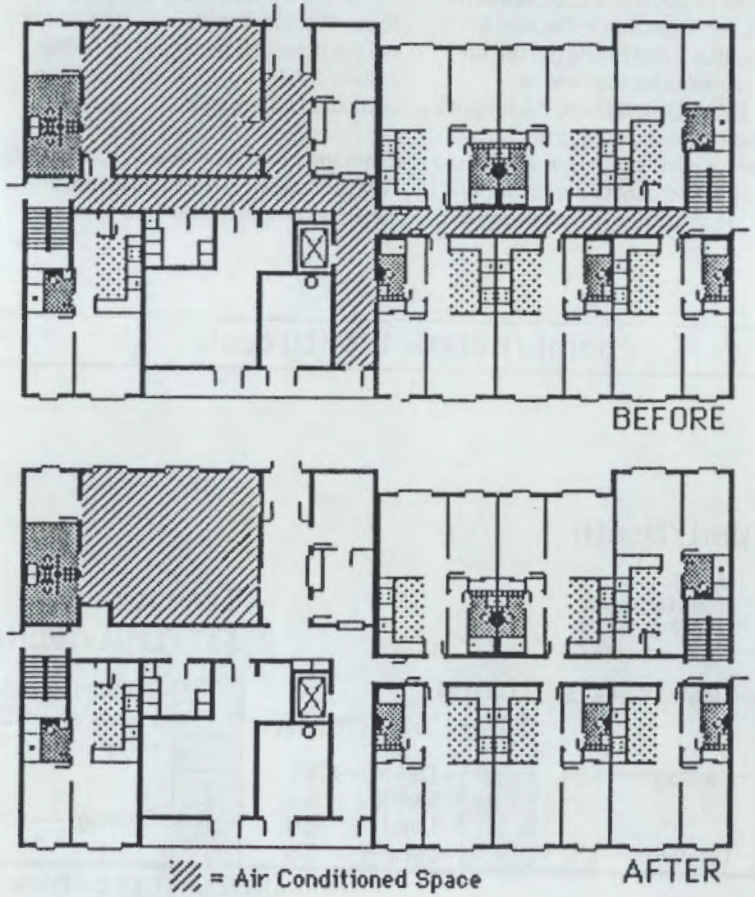
Three strategies were recommended for reducing cooling costs. First, the team recommended installing an automatic time clock to cut off corridor ventilation completely between 10 PM and 6 AM. Given the reduced amount of cooking done by the elderly population of the building, it is extremely unlikely that cooking odors would be a problem during this period.

Second, the team recommended that a tenant education program be conducted to instruct tenants to operate HVAC controls on "fan only" settings to exhaust internal heat gains during appropriate times of the day. This ventilation strategy could extend periods of natural ventilation and reduce the number of hours tenants may be cooling unnecessarily.

Finally, the team recommended that special effort be made by management to see that doors to the community room remain closed. As shown in the diagrams below, if doors to the community room are left open, the community room cools the lobby and corridors for the entire first floor. The team recommended a simple sign saying "Please Keep Door Closed At All Times" to encourage residents to keep the door closed. Glass doors could be installed between the community room and lobby to allow monitoring from the office without leaving the door open.

Total cost of this strategy set, excluding glass doors, is a modest $885, which would be paid back in energy savings in 6 months or less.

The owner's cooling bill can be cut by installing door closers which isolate the community room from the unconditioned corridors



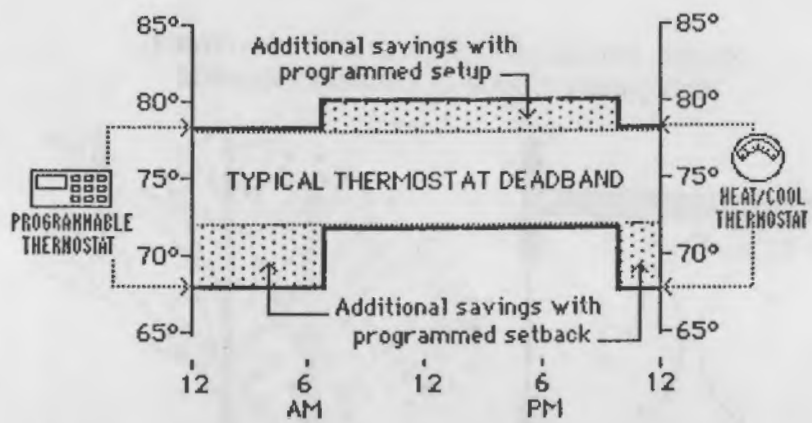
Team B took a similar approach in reducing lighting costs. Team B recommended photocell control in the stairwells and felt that such controls would also be of benefit in the lobby and community room, since both have abundant natural light much of the day. Rather than "disabling" one-half of the corridor lights, Team B suggested replacing existing 96-watt fixtures with new high efficiency "U tube" fixtures at 52 watts. As exterior lighting is already efficient high pressure sodium with photocell control, it was judged that little could be done to cut energy costs further.

The largest cost item recommended by Team B was the caulking of all windows by those specially trained in the procedures necessary to get a tight seal. The team believed that reducing infiltration would significantly reduce energy costs -- given that infiltration is the second highest cause of cooling loads. The team agreed that it would be important to ventilate apartment units whenever the climate permitted natural ventilation to reduce air conditioning costs whenever possible.

The team also suggested two improvements to the community room. First, it was assumed that exhaust fans in the community room toilets were often left running for long periods simply by inattention. An inexpensive timer switch was recommended to see that the fans shut off automatically, thus preventing the continuous exhausting of conditioned air from the space.

Second, the team recommended the installation of a programmable thermostat. As shown in the diagram below, a programmable thermostat makes it possible to have different temperature settings for several different times of the day. For example, in summer, the room can be cooled to 76° F during occupied hours, but allowed to rise to 80° F during unoccupied hours. The programmable thermostat insures that these settings will be adjusted automatically and not "forgotten" by either management or tenants.

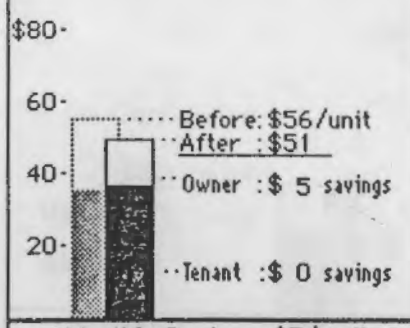
Given the added costs of caulking and new high-efficiency lighting fixtures, this strategy set is significantly higher than the Team A option -- costing just over $9,000. However, estimated savings in the owner's bill of some $3,000 per year give the package an attractive payback of only 3 years.



Programmable thermostats save energy by varying indoor temperature to meet user needs

STRATEGIES & COSTS	
Infiltration/Exhaust:	
- Caulk all windows	$5,500
- Utilize automatic door closers on community room	-0-
- Add timer fan control for community room toilets	100
HVAC:	
- Add programmable thermostat in community room	350
Lighting/Appliances:	
- Add photocell controls in community room, lobby, and stairwell	400
- Add fluorescent screw-in lights	216
- Install high efficiency lamps and ballasts in all common areas	2,500
TOTAL COST:	$9,146

UTILITY BILLS



Monthly Savings: $5/ unit

Annual Savings: $2,748

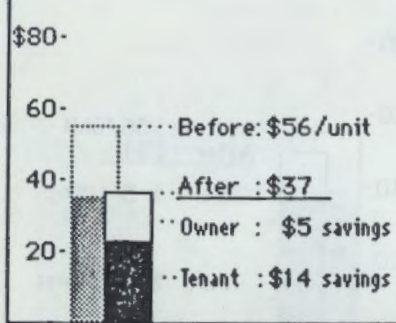
PAYBACK: 3.3 Years

Retrofit Team A

MIAMI, FL

STRATEGIES & COSTS	
Infiltration/Exhaudt:	
- Repeat Operations Strategies	-0-
- Install ceiling fans in all living rooms and bedrooms	12,500
HVAC:	
- Repeat Operations Strategies	165
- Replace apartment and community room DX units with higher efficiency models	6,264
Lighting/Appliances:	
- Repeat Operations Strategies	720
- Replace refrigerators with high efficiency models	5,000
DHW:	
- Add 840 s.f. solar DHW system	18,000
Building and Site:	
- Add landscaping on south	3,500
- Add solar film to windows	12,000
Trainin	
- Repeat Operations Strategies	-0-
TOTAL COST:	$58,149

UTILITY BILLS



Monthly Savings: $19/unit

Annual Savings: $11,573

PAYBACK: 5 Years

When considering retrofit alternatives, Team A proposed a broad set of strategies to improve tenant comfort while reducing cooling bills. This set of strategies consists of four elements.

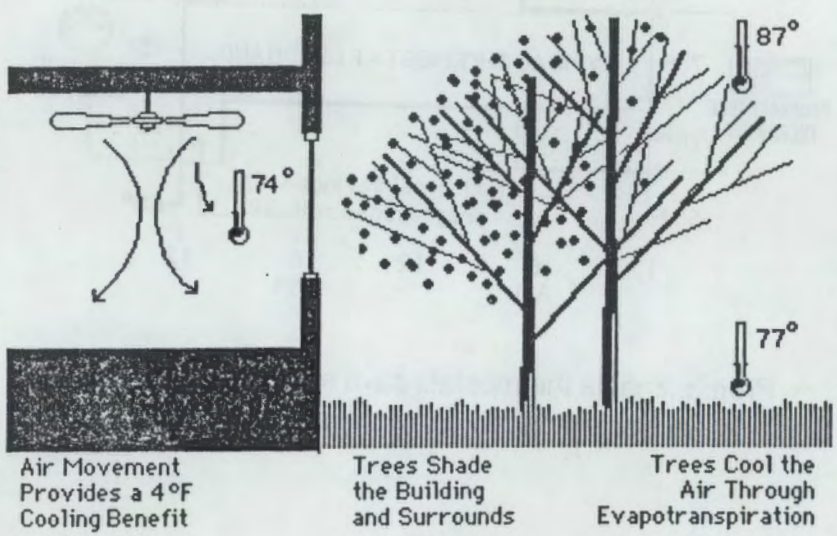
First, ceiling fans are recommended for all living rooms and bedrooms. Increasing air movement makes a room "feel" about 4° F cooler.

Second, as shown in the diagram below, trees are planted near the building for shade and to add additional cooling by the evapotranspiration of water from their leaves. It is estimated that the shaded area under trees can be 7°--9° F cooler than the ambient temperature.

Third, the team recommended installing solar films on all windows to reduce solar heat gains in the units. As explained in the energy section, Miami is so far south that solar films are the most effective option for blocking diffuse light.

Finally, the team recommended installing higher efficiency AC units at replacement. Equipment which is now available is significantly better than those with an EER of 7.3 installed in 1979.

Shade, natural ventilation, and air movement can greatly reduce air conditioning loads



To reduce miscellaneous costs, second highest for tenants, the team recommended installing high efficiency refrigerators at the time of the next normal replacement. The only cost is the slightly higher incremental cost of the equipment over less efficient models.

Finally, the team suggested the addition of a solar "pre-heater" to reduce the owner's hot water costs. It is estimated that the heater would reduce DHW costs by $600 to $1,000 per year. At an estimated cost of $18,000, the investment would not be at all practical. However, the team believed that a lower cost system using cheaper materials should be possible. The concept was left in the package at the estimated cost pending further analysis.

Even with the solar system, the package, at an overall cost of $58,000, can achieve a reasonable 5-year payback based on energy savings for the total building (owner plus tenant savings of $11,500 per year). However, owner savings alone are only about $3,000 per year, which would give an unattractive 18-year payback on the total investment. If the owner is to finance a package of improvements which would significantly improve tenant comfort while reducing tenant energy costs, further owner incentives will be required beyond what is possible under HUD's current methods of accounting for energy cost savings.

Retrofit Team B

MIAMI, FL

Team B focused on a balanced approach between savings for the owner and for the tenant. The team repeated most of their operations strategies. In the area of lighting, they installed higher efficiency fixtures in the lobby and canopy.

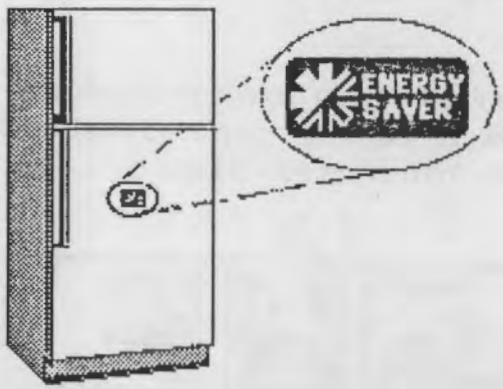
To reduce tenant heating and cooling bills, Team B recommended installing programmable thermostats in all units. As explained in their recommendation of this strategy for the community room, these improved thermostats will provide a closer match between tenant needs and HVAC setpoints. Allowing temperatures to vary more widely, when tenants are not in or at night, offers significant energy savings.

Team B, also recommended planting additional trees to reduce ambient temperatures around the building. Team B was more specific than Team A, however. They recommended at least six Royal Poinciana trees. These trees were selected not only because they are fast-growing, but also because they grow to a height of 40 feet -- offering coverage for most of the five-story building. Their dense fernlike leaves and wide branching structure increase shading and therefore benefit cooling in summer.

To reduce owner's bills, the team focused on reducing water heating costs. The team recommended installing low-flow shower heads in all units as part of the normal maintenance and repair process at the time of turn-over. The team also recommended reducing the temperature at the main storage tanks to 115° F and adding insulating jackets to the tanks. High efficiency laundry equipment should be installed at the time of normal replacement.

As with Team A, this team also recommended the installation of more efficient refrigerators at the time of replacement. Team B also recommended downsizing to 8 cubic foot units. This smaller size would surely meet the needs of the elderly tenants, given their reduced cooking requirements, and would reduce miscellaneous electric loads.

Team B's approach cost only $23,000, with estimated annual savings of total building energy costs of nearly $9,000 per year, yielding a 2 to 6 year payback. Even though owner savings are only about $5,000 per year, the owner could still pay for the entire package of improvements in less than 5 years.

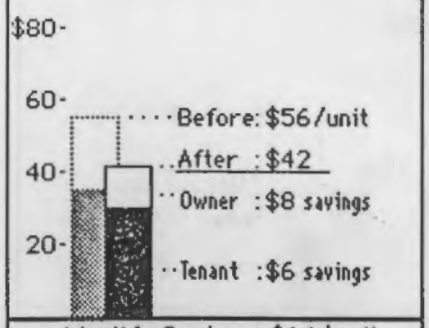


The team recommended installation of high efficiency, smaller-sized refrigerators, but no high efficiency ranges because the elderly tenants make minimal use of their kitchens

STRATEGIES & COSTS

Infiltration/Exhaust:	
- Repeat Operations Strategies	$5,680
HVAC:	
- Repeat Operations Strategies	350
- Add programmable thermostats in all units	6,400
Lighting/Appliances:	
- Repeat Operations Strategies	616
- Install high efficiency fixtures in lobby and canopy	600
- Install high efficiency refrigerators and downsize to 8 cubic foot in all on replacement	5,000
DHW	
- Install low flow shower heads	750
- Install high efficiency laundry equipment at replacement	-0-
- Reduce storage temperature to 115°F	-0-
- Insulate central storage	250
Building and Site Design:	
- Plant six Royal Poinciana trees on south side	3,500
TOTAL COST:	$23,146

UTILITY BILLS



Monthly Savings: $14/unit

Annual Savings: $8,801

PAYBACK: 2.6 Years

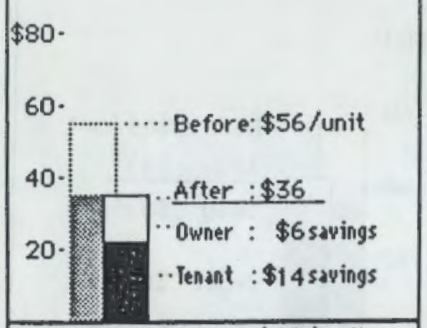
Rehabilitation Team A

MIAMI, FL

STRATEGIES & COSTS	
Infiltration/Exhaust:	
- Repeat Retrofit Strategies	12,500
HVAC:	
- Repeat Retrofit Strategies	6,614
Lighting/Appliances:	
- Repeat Retrofit Strategies	5,720
DHW:	
- Repeat Retrofit Strategies	18,000
Building and Site:	
- Delete solar film on windows	-0-
- Add landscaping (as previously)	3,500
- Add awnings on north and south sides of building	30,000
Training:	
- Repeat Retrofit Strategies	-0-
TOTAL COST:	$76,334

Note: Added "Florida Rooms" (not paid for with energy savings alone) $115,000

UTILITY BILLS



Monthly Savings: $20/unit

Annual Savings: $12,014

PAYBACK: 6.4 Years

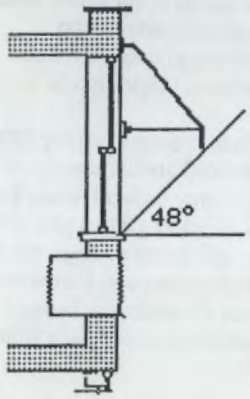
Team A repeated all of its retrofit strategies in the rehabilitation set, with one important exception. Instead of applying solar film to the tenant windows, the team recommended adding awnings on the north and south sides of the building. Although not as effective as solar film, the team recommended an awning to be installed low on the existing windows and one that is designed in such a way that the overhang prevents direct sunlight from entering units during the warm months and blocks a significant amount of diffuse sunlight as well. The awnings are made of fabric on a tubular frame to keep costs down. However, the choice of colorful fabrics could make a significant design statement for the building. The design team felt that the low awning could be nearly as effective as film in blocking diffuse radiation from much of the sky dome, but would still allow the use of clear glass in the windows which would likely be more acceptable to tenants.

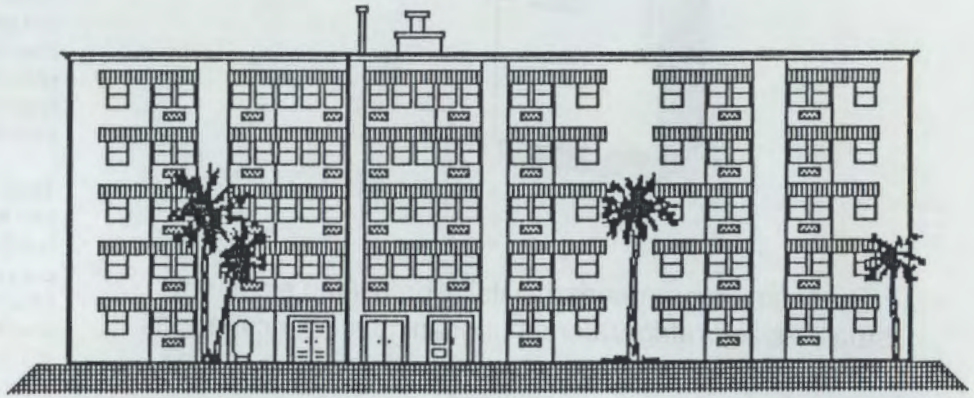
Team A also "filled in the notch" on the north and south side of the building (next to the handicapped units) to create a new "Florida Room" or enclosed balcony off of four of the one-bedroom units on each floor. This enclosed porch would not only be an attractive usable space, but would provide a temperate buffer zone with lots of shading between the units and the outside.

Cost of the package (excluding the balconies) is $76,334. Awnings are roughly twice as expensive as the solar film option. The 18 Florida Rooms can be added for additional $115,000 or a relatively modest $6,400 each. It should be noted that the addition of the Florida Rooms is likely only if the building is taken out of the Section-8 program at some point in the future. In that case, increased rents could be used to pay for the new spaces.

The energy package reduced tenant bills by some $235 each per year and would reduce owner bills by over $3,000 per year (not counting tax advantages from improving the building) yielding a payback of just over 6 years.

Enclosed "Florida Rooms" increase the rentable square footage with energy conserving buffer spaces which are easily ventilated. Window awnings placed on all apartment windows act like a cowl, shading the windows from direct sunlight and diffuse sky brightness





Team A Rehabilitation South Elevation

Rehabilitation Team B

MIAMI, FL

Team B also proposed creating a balcony in the "notch" of the building on the north and south sides, chosing a simple design and not enclosing the balcony. Total cost of the balconies is estimated to be $58,000 or about $3,500 each. As shown in the box below, a very modest rent increase of $0.25 per square foot of balcony ($27.50 per unit) per month would cover the cost of the improvement. The tenants would benefit by reduced energy costs and the owner would gain some modest tax advantages through increased depreciation.

Team B also took a different approach to shading. They used solar film only on the north side of the building to block diffuse light. On the south side of the building, they designed a low cost aluminum louvered sunscreen. This solution proved less costly than the fabric awnings and has the potential of being more durable.

Team B recommended installing ceiling fans in the living rooms of all units and three fans in the community room. They also recommended installing new high-efficiency HVAC units at the time of replacement -- recommending an EER of at least 11.0.

Cost of this package of improvements is about $100,000, excluding the solar system. Assuming that the balconies could pay for themselves with increased rents, the real cost of this package is only about $43,000, yielding a payback of 3.5 years. Estimated owner savings alone of $5,700 per year could pay for the package in just 7-1/2 years.

Balconies off of the public corridors and apartments add amenity value to the whole building while shading the glass. Aluminum louvered sunscreens provide low cost shading devices which stop direct sunlight, but allow much of the diffuse radiation into the building

STRATEGIES & COSTS

Infiltration/Exhaust:	
- Repeat Retrofit Strategies	$5,680
HVAC:	
- Add programmable thermostat in community room only	350
- Modify existing mechanical systems in all units	10,314
- Install 48" ceiling fans to all living rooms and three to community room	7600
Lighting/Appliances:	
- Repeat Retrofit Strategies	6,216
DHW:	
- Repeat Retrofit Strategies	1,000
Building and Site Design:	
- Add reflective film on north glass	900
- Plant six Royal Poinciana trees	3,500
- Add balconies on each floor	58,000
- Add 2 feet exterior louvered aluminum sunscreens on 19 south-side units	3,250
TOTAL COST:	$42,810

ECONOMICS OF A NEW BALCONY

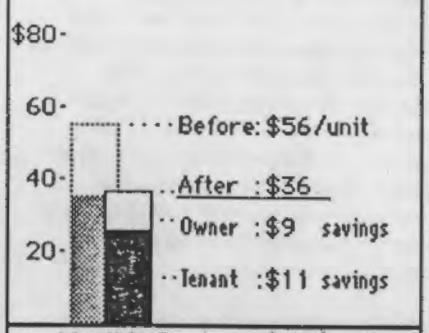
New Balcony Area	110 sf
Rehab Cost (at $30/sq.ft.)	$3,300/unit
Increased Rent (at $27.50/mo.)	$ 330/yr
Capitalize Rent (at 10%)	$3,300

Conclusion: Rehab balconies can pay for themselves with reasonable increase in rent.

Plus: Reduced Energy Cost to Tenants

Plus: Tax Benefit of Depreciation on Balcony to Owner, $40/balcony/yr

UTILITY BILLS



Monthly Savings: $20/unit

Annual Savings: $12,417

PAYBACK: 3.5 Years

Team B Rebailitation South Elevation

MIAMI, FL

Jury Comments

For Team A, the jury expressed concern about the plan to reduce corridor lighting in the operations strategy set. Although the jury agreed that light levels were currently too high, care should be taken not to reduce light so much that the corridors "look dingy and feel unsafe."

One jury member offered that the use of solar film might have an additional benefit not mentioned by the team. To the extent that tinted film would reduce the contrast between the brilliant window and the darker wall (as seen from inside the units) it could improve visual comfort for occupants.

The jury questioned whether Team A could really get a solar collector for $21 per square foot in the retrofit set. The jury believed that the search for a low cost solar system merited attention but felt that the teams had not yet found one.

In reviewing the "Florida Rooms," the jury felt that the final design selected by the owner would reflect far more what the market wanted than what was optimal from an energy point of view. For example, an enclosed balcony would probably be more attractive to elderly tenants, but they would also be likely to cool it -- thus negating some of the energy credits claimed. If used properly, though, the rooms could be a very attractive improvement.

The jury pointed out that neither team had proposed using vertical fine-mesh solar screens. These products are available and do block diffuse radiation. An analysis of possible design solutions and comparative costs merits attention.

Turning to Team B, the jury noted that the use of a photocell control, a dimming system, in the community room would be more acceptable to occupants, but would likely be more costly to install than an "on/off" system.

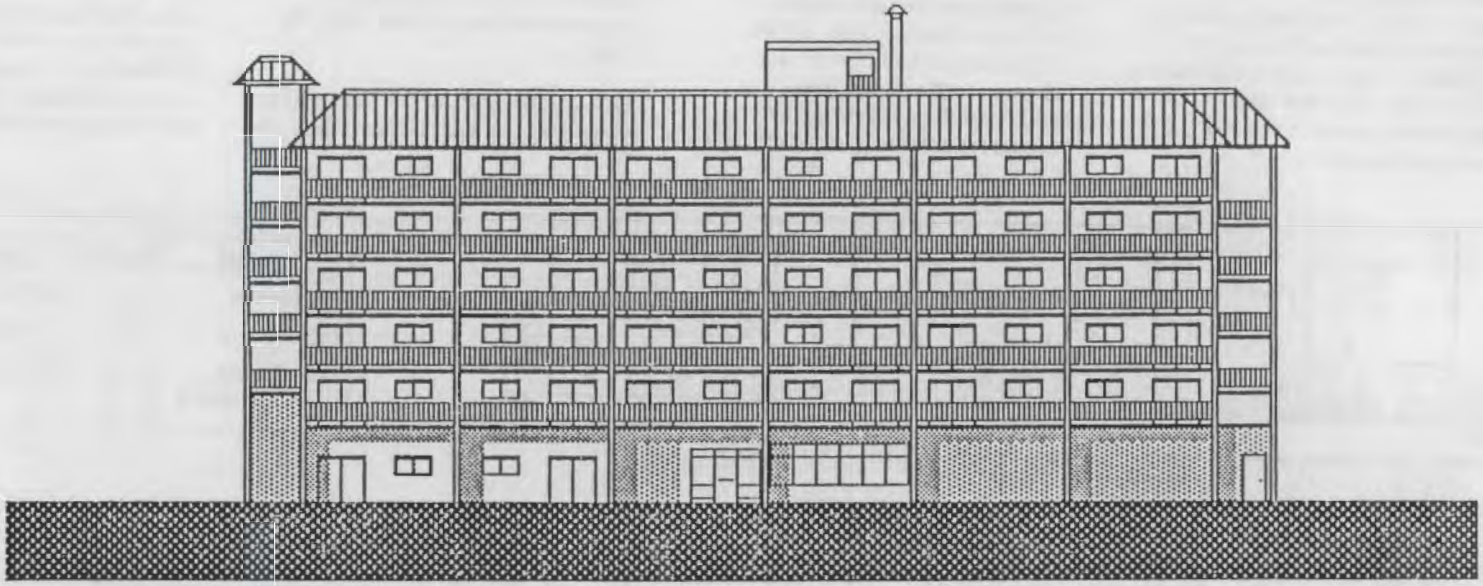
Team B reported that they had investigated the possibility of going to individual hot water heaters for all units and found it to be a complex issue. Although the cost of the conversion would significantly reduce owner bills (by transferring them to tenants), the overall payback based on energy savings would be over 25 years. If the building is ever removed from the Section-8 program, this would be a likely strategy for a new owner to consider.

The jury commended Team B for their strong effort in finding a low cost exterior shade. Based on the designs presented, it appears possible that a durable shade could be installed for less than it would cost to apply window films. This definitely merits further analysis to see if estimated costs can be achieved.

The jury recognized the logic of different window treatments on the north and south of the building but wondered whether or not this would be acceptable to owners and tenants.

The jury concluded with a discussion of landscaping as a means to lower ambient air temperature next to the building. One concept suggested was moving parking further south, away from the building, to allow for more lawn and landscaping next to the building. Another suggestion proposed covering parking spaces with an arbor giving tenants cooler cars while also shading the paved parking area.

Oakland Midrise



Energy costs in this 1979, six-story building in Oakland are the lowest of any building in the study. The combination of an extremely mild climate and below average energy costs give both the owner and tenants an average energy bill of just over $20 per unit per month each.

The building is designed for elderly occupancy. All seventy-seven units are either efficiency or one-bedroom types. There are five units specially designed for handicapped occupants.

Tenants pay their own utility costs which are metered individually. The owner provides all hot water for apartments and laundries. No cooling is required in the building.

The building is unusual for the large amount of community space provided tenants. In addition to a large social hall on the first floor, each floor has a community or "TV" room. Higher than average rents in this building represent a way of paying for this added space.

Because the climate is so mild and energy costs are so low, it is difficult to achieve dramatic energy improvements cost effectively. Proposed operations strategies focus on improved setback thermostats and lowering hot water costs. One innovative retrofit strategy proposes shifting DHW costs from the owner to tenants through the use of remote flow meters. Both rehabilitation strategies focus on enclosing part of existing balconies in order to enlarge living rooms.

The modest energy proposals for this building have good paybacks of about one year, though one strategy set goes as high as four years. The proposal to improve balconies actually adds value to the building while modestly improving energy performance.

Building Layout

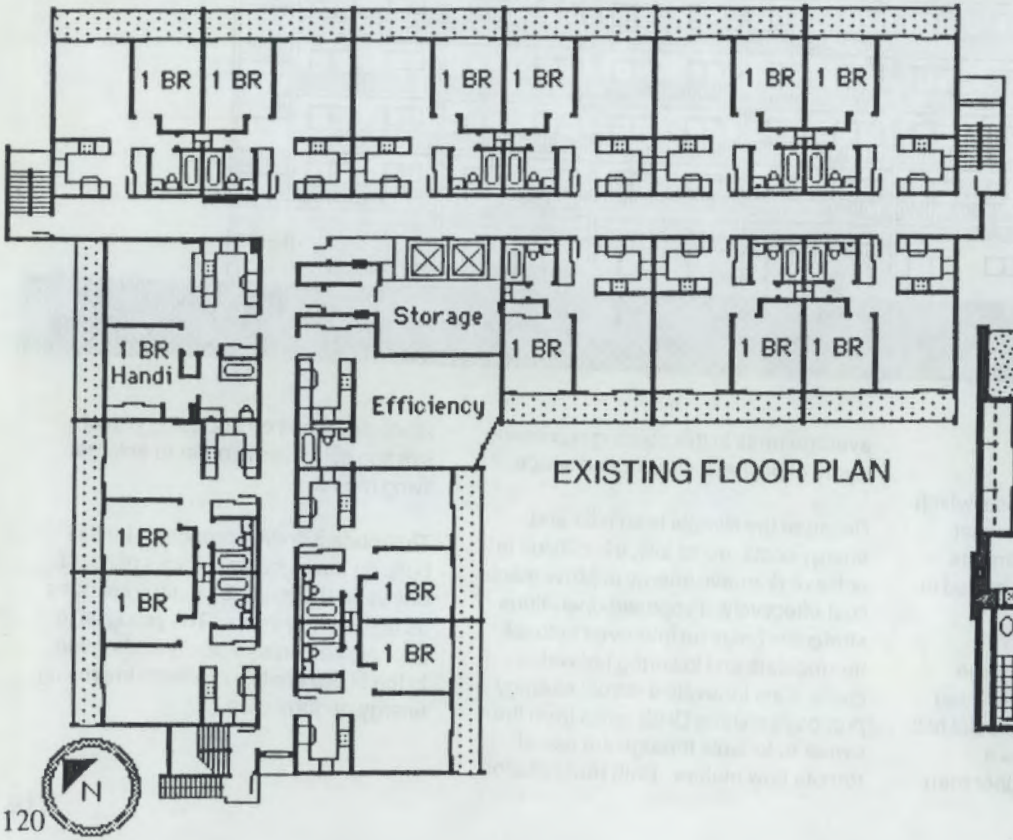
A typical floor in this L-shaped building has fifteen units laid out along two intersecting double loaded corridors. There are five residential floors, as shown on the typical floor plan below, and the ground floor which is approximately half parking (nineteen spaces) and half common areas including: a large social hall (25 feet by 40 feet) with an adjoining kitchen, a large lobby, laundry, office, and the manager's apartment.

As indicated by the unit mix table below, this building was designed specifically for elderly housing. All units are either one-bedrooms or efficiencies. Five of the 77 units in the building are designed for handicapped access. Careful comparison of the typical and handicapped units,shown at right, illustrates important differences between the two units. The handicapped unit is five feet wider than the typical unit which allows for a larger kitchen floor, a wider entry, a larger bath, and direct access form the bedroom to the bathroom.

The building is designed so that only three units per floor face south. In this situation, it is difficult to seek any passive solar design options for this building.

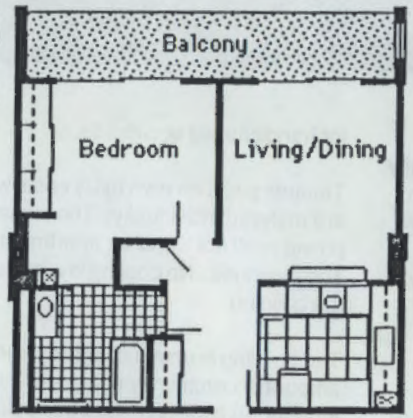
An unusual feature of this building is a community room or "TV room" on each floor -- at the intersection of the two corridors. All heating and lights are provided to these rooms by the owner. With the exception of one efficiency unit per floor, all units have balconies.

With a net rentable area of about 47,000 square feet and a gross of about 70,000 square feet, the net-to-gross ratio for this building is about 67% -- a little below average, reflecting the large amount of common space in the building.

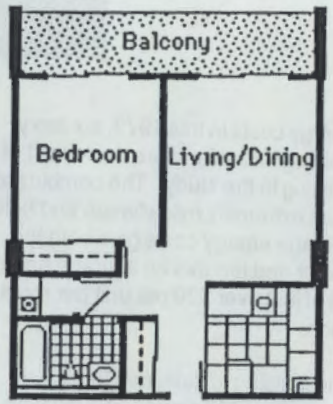


EXISTING FLOOR PLAN

MIX OF UNIT TYPES			
Type	Tot.	Mix	Size
Efficiency	5	6%	593 SF
1-Bedroom	67	88%	604 SF
1-Bedroom Handicapped	5	6%	753 SF



HANDICAPPED UNIT



ONE BEDROOM UNIT

Building Specifications & Operations

OAKLAND, CA

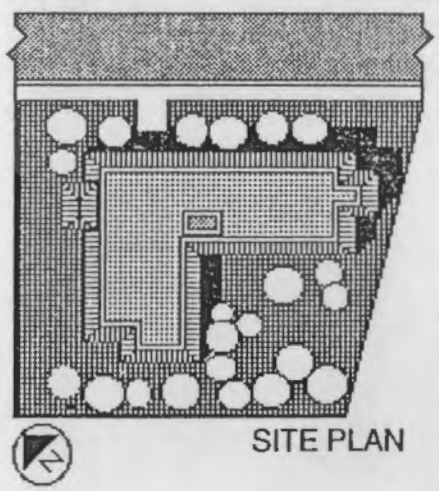
Built in 1979, this building shows an interesting mix of energy conserving features and common sense equipment selecton. For example, the walls are well insulated with R-11 batt insulation and the roof has both 3-1/2 inches of expanded polystyrene insulation and light weight insulating concrete. One may be surprised, however, to see single pane glass and all-electric resistance heating. Upon reflection, these lower first cost alternatives make perfectly good sense. The extremely mild Oakland climate cannot justify very costly HVAC equipment.

Given the fact of single-glazed sliding windows and the number of years since construction, the design teams assumed that air infiltration in the apartment units must be at least 0.7 air changes per hour -- somewhat higher than current practice but still well below many of the older buildings in the study. The lobby has a higher infiltration rate (1.0 ACH) because of its multiple entrances.

Tenants pay for their own heating and lighting costs via individual electric meters. No cooling is provided for the building as none appears to be required. The owner provides all domestic hot water for the units and the central laundry from a central boiler (boiler efficiency equals 80%; nominal system efficiency equals 70%; and estimated seasonal efficiency equals 63%). Lighting and appliance loads are average. Incandescent lights are used in most common areas.

A separate ventilation system serves the corridors, lobby, and TV rooms. It has a gas-fired rooftop unit for heating only. The system supplies 3,500 CFM of 100% outside air, 75% of which goes to the corridors.

Although individual metering provides incentives for tenants to conserve, the units are not equipped with automatic setback thermostats.



SITE PLAN

BUILDING SPECS

ENVELOPE:

- Exterior Wall
  7/8" cement plaster, 3-5/8" metal studs @ 24" o.c. with R-11 batt insulation. 5/8" gypsum board
- Window
  Aluminum frame, single-pane, sliding and fixed units
  U=1.42; shading coefficient = 0.64 with blinds
- Roof
  Ballasted built up roofing, 3-1/2" expanded polystyrene, 5" light weight insulating concrete, 7-1/2" concrete roof slab acoustic spray finish on interior

INTERNAL LOADS

- Lights: 0.5 Watts/s.f.
- Appliances: 0.4 Watts/s.f.
- Cooking: 6000 Btu/day (40% latent)
- Infiltration: 0.7 Air Change/hr.(lobby, 1.0 ACH; corridors, 0.5 ACH)

OTHER LOADS:

- Lighting in common areas: corridors, 0.4 W/s.f.
  social hall, 1600W, 16hrs./day
  garage, 450W, fluorescent; 10hrs./day
- Elevators: 20 kW each
- Exterior Lighting: 1250W, HID; 10 hrs./day

VENTILATION/EXHAUST:

- 70 cfm bath exhaust and 70 cfm range fan, both individually switched
- Lobby, corridors, TV rooms, 3500 cfm, 16 hrs./day

SYSTEM SPECS

HVAC

Units and Social Hall: electric resistance heating;
Corridors/Lobby/TV Rooms: Gas-fired rooftop unit

TEMPERATURE SETPOINTS

Heating: 72°F
No cooling provided

DOMESTIC HOT WATER

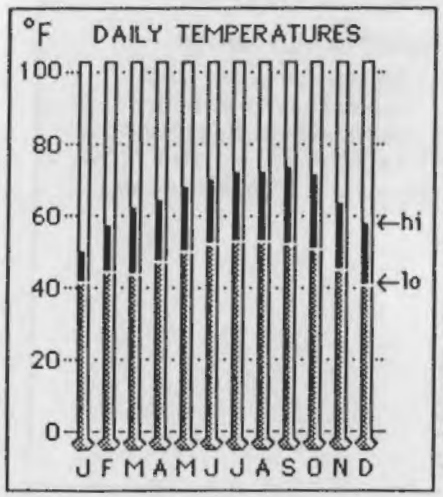
25 gals/unit/day from central gas-fired boiler (63% efficiency); stored at 140°F in 120 gal. tank
Laundry: 10 gals/unit/day

Energy Analysis

With a good basic design in a very mild climate, this is one of the lowest energy consuming buildings in the study. With total annual energy use of less than 50,000 Btus per square foot, energy bills are so low as to make significant energy investments difficult to justify on the basis of short payback periods.

As indicated on the graph below, daily temperatures are almost constantly between 50°F and 70° F. The temperature virtually never falls below 40°F and never above 75-80°F As a result, there are only 2,900 heating degree days (65° base) and cooling degree days are virtually nonexistent -- only 128.

Oakland temperatures are temperate and constant



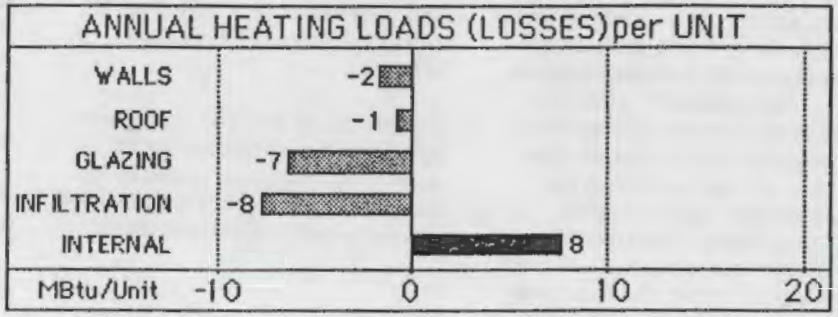
On a total building basis, heating is the largest energy problem. As shown on the bar chart of heating loads, infiltration losses (mostly around windows) and glazing losses (through single glazing) are the principal causes of heat losses in the building.

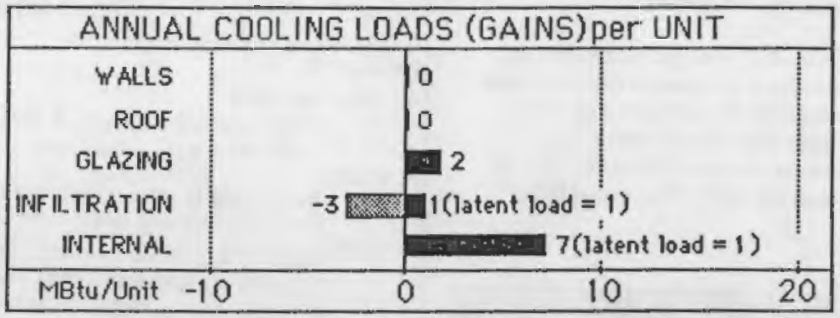
Given the mildness of the climate, there is an important tradeoff to keep in mind, however. If the building is sealed too tightly to reduce heating loads, there is a risk of increasing cooling loads, or at least uncomfortable conditions of overheating. Any attempts to "seal up" the building must leave tenants the opportunity to naturally ventilate their apartments when mild outdoor temperatures warrant.

Although there are often cloudy conditions in this area, solar gains in winter are almost always helpful and are to be encouraged. In this location, there is 25% more heat gain on a south wall in winter than occurs in Washington, D. C.

Because heating and cooling loads are so low, lighting and domestic hot water heating become a much larger share of the energy problem in this building. As shown on the bar chart of energy costs on the next page, lighting is nearly as costly as heating, and water heating is not far behind.

The continued use of incandescent lights in much of the building contributes to higher energy costs. Given the habits of elderly tenants, it is unlikely that cooking is likely to ever represent a serious energy problem.





Ventilating the corridors with 100% outside air is also contributing to the heating problem. Using a gas-fired unit to meet any necessary heating loads clearly keeps this cost down.

There is no single overriding energy issue in this building and only limited savings to be found in energy conservation -- a tough problem for the design teams assigned to cut energy costs with reasonably short paybacks.

At an average cost of $44 per unit per month, this building has the lowest energy cost of any building in the study. This is not surprising given the very mild climate and energy costs which are below the national average.

As shown on the bar charts of energy costs below, the owner and tenant virtually split the annual energy bill. The owner pays, on average $23 per unit per month and the tenants $21.

Because the owner supplies all domestic hot water for the building (and because heating costs are so low in this mild climate), water heating is the owner's largest energy cost. Heating and lights are the second and third highest costs at about $5 each per month. Elevators costs a modest $3 per month, and the cost of running fans for corridor ventilation (called HVAC on the bar chart) cost about $1 per month.

Heating is the tenant's highest energy cost, but the fact that it is almost equal to miscellaneous receptacle loads indicates how small a load it really is. Lights are the third highest energy cost at $5 per month. Cooking is a very modest $3 per month. All apartment units are individually metered.

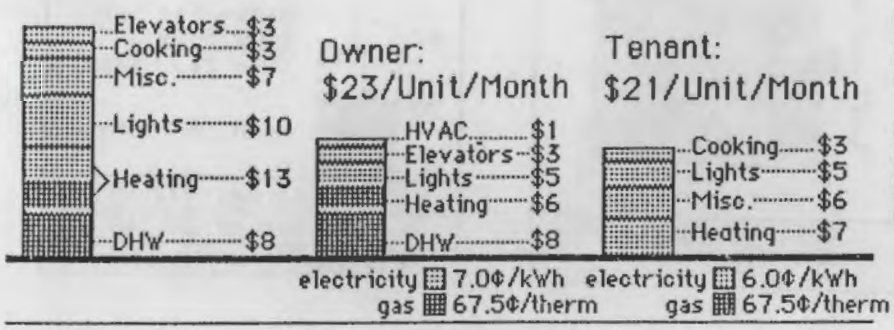
In looking for energy conservation alternatives, the design team did several sensitivity analyses using a computer model of the building to see what might be economically feasible in this mild climate. Results were restrictive at best. If infiltration were lowered from 0.7 to 0.5 air changes per hour, it would reduce building energy costs only about $1,500 per year -- not a lot of money to pay for extensive caulking and weatherstripping. If double glazing were added to the building, it would save about $3,000 per year -- not enough to justify the high first cost of the second pane of glass.

Hypothetically turning off outside air supply to corridors completely would save over $5,000 per year -- suggesting a good area for investigation. Outside air cannot be eliminated completely, of course, for code reasons, but there does seem to be sufficient savings here to merit further investigation.

As shown on the "Energy and Rent Analysis" below, this a good building which is able to command substantial rents. Rents are well above the average high rent for the region as reported by the Institute of Real Estate Management. From an economic point of view, these higher rents can be seen as paying for the uncommonly large amount of common space in this building.

Given that energy costs are such a relatively small part of total shelter cost, it is difficult to find dramatic energy cost reductions in this building.

Oakland Midrise Utility Costs



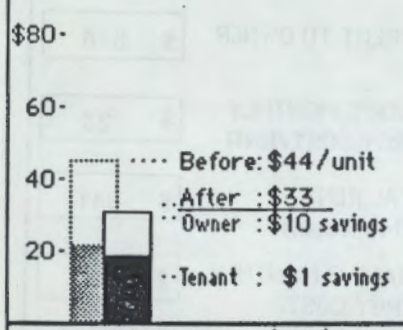
ENERGY & RENT ANALYSIS	
Typical One-Bedroom Unit:	
NET RENT TO OWNER	$ 818
OWNER'S MONTHLY ENERGY COST/UNIT	$ 23
TOTAL RENT (IREM Median)	$ 841
TENANT'S MONTHLY ENERGY COST	$ 21
SHELTER COST	$ 862

Operations Team A & Team B

STRATEGIES & COSTS

Infiltration/Exhaust:	
- Reduce corridor vent fan speed	-0-
- Install corridor vent. time clock	200
HVAC:	
- Add setback t-stat all bedrooms	9,000
- Reduce corridor temperature	-0-
Lighting/Appliances:	
- Replace 17 inc. lamps w/screw-in fluorescent; add dimmer on 5	260
- Add photocell control on ext. lights	400
- Relamp stair.with screw-in fluor.	50
DHW:	
- Reduce DHW temp. to 115°F	-0-
- Install ins. jacket on central DHW tank	250
Training:	
- Conduct tenant ed.prog. on setbacks	-0-
TOTAL COST:	$10,160

UTILITY BILLS



Monthly Savings: $11/unit

Annual Savings: $9,933

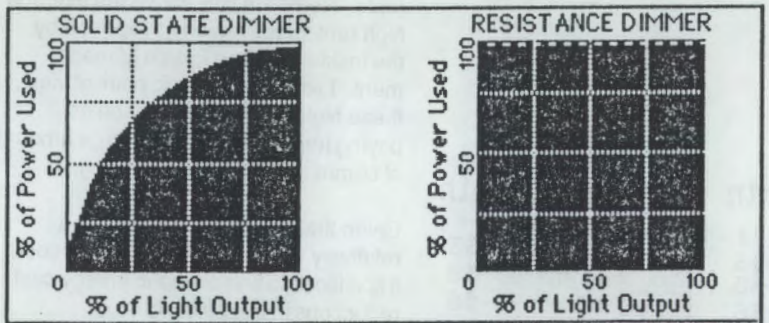
PAYBACK: 1 Year

The centerpiece of Team A's proposals to improve building operations is to provide tenants with the ability to cut their energy costs with automatic setback thermostats. It is recommended that the owner select and install these thermostats to insure consistency and easy maintenance across all units. Although a costly item, the improved thermostats can be seen as an amenity that gives tenants more control and an opportunity to reduce costs.

Team A also recommended reducing corridor ventilation by reducing fan speed somewhat and by installing a time clock to run the fan only when needed. The team also proposed replacing many incandescent lamps with screw-in fluorescents. Where aesthetics seemed to require continued use of incandescent lights, the team recommended installing solid state dimmers to reduce energy use. As shown on the graphs below, solid state dimmers are recommended because they actually reduce energy use when lights are dimmed. The package of improvements proposed by Team A is estimated to pay for itself in about a year.

Team B recommended a package of many smaller items. Team B also reduced corridor ventilation with a time clock but did not reduce fan speeds. The team also noted that putting time switches on lobby toilet fans would prevent them from being left on and aggravating infiltration losses. The team also recommended reducing corridor temperatures during unoccupied hours with a time clock.

In an attempt to reduce the owner's largest energy cost, the team also recommended installing flow restrictors on all showers, reducing water temperature, and insulating the central domestic hot water tank. The entire package has an attractive payback of only four months.



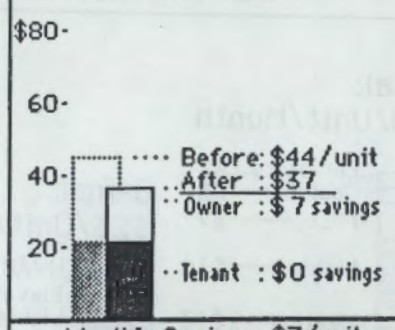
ENERGY IS CONSUMED ROUGHLY PROPORTIONAL TO THE LIGHT OUTPUT

CONSUMPTION OF ENERGY IS CONSTANT

STRATEGIES & COSTS

Infiltration/Exhaust:	
- Install time clock on corridor vent.	200
- Install time switches on lobby fans	100
HVAC:	
- Install clock t-stat in social room	170
- Reduce corridor temp w/time clock	200
Lighting/Appliances:	
- Relamp stair w/screw-in fluor.	50
DHW:	
- Reduce DHW temp to 115°F	-0-
- Install ins. jacket on DHW tank	250
- Install flow restrictors in shower	1,100
- Install high eff. laundry equip.	-0-
Training:	
- Conduct tenant ed. prog. on setbacks	-0-
TOTAL COST:	$2,070

UTILITY BILLS



Monthly Savings: $7/unit

Annual Savings: $6,348

PAYBACK: 4 Months

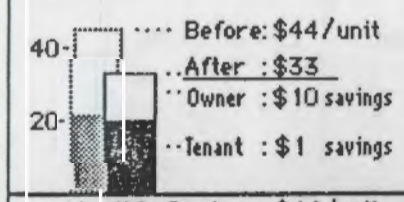
Retrofit Team A & Team B

OAKLAND, CA

STRATEGIES & COSTS

Infiltration/Exhaust:	
- Repeat operations strategies	200
- Caulk &weatherstrip doors & wind.	16,600
HVAC:	
- Repeat operations strategies	0,000
Lighting/Appliances:	
- Repeat operations strategies	710
- Install high effi. refrig. on replac.	7,000
DHW:	
- Repeat operations strategies	250
- Add GPM flow meters on DHW line to each unit with remote read out	11,165
Training:	
- Repeat operations strategies	-0-
TOTAL COST:	$44,925

UTILITY BILLS



Monthly Savings: $11/unit

Annual Savings: $10,571

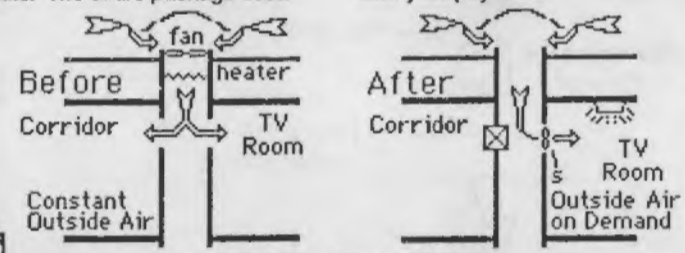
PAYBACK: 4.3 Years

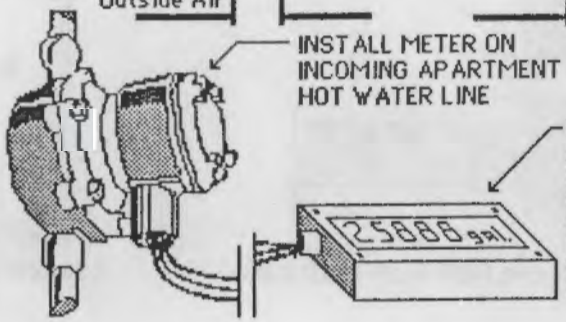
Turning to retrofit strategies, Team A recommended three rather costly building alterations. First, the team recommended caulking and weatherstripping all doors and windows. Although results of the sensitivity analysis suggested a long payback on this item, the team argued for its inclusion to improve tenant comfort.

Second, the team recommended installing gallon-per-minute flow meters (shown below) on all apartment DHW lines so that tenants could be billed directly for hot water use. At a cost of about $150 per unit, this improvement allows the owner to shift most of his $8 per month DHW bill to tenants (a 1-1/2 year payback) while also encouraging water conservation. The team also recommended installing high efficiency refrigerators at replacement to reduce tenant bills. The entire package costs about $45,000 with a reasonable four-year payback.

Team B focused on changing the ventilation system for the corridors and "TV" rooms, source of the owner's second highest energy cost. The team proposed disabling the package heater from the corridor ventilation and sealing existing corridor ducts. Existing windows in the corridors would be used for natural ventilation. Small in-duct fans would be installed at each "TV" room with switches to provide ventilation on demand. Lights alone were judged to be sufficient to heat these rooms without the ventilation heater.

Team B also recommended installing more energy efficient refrigerators at replacement. Cost of this strategy set was a modest $10,000 with an attractive one-year payback.

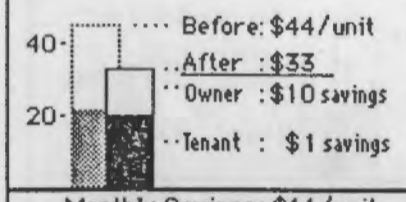




STRATEGIES & COSTS

Infiltration/Exhaust:	
- Disable rooftop corridor heating unit and seal corridor supply grill	1,400
- Install time switches on lobby toilet	100
HVAC:	
- Install clock t-stat for social room	170
Lighting/Appliances:	
- Repeat operations strategy	50
- Replace 12 cu. ft. refrig. with 8 cu.ft. high efficiency unit on replacement	7,000
DHW:	
- Repeat operations strategies	1,350
Training:	
- Repeat operations strategy	-0-
TOTAL COST:	$10,070

UTILITY BILLS



Monthly Savings: $11/unit

Annual Savings: $10,136

PAYBACK: 1 Year

Rehabilitation Team A

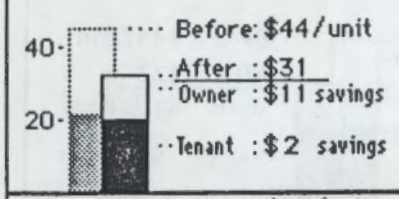
OAKLAND, CA

STRATEGIES & COSTS

Envelope:	
- Add 2" to ins. garage ceiling	9,100
Infiltration/Exhaust:	
- Repeat retrofit strategies	16,800
HVAC:	
- Repeat retrofit strategies	9,000
Lighting/Appliances:	
- Repeat retrofit strategies	7,710
DHW:	
- Repeat retrofit strategies	11,415
- Add solar DHW preheat	25,000
Training:	
- Repeat retrofit strategy	-0-
TOTAL COST:	$79,025

NOTE: Added cost for enclosing balconies (not paid for with energy savings alone) is $142,000.

UTILITY BILLS



Monthly Savings: $13/unit

Annual Savings: $11,689

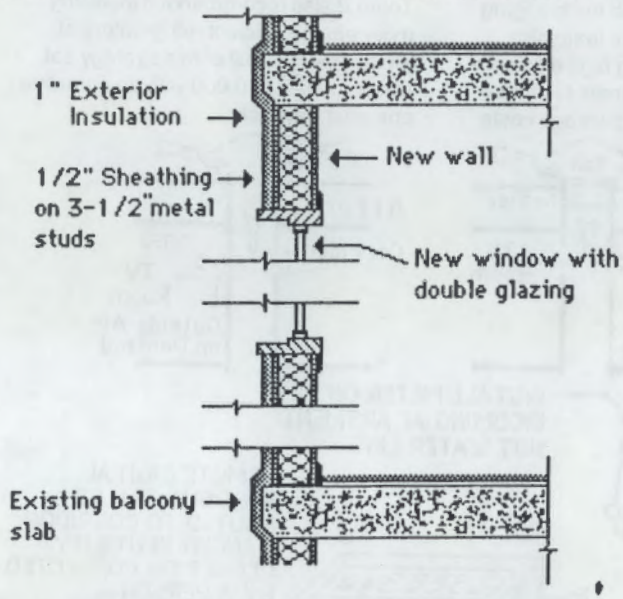
PAYBACK: 6.8 Years

Team A recommended three major strategies in the event of a complete building rehabilitation. First, as shown on the sketches below, the team proposed enlarging living rooms by enclosing half of the existing balconies. The exterior living room wall is removed and replaced on the outside edge of each balcony with a new and improved wall, from an energy point of view. Metal studs and batt insulation in the new wall are similar to the original design, but one inch of exterior insulation is added to further reduce conduction losses and to seal building seams to reduce infiltration. As shown on a typical wall section, exterior insulation extends over the exposed end of the balcony slab to prevent radiative losses and a potentially cold living room floor. Installation of masonry or tile floor is recommended for the southeaast and southwest balconies for thermal storage. This will moderate the temperature savings in these areas and help store solar gains for use during the nighttime periods.

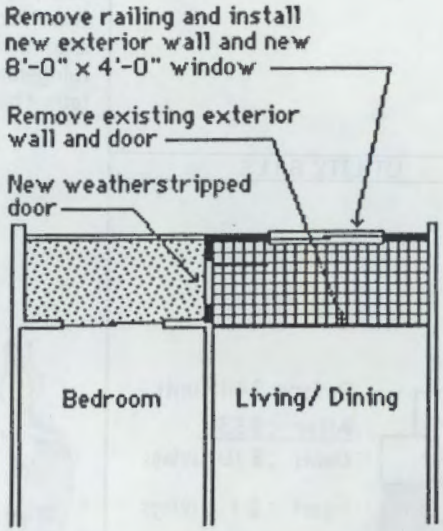
Existing patio doors are removed from the living room portion of the exterior wall and replaced with a new four by eight foot window. The new windows are double glazed. The team argued that if installed as a new unit, the second pane of glass would not be very costly and would be effective in reducing both infiltration and conduction losses. This recommendation was disputed by the other team and should be studied more closely before it is accepted.

The team also recommended adding a solar preheater for the domestic hot water system. Engineering estimates are that this system would require about fifty standard sized solar collectors and about two thousand gallons of storage. At an estimated cost of $25,000, the system could pay for itself in six or seven years if it reduced the owner's water heating bill by half.

Not counting the cost of the remodeled balconies, which could pay for themselves in added rent, this strategy set has about a seven-year payback.



Exterior insulation reduces floor slab heat loss

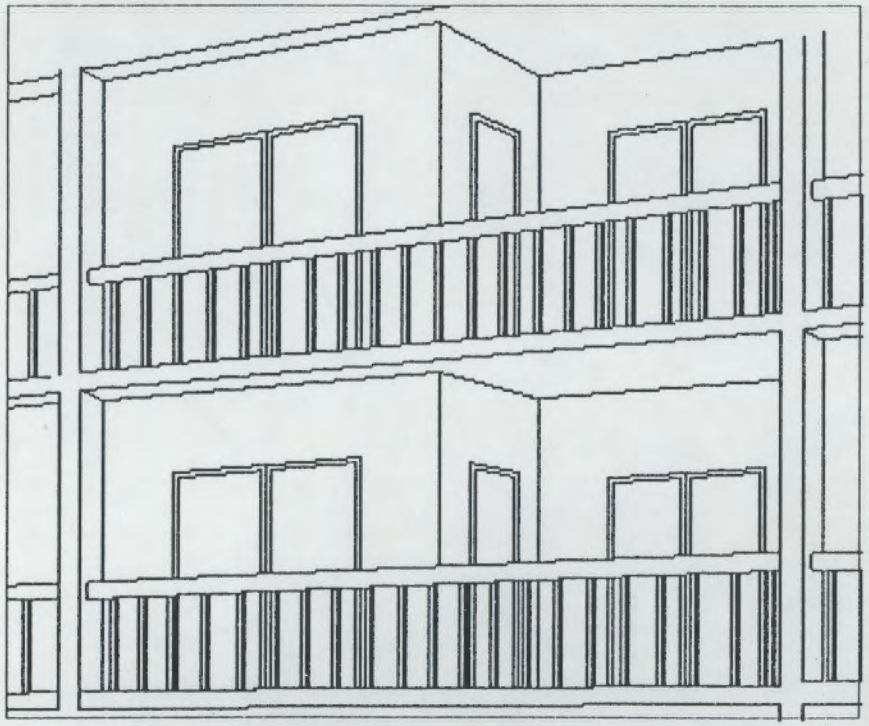


Enclosing the balcony converts seldom used space into living space

Team B also proposed enclosing half of each existing balcony in order to enlarge the living room. Team B, however, proposed reusing more of the existing building materials in order to keep the cost of renovation down. As a result, the cost estimate for Team B's approach is $47,000 (or 33%) less than Team A's.

As shown on the elevation below, the team reused existing sliding glass doors and simply moved them up to the balcony rail. The rail can thus be used to meet code requirements for protecting the opening out of the living room and save the cost of replacing the existing sliding door with a window. These renovations can be made without disturbing the current exterior appearance of the building.

Team B also provided an analysis of the economic value of this renovation to the building owner. As shown in the box below, the additional sixty square feet of space should generate at least an additional $30 per month. The capitalized value of this increased cash flow is $3,600 (at 10%). If construction costs can be held to $30 per square foot, the net value of the new enclosed space is $1,800. Capitalizing very modest energy savings of $7 per unit per year adds an additional $70 per dwelling unit. Under current tax law, depreciation on the improvement adds another $360 of value. Total value is $2,230 and after paying the added cost of construction, is $430 per unit in the first year.



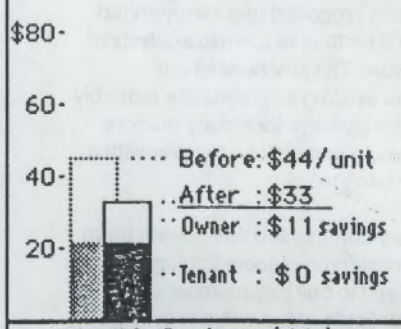
Team B rehabilitation relocated existing glass doors to minimize building costs

ECONOMICS OF A NEW ENCLOSED BALCONY	
Capital value of enclosed living room/balcony	
- Added rent from enclosed balcony (60s.f. x $1/mo/s.f. base rent x 50%)	$30/DU/MO
- Value of enclosed balcony ($30.s.f.,annualized & capitalized @10%)	$3,600/DU
- Actual Cost of remodeling ($30/s.f. including recycled materials)	$1,800/DU
- Net increase in capital value	*$1,800/DU
Value of Reduced Energy Costs	
- Assume energy savings of	$7/DU/yr.
- Capitalize savings at 10%	*$70/DU
Value of tax benefits	
- Depreciation of $1,800/DU over 25 years	$72/DU
- Cash value of depreciation in 50% bracket	$36/DU
- Capitalize cash value at 10%	*$360/DU
Total capitalized value of enclosed balcony	*$2,230
Less Const. Cost of	1,800
Net value of enclosed balcony (year 1)	*$430/DU

STRATEGIES & COSTS	
Infiltration/Exhaust:	
- Repeat retrofit strategies	1,500
HVAC:	
- Repeat retrofit strategies	170
Lighting/Appliances:	
- Repeat retrofit strategies	7,050
DHW:	
- Repeat retrofit strategies	1,350
Training:	
- Repeat retrofit strategy	-0-
TOTAL COST:	$10,070

NOTE: Added costs for enclosing balconies (not paid for by energy savings alone) is $95,000.

UTILITY BILLS



Monthly Savings: $11/unit

Annual Savings: $10,109

PAYBACK: 1 Year

Jury Comments

During discussions with the jury, Team A reported that they had spent considerable time trying to find alternatives to the individual electric heating and central gas water heating systems in the building but without success. It appeared, based on preliminary analysis, that the cost of constructing flues and piping gas in order to be able to install individual gas-fired space heaters and water heaters would outweigh the modest savings possible in such a moderate climate.

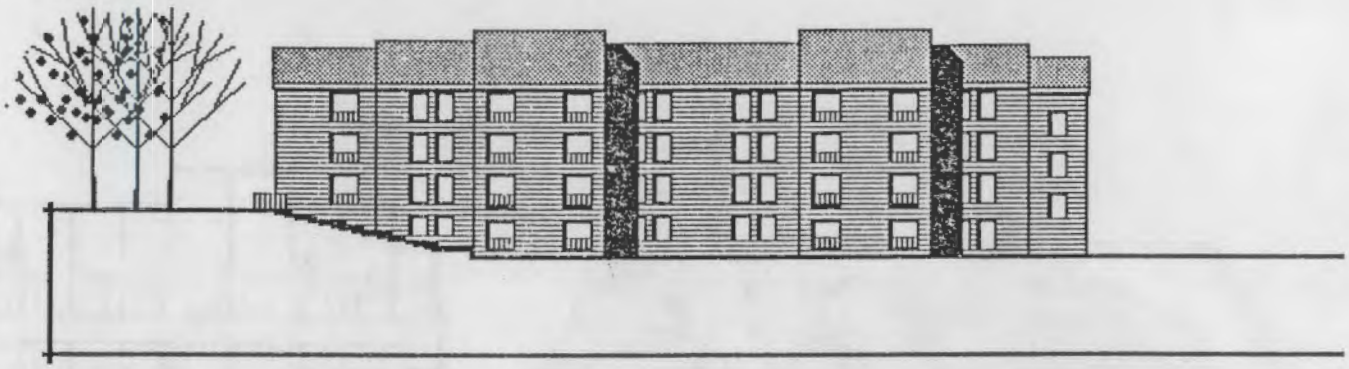
The jury agreed that the current ventilation system in the building was likely to be excessive but questioned the extreme measures taken by Team B in closing off the system completely. One jury member commented that although the existing windows would be sufficient to meet code, it was unlikely that they would be controlled effectively by hand. If windows were not opened and closed daily, corridor air would surely be unacceptable to tenants.

The jury generally liked the balcony solutions proposed and commended Team B for their economic analysis of the issue. The jury pointed out that the existing balconies are probably excessively large for elderly tenants who would probably be happier with a larger living room.

The jury commented that neither team had considered outdoor lighting. It appeared to one jury member that exterior lighting was sufficiently high that it merited review for possible reductions.

Maryland Lowrise

ST. CHARLES, MD



Situated just south of Washington, D. C. in southern Maryland between the Potomac River and the Chesapeake Bay, this four-story lowrise built in 1980 reflects good contemporary building practice. It is one of six buildings, each with 34 units. With R-16 exterior walls, an R-30 roof, and a reasonably efficient heat pump, one might well ask how much more can be done to reduce energy costs in this climate? According to design teams working on the problem, another 15 to 30 percent can be cut from annual energy bills by a collection of modest improvements.

The building is all electric and individually metered, with the owner paying about $9,500 per year in electric costs. Because this building is entirely Section-8 subsidized housing, the majority of the total annual tenant utility bill of $21,000 is paid for by the U.S. Government. With potential savings ranging from $4,500 to over $9,000 per year per building, conservation in this six-building complex could generate over $50,000 per year in energy savings. Whether or not maximum energy savings are sought depends to a large extent on contracts between the building owner and the government. If the owner is to pay for major energy improvements to the building, he must be allowed to realize a gain from the savings generated by energy conservation.

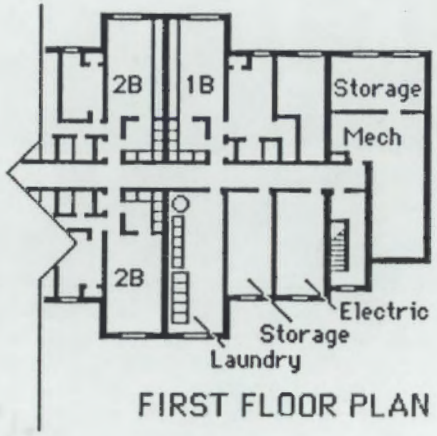
Building Layout

By coordinating building layout and site topography, designers of this project were able to achieve a very efficient four-story design without elevators. Topographic lines are not shown, but the site slopes dramatically from north to south. Tenants parking in the higher north lot walk directly onto the second floor or up two flights of steps to the fourth. Tenants parking in the low south lot walk directly onto the first floor or up one flight of steps to the second floor. The effect is the efficiency of a four-story building with the access of a three-story building. What is gained in building efficiency, however, is lost in building orientation. Only one of the six buildings on the site is oriented with a southern exposure suitable for solar design strategies. It would have been interesting to see if the efficiencies gained by using a double loaded corridor, with only two stairs per building, could be preserved in a site design that also had good solar orientation.

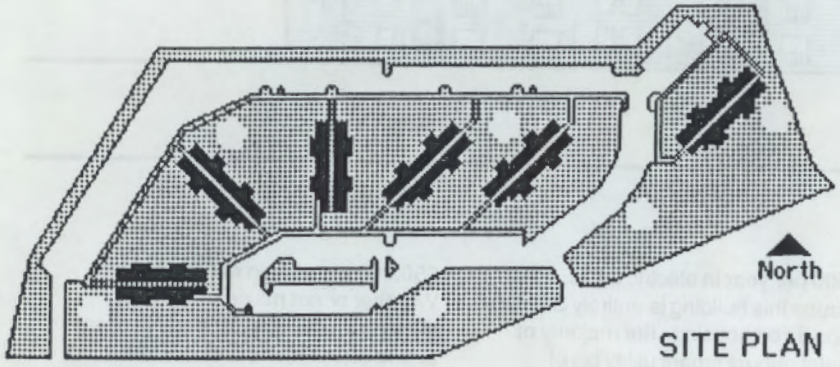
Each building has nine units per floor, as shown on the typical floor plan below. The mix is roughly 10 percent three-bedroom units (1,055 square feet), 60 percent two-bedroom units (865 square feet), and 30 percent one-bedroom units with an option of either 600 or 855 square feet. Unit plans are shown on the next page. However, only the larger one-bedroom unit is illustrated.

On the first floor, two one-bedroom units are omitted to make room for the laundry, storage areas, and other services. No elevator is provided for the building, and there is no lobby.

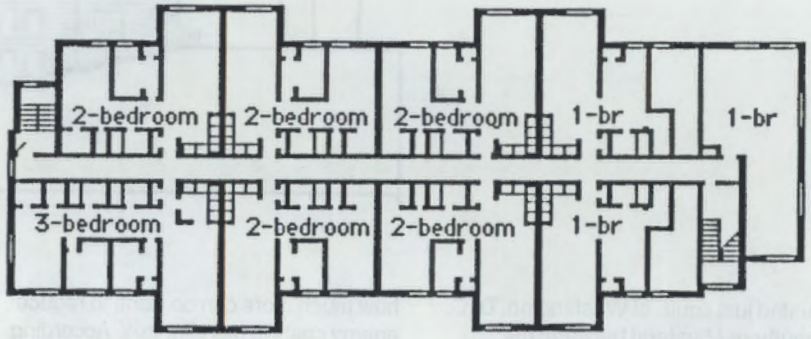
With a net rentable area of about 33,000 square feet and a gross of about 39,000 square feet, the net-to-gross of this building is an excellent 87 percent -- the highest of any building in the study.



FIRST FLOOR PLAN



SITE PLAN



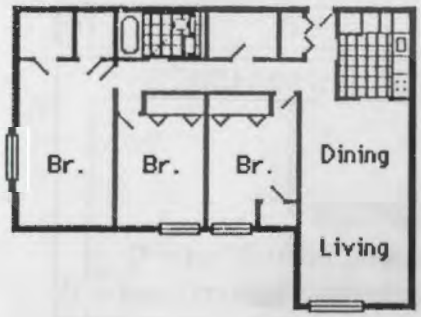
TYPICAL FLOOR PLAN

Building Specifications & Operations

ST. CHARLES, MD

One Bedroom

Two Bedroom



Three Bedroom

This building was clearly designed after the energy crisis of the 1970's. It is well insulated in both the walls and roof and all windows are double glazed. Good quality heat pumps give tenants individual comfort and the opportunity for individual conservation. In general, a good basic design hard to improve upon.

With frame construction and double pane glass, this building is assumed to have infiltration of about 0.8 air changes per hour on average. Infiltration into the units may be somewhat lower because they are isolated from the corridor with weather-stripping on the entry doors. In corridors, infiltration is likely to be somewhat higher. The corridor ventilation system provides 100 percent outside air and may leak a good deal when the system is not in operation. This system merits special attention because existing electric resistance heating (with a 70° F setpoint) causes the single highest cost for the owner.

Lighting energy use is above the minimum possible because of incandescent lamps in the corridors and stairwells. Outside lighting, however, is modest and automatically switched on with a timer.

BUILDING SPECS

ENVELOPE:

- Exterior Wall
  4" brick facing, 4" CMU 70% solid, with R-16, 2.5" urethane insulation, 2 x 3 studs 24" O.C., 1/2" gypsum board
- Window
  Metal frame, double pane glass, sliding windows
  U = 0.57, shading coefficient = 0.64 with blinds
- Roof
  Asphalt shingle, plywood, airspace, R-30 insulation, gypsum board; U = 0.03

INTERNAL LOADS

- Lights: 0.5 Watts/s.f.
- Appliances: 0.4 Watts/s.f.
- Cooking: 6000 Btu/day (40% latent)
- Infiltration: 0.8 Air Change/hr.

OTHER LOADS:

- Exterior Lighting: 2 kW operated 12 Hours/day

VENTILATION/EXHAUST

- 70 cfm bath exhaust; 150 cfm range exhaust; individually switched
- Corridors, 2000 cfm

SYSTEM SPECS

HVAC

Split air-to-air heat pump with supplemental electric resistance heating; cooling EER=7.06, heating COP=2.07
corridors: resistance heating, no cooling

TEMPERATURE SETPOINTS

Heating: 70°F
Cooling: 78°F

DOMESTIC HOT WATER

Nominal efficiency = 71%
35 gal./unit/day @125°F

Energy Analysis

ST. CHARLES, MD

The mid-Atlantic region is a "middling" climate -- about half as cold as Minneapolis and about half as hot as Savannah, Georgia.

Although heating degree days (5,000) are five times greater than cooling degree days (1,000), the heating costs are only twice cooling costs. This is true because heat generated and held within the building (from occupants, lights, and equipment) helps to offset winter heating loads but seriously aggravates summer cooling loads. High summer humidity also increases the need for mechanical cooling.

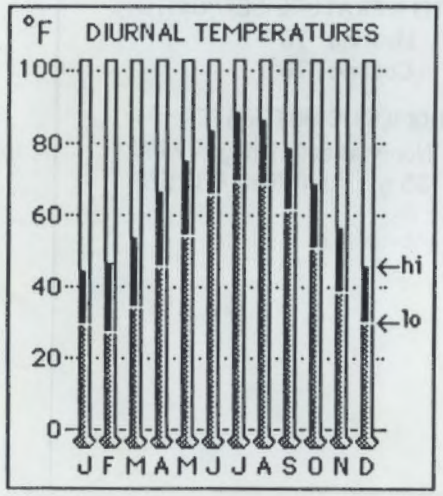
The typical wall section (shown at the right), illustrates the various energy conservation design features already included. It is difficult to achieve dramatic improvements on a good basic design such as this.

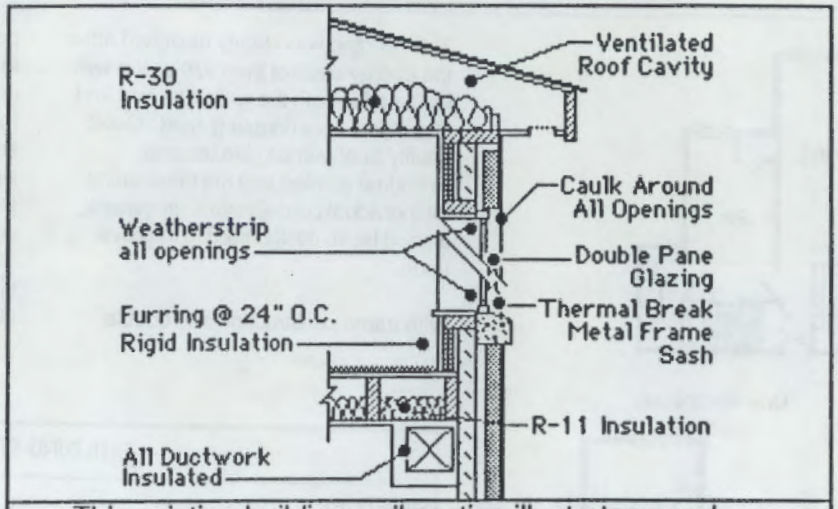
Furthermore, saving energy is difficult due to "trade-offs" between conservation strategies. For example, sealing the building to cut infiltration will reduce heating costs by holding more heat in the building but will aggravate cooling loads. When savings in one area creates costs in another, it is difficult to get the total savings necessary to pay for major energy improvements.

In analyzing the causes of loads in this building (see bar charts at right), it is clear that infiltration is the principal cause of heating. It is large enough that it cannot be offset by the benefit of internal heat gains.

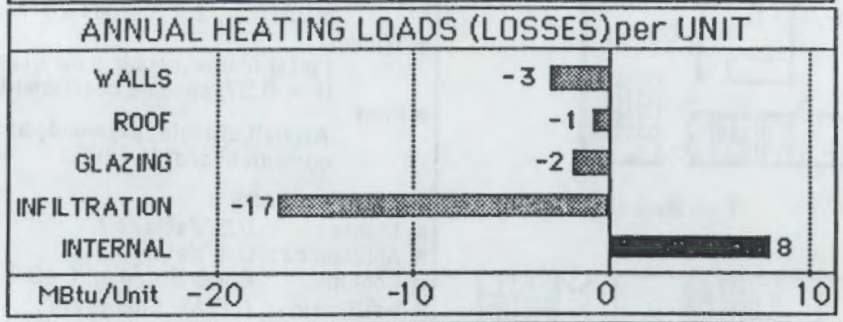
On the cooling side, internal heat gains, heat gains from direct solar radiation on glazing, and infiltration are the three main causes of cooling loads.

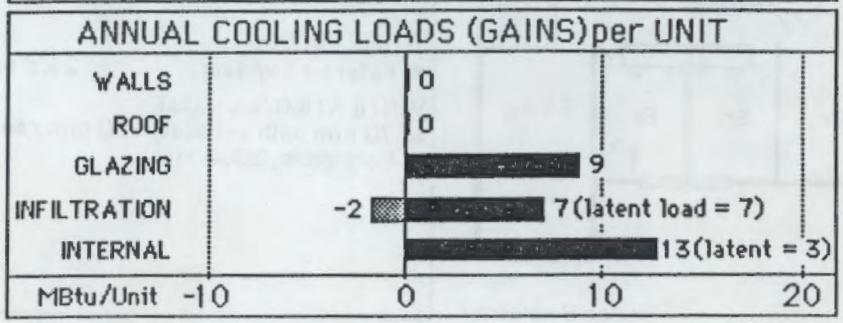
Given that infiltration is a cause of both heating and cooling loads intuition suggests it should be reduced. There are times however, especially in the spring and fall, when infiltration is a benefit because it offsets internal heat gains. At these times, reducing infiltration will increase cooling costs. This illustrates the energy problem in this building. How does one reduce heating costs without increasing cooling costs?





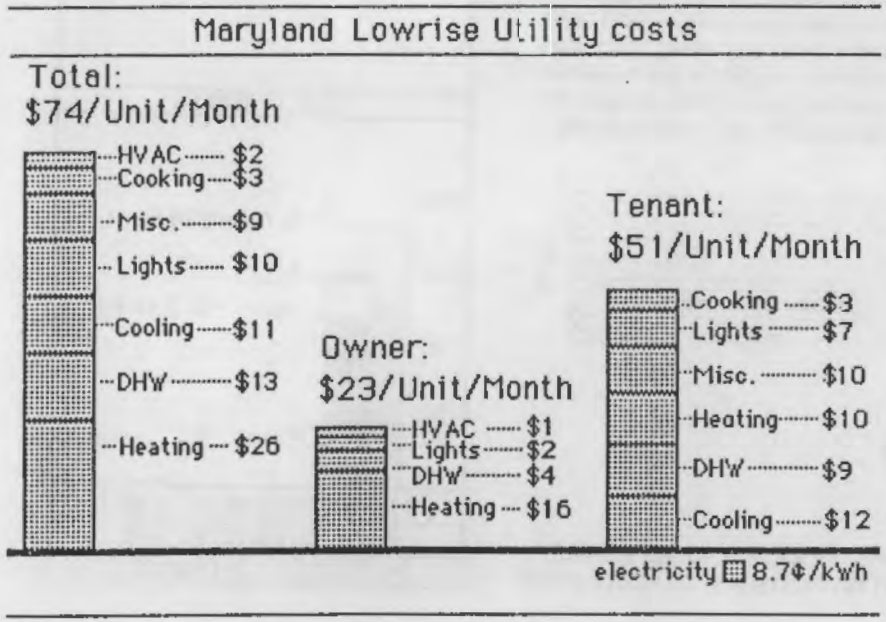
This existing building wall section illustrates good contemporary design





The economics in this building are influenced to a great extent by the fact that all units in the project fall under government regulations for Section-8 housing. Although the owner's energy bill alone is large enough to justify many energy conservation efforts, it is questionable whether there is sufficient incentive for the owner to pay for energy conservation improvements that benefit tenants only.

As shown on the bar chart of energy costs below, the owner's bill in this building is less than half that of the tenants. Heating is clearly the most important energy cost for the owner. The owner has no cooling costs because only heat is provided to the corridors. The tenant's bill is divided almost equally among cooling, heating, water heating, receptacles, and lights. The relative equality of these costs makes it difficult to focus on any one area to obtain major energy cost savings.



Allocating costs and benefits under the Section-8 program is complex. The government first computes a "market rent" and a "utility allowance" for each unit to be subsidized, based on comparable units in the area. Generally, 30 percent of the tenant's adjusted annual income is computed to be the "tenant's contribution" and the balance is paid by HUD as a subsidy. Although the tenant is typically responsible for paying the entire utility bill when due, he really pays only the difference (if any) between the actual bill and the credit they have already received in the "utility allowance". The owner's revenue for each unit is the total of the tenant's contribution and the subsidy payment from the government.

If the utility allowance is not reduced based on actual bill information , any savings on utility bills actually increases the tenant's net income. The government subsidy is not reduced and the owner's revenue is not increased.

If benefits of energy conservation go entirely to the tenant, there is little incentive for either the government or the owner to pay for conservation measures. Both the government and building owners must share energy cost savings, if building improvements are going to be made.

One reason an owner might be inclined to pay for energy conservation without any immediate return is to improve a building before removing it from the Section-8 program. If plans are to convert the building to condominium ownership, a history of low energy bills would be attractive to prospective buyers.

In considering strategy sets for this building, the design teams did not focus on distinctions between owner and tenant savings. They took a whole building approach in seeking the best total package for the price. It is interesting to note that paybacks can increase significantly when improvements must be paid by owner savings alone.

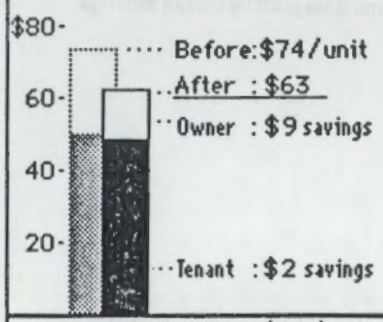
Operations Team A & Team B

ST. CHARLES, MD

STRATEGIES & COSTS

Infiltration/Exhaust:	
- Add time clock on corridor & laundry HVAC	250
HVAC:	
- Disable stairwell heat	200
- Add heat tape on standpipe	400
- Lower laundry and corridor set points to 55°F	-0-
Lighting/Appliances:	
- Add photocell to ex. ltg.	200
DHW:	
- Lower DHW temp. to 120°F	-0-
- Install insulation jacket on ind. & laundry DHW tanks	1820
- High eff. laundry equipment	-0-
TOTAL COST:	$2,870

UTILITY BILLS



Monthly Savings: $11/unit

Annual Savings: $4,467

PAYBACK: 8 Months

Both teams focused on cutting the owner's operating costs and both achieved paybacks of less than one year.

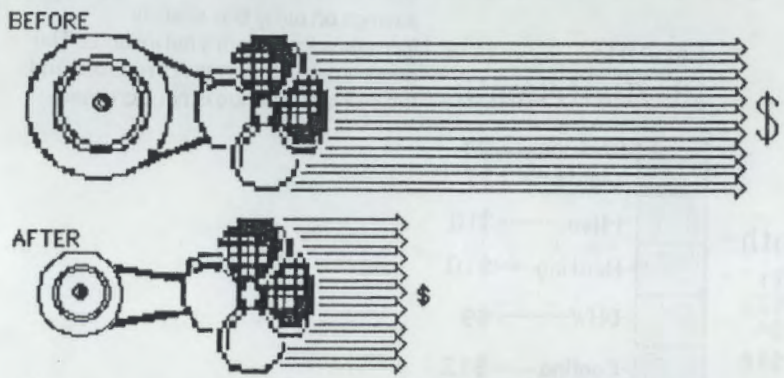
In the area of infiltration and HVAC, both teams focused on reducing the owner's largest energy bill -- the heating of corridors. Both teams suggested controlling corridor ventilation with a time clock to limit ventilation to times of the day when it is most needed (e.g. meal times). Both teams also recommended lowering the corridor setpoint to 55° F. Team A disabled stairwell heat, but protected the stand pipe with a heat tape. Team B refit the corridor fan with new pullies to get a lower fan speed.

For domestic hot water, both teams recommended a lower temperature setpoint on the laundry water storage tank and the addition of insulation around the tank. Both teams also recommended that higher efficiency laundry equipment be provided by the laundry subcontractor. Team B also recommended a time clock on the laundry heater and limiting hours of laundry use.

Team B recommended insulating the hot water heaters in each unit. At a cost of $1,700 per building and estimated annual savings of $575, less than a three-year payback.

Team A recommended photocell control on exterior lighting. Team B recommended screw-in fluorescent lights in all common areas.

Team A strategies are estimated to save $4,500 annually for an investment of $2,900. Team B strategies will save $6,700 annually at a cost of $4,500. Both sets will pay back in about eight months on a total building basis. If all costs must be paid for with owner savings alone, the paybacks increase to 9 months and 15 months respectively.

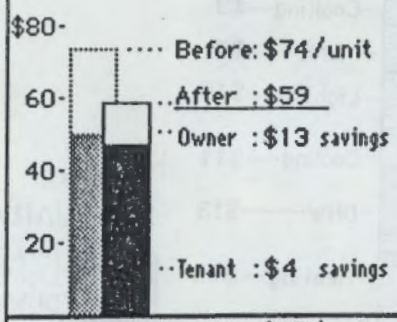


HALVING FAN PULLEY SIZE AND CUTTING OPERATION HOURS IN HALF RESULTS IN A 75% REDUCTION IN HEATING COSTS DUE TO VENTILATION

STRATEGIES & COSTS

Infiltration/Exhaust:	
- Seal duct penetration from mech. closet	667
- Add time clock on corridor/ laundry HVAC	250
- Slow corridor supp. fan to 1/5 ACH	400
HVAC:	
- Reduce corridor temp set points to 55°F	-0-
Lighting/Appliances:	
- Replace all com. area incandescents with screw-in fluorescents	1,000
DHW:	
- Time clock on cent. laundry DHW	333
- Install high eff. laundry equip.	-0-
- Add insulated jacket for laundry	120
- Add insulated jacket for tenant	1,700
- Lower DHW storage temp to 120°F	-0-
TOTAL COST:	$4,470

UTILITY BILLS



Monthly Savings: $17/unit

Annual Savings: $6,773

PAYBACK: 8 Months

Retrofit Team A

Team A added strategies focused primarily on reducing tenant cooling costs. Three basic strategies were proposed.

First, Team A recommended capping kitchen ventilating ducts and replacing range hoods with recirculating charcoal filters. They argued that this would reduce infiltration, reducing both heating and cooling loads. However, careful inspection of the computer simulation showed that retaining the heat from cooking outweighed the effects of infiltration. As a result, annual heating loads dropped, but annual cooling loads increased. The strategy was retained in the set because of its benefits for heating, not for cooling.

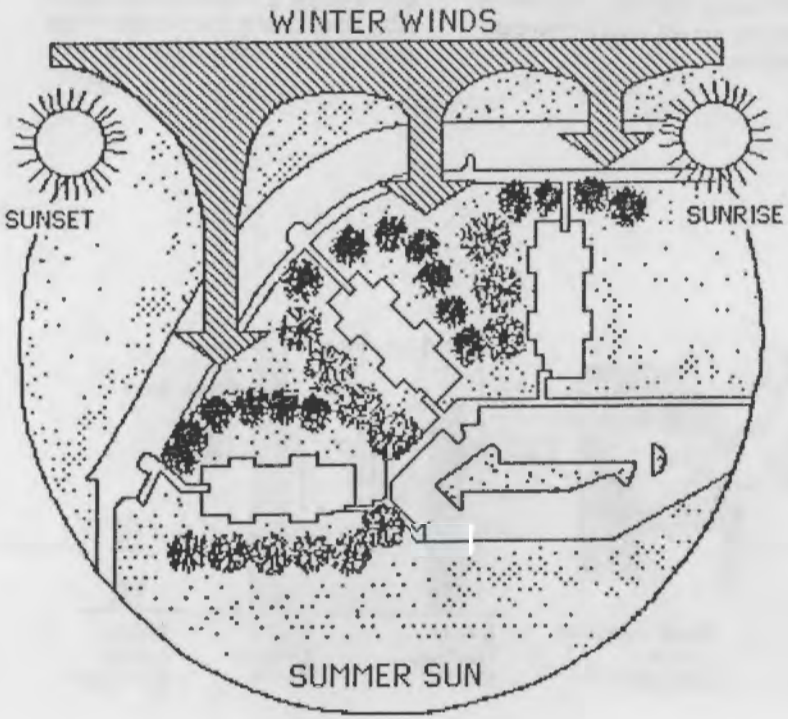
Second, the team recommended application of solar film to all east and west glass. This is an easy way to block low east or west sun and reduce cooling loads due to the orientation of these buildings. The computer model showed this to be an effective strategy for reducing cooling loads.

Finally, the team recommended landscaping to reduce climate effects on the building. Deciduous trees were recommended for the east and south sides of the building so leaves could block sunlight in the summer but allow sun to warm the building in winter. Neither the amenity values nor the maintenance costs of these landscaping recommendations were computed in detail.

Evergreens were recommended for the west and north -- to block prevailing winds in the winter and to block low western sun all year long. It appears that the relatively high cost of landscaping may be justified on energy savings alone. Some marketing advantage, due to better landscaping, might better justify the costs.

Total cost of this strategy set is $18,400. With annual estimated savings of $6,300, payback is under 3 years. If costs must be justified on owner savings alone, the payback increases to 4.6 years.

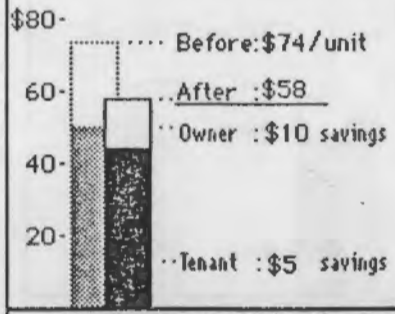
Landscaping with a combination of evergreen and deciduous trees adds amenity value, buffers winter winds and shades the buildings from summer sun



STRATEGIES & COSTS

Infiltration/Exhaust:	
- Repeat Operations Strategy	250
- Cap existing kitchen and bath exhaust; replace with recirculating fan	5,000
HVAC:	
- Repeat Operations Strategies	600
Lighting/Appliances:	
- Repeat Operations Strategy	200
- Replace all com. area inc. with screw-in fluor.	1,000
- Add timer switches on laundry/ storage lights	400
DHW:	
- Repeat Operations Strategies	1,820
Building Site and Solar:	
- Apply solar film E/W glazing	5,000
- Plant deciduous trees on east	1,250
- Plant evergreens on west and north (30)	2,500
- Plant ivy on south and west sides of bldg.	333
TOTAL COST:	$18,353

UTILITY BILLS



Monthly Savings: $15/unit

Annual Savings: $6,348

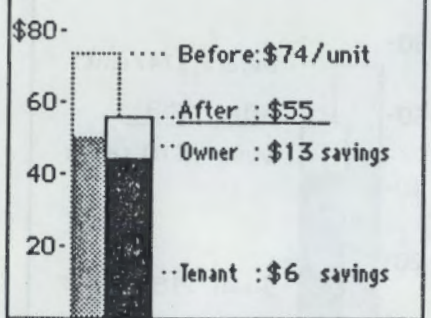
PAYBACK: 2.9 Years

Retrofit Team B

ST. CHARLES, MD

STRATEGIES & COSTS	
Envelope:	
- Add storm windows (3rd pane)	21,667
Infiltration/Exhaust:	
- Repeat Operations Strategies except in laundry	1,067
- Thermostat control on laundry exhaust fan	1,500
- Cap existing apartment exhaust ducts and install recirculating fans in kitchen and bath	5,000
HVAC:	
- Repeat Operations Strategy	-0-
Lighting/Appliances:	
- Repeat Operations Strategy	1,000
- High-eff. appl. at replacement	6,667
DHW:	
- Repeat Operations Strategies	2,153
Building Site and Solar:	
- Landscape with 24 white pines on east and west	1,666
TOTAL COST:	$40,720

UTILITY BILLS



Monthly Savings: $19/unit

Annual Savings: $7,825

PAYBACK: 5.2 Years

Team B also focused on reducing building heating and cooling loads, but with a slightly different approach than Team A. Team B added a third pane of glass as a storm window and called for more efficient appliances for tenants. The cost of this approach is nearly twice as high, while savings increased by only 25 percent -- giving this retrofit strategy set a significantly longer payback.

This team had the same problem with "tradeoffs" as Team A. It is very difficult in this climate to find strategies that will reduce heating loads without increasing cooling loads, and vice-versa. The diagram below illustrates the problem.

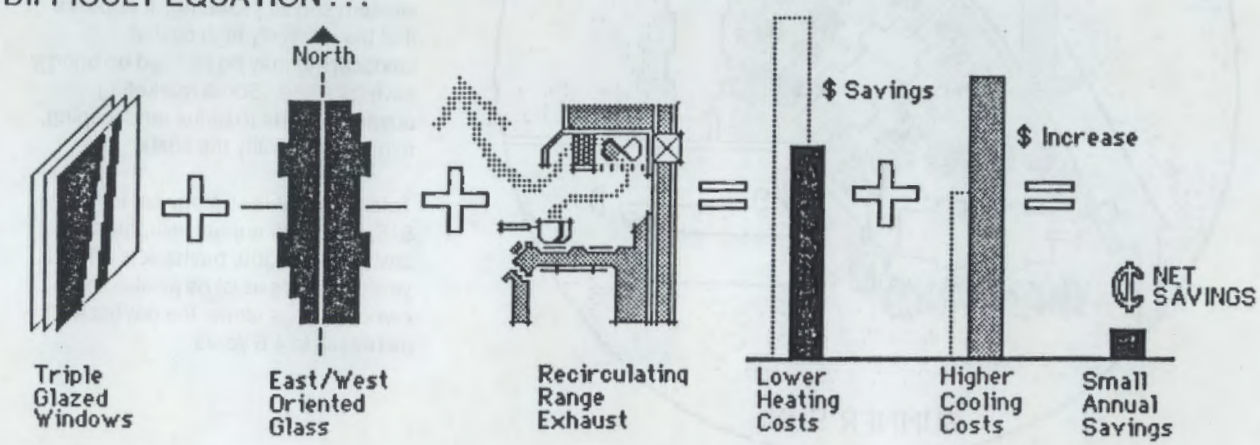
Triple glazed windows reduce both infiltration and conduction losses, east/west glass increases heat from solar gains, and using recirculating range hoods keeps the heat from cooking in the kitchen. All three add heat to the apartment space. This added heat has the benefit of lowering mechanical heating costs, but has the offsetting effect of increasing mechanical cooling costs. The net effect is small annual savings.

It is possible, as in this strategy set, to achieve modest savings in both heating (13 percent) and cooling (9 percent) costs. However, a major attempt to reduce one cost is likely to create a major offsetting increase. This climate, in particular, will not allow focusing on only one load.

Cutting the cost of operating appliances is a clear benefit, without tradeoffs. Conversion to higher efficiency appliances is the second most costly item in this strategy set. The incremental cost of high efficiency models over standard models, at the time of normal changeout, is about $7,000. That is a 6-year payback with estimated annual savings of about $1,100. This is over the 5-year payback rule of thumb, but still less than the useful life of the appliances.

With a total cost for the strategy set of $41,000 and estimated annual savings of about $7,800, the payback is just over 5 years. If all improvement costs must be paid for out of owner savings alone, payback increases to 7.8 years.

A DIFFICULT EQUATION . . .



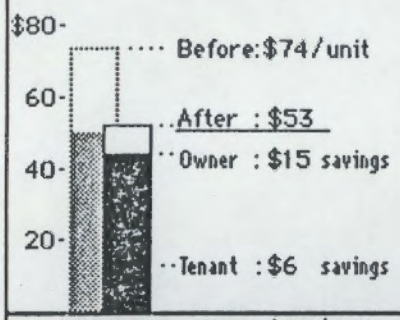
Rehabilitation Team A & Team B

ST. CHARLES, MD

STRATEGIES & COSTS

Infiltration/Exhaust:	
- Cap existing kitchen and bath exhaust; replace with recirc fan	5,000
HVAC:	
- Repeat Retrofit Strategies	600
- Replace corridor HVAC with strip electric	2,580
- Add ceiling fans, all MBR's and living rooms	8,500
Lighting/Appliances:	
- Repeat Retrofit Strategies	1,600
- High-eff. appliances at replacement	6,667
DHW:	
- Repeat Retrofit Strategies	1,820
Building Site and Solar:	
- Repeat Retrofit Strategies, but omit solar film	4,083
TOTAL COST:	$30,850

UTILITY BILLS



Monthly Savings: $21/unit

Annual Savings: $8,584

PAYBACK: 3.6 Years

Team A recommended installing ceiling fans to reduce cooling costs and increase tenant comfort. They also suggested completely removing the corridor ventilation system and using strip heat instead. Code requirements could still be met by windows existing in the corridors. Solar films were omitted in this strategy set.

Team B recommended installing newer, high efficiency heat pumps at the time of rehabilitation and suggested they be "downsized" due to reduced loads from conservation. Team B also suggested a more widespread use of fluorescent lights in the building, assuming that new color corrected lights, now becoming available, would be acceptable to tenants.

Costs and projected savings are shown in the sidebars and on the chart below. Team A achieved a 3-1/2-year payback on a $31,000 investment. Team B got an 8-year payback on a $74,000 investment.

Differences in the approaches of these two teams illustrate very well the lack of incentives for energy conservation in Section-8 housing. Team B's strategy set focuses far more on reducing tenant energy bills. Of the $74,000 cost of the strategy set, 75 percent is for a third pane of glass and high efficiency heat pumps -- strategies affecting tenant bills far more than owner bills.

As shown on the chart, if paybacks are recomputed for both strategy sets, assuming that all improve-ments must be paid for by savings from the owner's bill alone, the payback for Team A increases from 3-1/2 years to 5 years, while the payback for Team B increases from 8 years to 18 years.

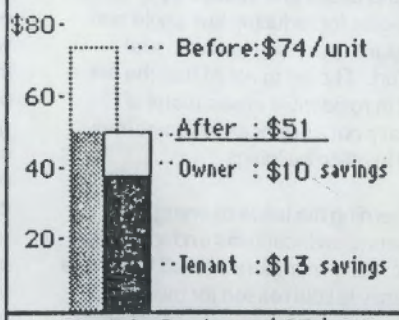
PAYBACKS ARE VERY DEPENDENT ON WHO BENEFITS FROM SAVINGS

Rehabilitation Strategy		WHOLE BUILDING VIEW		OWNER'S VIEW	
Team	Cost	ANNUAL SAVINGS	PAYBACK	ANNUAL SAVINGS	PAYBACK
A	$31,000	$ 8,600	3-1/2 yrs.	$6,200	5 yrs.
B	$74,000	$ 9,500	8 yrs.	$4,100	18 yrs.

STRATEGIES & COSTS

Envelope:	
- Repeat Retrofit Strategy	21,667
Infiltration/Exhaust:	
- Repeat Retrofit Strategies	7,567
HVAC:	
- Repeat Retrofit Strategy	-0-
- Replace existing heat pumps with high-eff. down-sized unit	33, 300
Lighting/Appliances:	
- Repeat Retrofit Strategies	7,667
- Replace incand. in unit baths, kitchens, and bed corridors with screw-in fluor.	583
DHW:	
- Repeat Retrofit Strategies	2,153
Building Site and Solar:	
- Repeat Retrofit Strategy	1,667
TOTAL COST:	$74,604

UTILITY BILLS



Monthly Savings: $23/unit

Annual Savings: $9,470

PAYBACK: 7.9 Years

Jury Comments

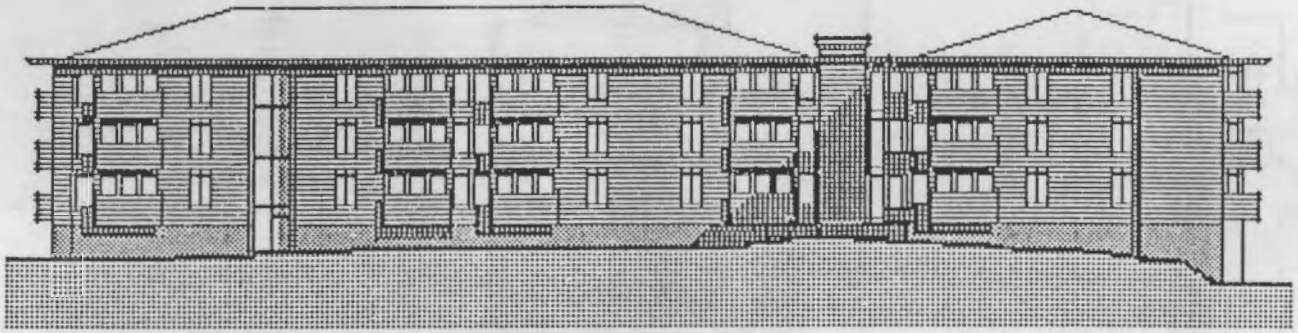
In this building, corridor ventilation creates the largest single energy cost for the owner. It is clear that the owner has strong incentives to reduce ventilation as much as possible. Jury members commented that current building codes require unnecessarily high ventilation rates in corridors, causing many building owners to simply turn off corridor ventilation systems for most of the day rather than seek reasonable alternatives. Based on the importance of corridor ventilation to building load, as shown here and in many other buildings in the study , the jury recommended that the government should work with researchers and code officials to arrive at better corridor ventilation solutions which will serve tenant comfort needs while still significantly reducing energy costs in multifamily housing.

One reviewer questioned the use of tinted glass in residential buildings at all. Team members responded that tinted glass has often been used in multifamily housing and is one of the only effective strategies for reducing low angle sun and glare to provide tenant visual comfort. The team noted that the tint used in residential applications is typically not as dark as is sometimes used in office buildings.

Concerning the issue of energy conservation incentives under Section-8, most jury members agreed that there currently is little reason for owners to pay for energy conservation in tenant apartments. One jury member did point out, however, that the Department of Housing and Urban Development (HUD) has been willing in the past to spend $5,000 to$10,000 per unit for major rehabilitation projects. Energy improvements are an important issue in this program.

One jury member questioned the assumed infiltration rate in this building. He argued that an overall infiltration rate of 0.8 air changes per hour is still relatively high; too high in fact, for a building as tight as this one. If he is correct, projected savings would be lower and paybacks longer than those reported here. Given normal construction practices for frame buildings, the majority of the design team members did not agree with this point of view.

Finally, one jury member proposed a revision of current HUD regulations that would allow the government and building owners to share in energy savings. Energy cost savings could be shared by the three principal interested parties. For example, an energy bill reduction of 25 percent could be divided into three equal portions. One-third of the savings would be an increase in tenant's net income and an incentive to conserve; one- third could be used to reduce government subsidy; and one-third could be used to increase owner revenue as an incentive to finance conservation improvements. The tenant's contribution would have to increase as a percentage of total income, but this should be acceptable given that net income actually increases.



Low energy costs in a northwest low-rise

Situated in Bellevue, Washington, just east of Seattle, this three-story low-rise building presented a most difficult problem when looking for cost-effective energy savings. Not only is this area relatively temperate, but it has the lowest energy costs in the country -- 30 percent below the national average in spite of recent significant increases.

Although there are 48 units in this 55,000 gross square foot all-electric building, the owner's total annual energy bill is only $3,000. This is true because of very low common area heating and lighting costs, and because tenants pay all energy costs for the units through individual meters. Tenant energy bills average $49 per unit per month or $28,000 annually for the building.

Although the design teams found potential energy cost savings of $3,000 to $11,000 per year, benefits fell almost entirely to tenants. If reasonable paybacks are to be achieved on improvements paid for by the owner, the owner must get some advantage for lowering tenant utility bills -- either in higher rents or in some market advantage gained by offering a building with lower utility costs. This may be possible in an area recently sensitized by rapidly rising energy costs.

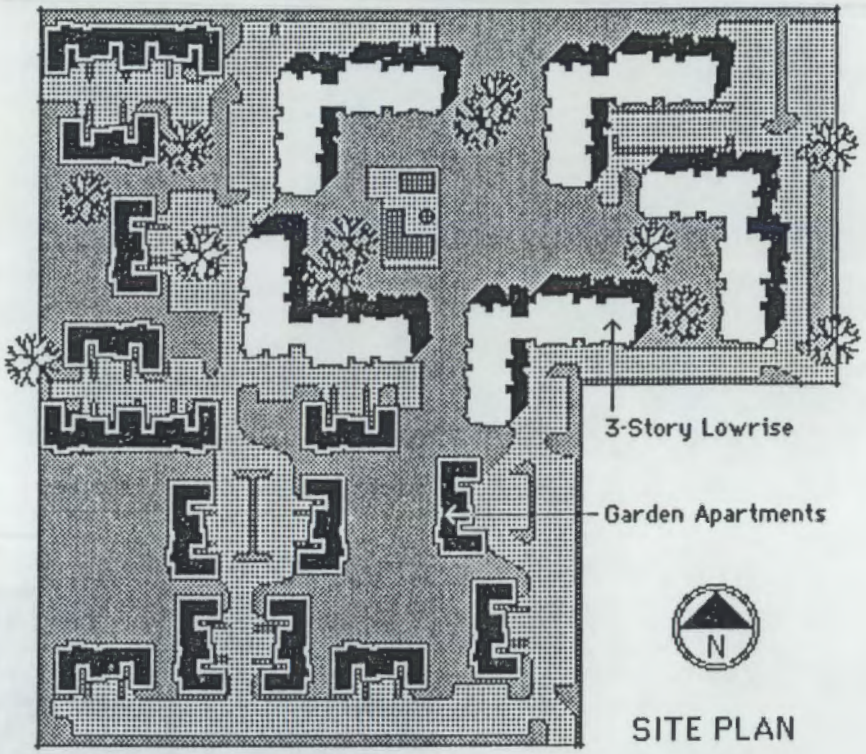
Building Layout

Bellevue, WA

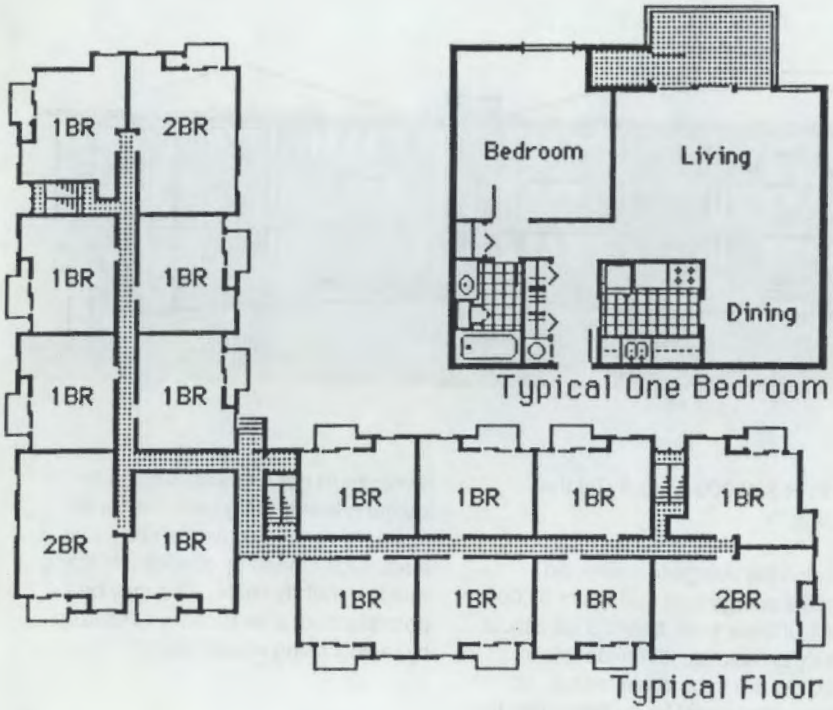
The building selected for analysis is one of 19 buildings on a large 16-acre site. As seen on the site plan (at right), building orientations are highly varied. The building selected is the largest of three types on the site. It has 48 units allocated equally over 3 floors (see typical floor below). Thirty units are modest sized one-bedrooms (700 square feet average). Nine units are larger one-bedrooms (900 square feet) and nine units are two-bedrooms (1,000 square feet). The most common unit floor plan is illustrated below.

Parking is provided in open garages located beneath the first floor. There are 27 covered parking spaces per building.

A small common area (not shown) is located at the juncture of the two wings of the building on the garage level. It has a small lobby, three large storage rooms with individual storage closets, and a laundry with six washers and four dryers. One elevator is also located in this area for freight access.



SITE PLAN



Typical One Bedroom

Typical Floor

Each unit is supplied with an electric stove and refrigerator. According to management, there are no electric window air conditioners in the building. The building is individually metered. The common area of each building is metered separately from all other buildings in the complex. The community pool is heated but was not included in this analysis.

Net rentable area is approximately 38,000 square feet out of a gross area of 55,000 square feet. This yields a net-to-gross ratio of approximately 70 percent.

Building Specifications & Operations

The specifications for this 1968 building show an awareness of energy conservation ahead of its time. It has 2" batt insulation in all exterior walls, 4" batt insulation in the roof, and an overall electrical design well under two watts per square foot. All are good basic conservation strategies and hard to improve upon cost-effectively.

BUILDING SPECS

ENVELOPE:

- Exterior Wall
  1/2" cedar siding, 1/2" gypsum sheathing, 2" batt insulation, 2x4 wood framing, and 1/2" gypsum wall board (R=12.0).
- Window
  Aluminum frame anodized sliding windows with single pane, U = 1.42, shading coefficient = 0.64 with blinds
- Roof
  3-ply built-up roofing, 1/2" plywood roof sheathing, 4" batt insulation, joist/attic space, and 1/2" gypsum wall board ceiling finish (R=14.2)

INTERNAL LOADS

- Lights: 0.5 Watts/s.f.
- Appliances: 0.4 Watts/s.f.
- Cooking: 6000 Btu/day (40% latent)
- Infiltration: 0.8 Air Change/hr.(corridors, 1.0 ACH)

OTHER LOADS:

- Lighting in common areas : 0.3W/sq. ft.
- Exterior Lighting: 2.4 kW operated 12 Hours/day

Given the wood frame construction, single-pane sliding windows without storm windows, and the likelihood of modest caulking, the team assumed the infiltration rate for the building to be between 0.8 and 1.0 air changes per hour. This is not especially high but could be improved.

Electric resistance heat provides tenants with a high degree of individual control and opportunities for individual conservation via nighttime and daytime set-back. Modest set-backs are assumed in our calculations. Although electric resistance heating is a costly option when heating is called for, more efficient heat pumps cannot really be justified here because there is virtually no cooling load and therefore no need for the air conditioning feature offered by heat pumps.

Although the owner does supply a modest amount of heat to the corridors, the main energy issue for the owner is in supplying hot water for the laundry. We have assumed usage of ten gallons per unit per day for the laundry.

Since the owner is supplying "free" hot water to the units, management may want to monitor laundry use. It has been found that outsiders sometimes enter the building and use washers. Since the coin fee goes to the laundry equipment supplier, the cost of extra hot water is lost to the owner. If this problem is found to exist, laundry equipment can be changed to accept only tokens which may be purchased by tenants from the resident manager.

SYSTEM SPECS

HVAC

Electric resistance baseboard with individual thermostats

TEMPERATURE SETPOINTS

Heating: 70°F, weekdays: 7-9 a.m, 6-11 p.m. weekends: 7 a.m.- 11 p.m. 60° F, at other hours (corridor, 45°F, at all times)

Cooling: none provided

DOMESTIC HOT WATER

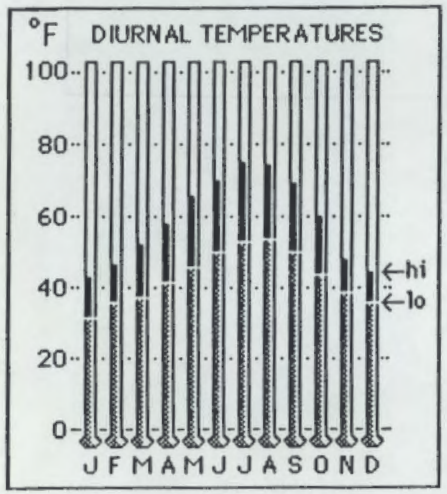
25 gallons/unit/day
Nominal efficiency = 75%
Stored at 125 °F
Laundry : 10 gallons/unit/day

Energy Analysis

Bellevue, WA

With a reasonable design and a temperate climate, this building has one of the lowest annual energy consumptions of the nine existing buildings studied in this book. In an area with the lowest energy rates in the country, it also has the second lowest annual energy bill. There are opportunities for energy conservation in this building, but the savings to pay for these improvements are small.

The climate has cool temperatures throughout the year. It rarely gets extremely cold, but many hours of the year require heating



Although this climate is generally temperate, there is still a heating requirement. As illustrated on the chart (below), average daily temperatures in December and January drop into the 30s. A low but rather constant requirement for heating adds up to 1,600 hours a year requiring some mechanical heating. Heating can be called for in <u>any</u> month of the year.

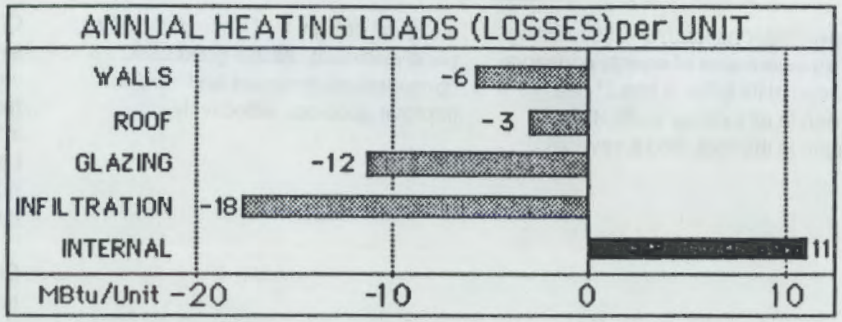
Also, this is not an ideal climate for passive solar heating. There is simply not enough winter sun. On average, there are only four to seven clear days during any winter month.

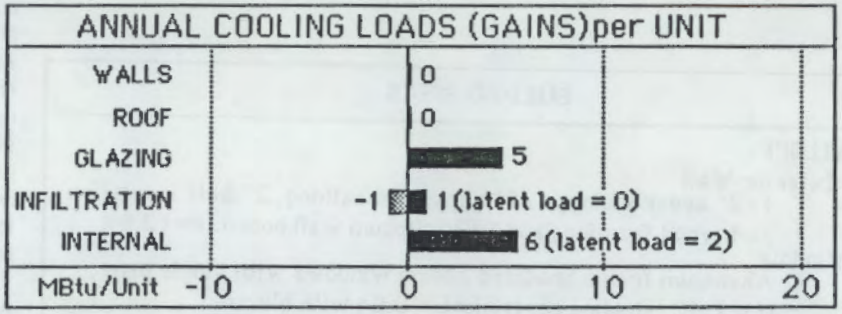
Heating is the greatest energy demand in the building. On average, heating costs tenants $24 per month, but heating bills in winter can be twice that amount. There are two main causes of heating loads. The main heat loss is due to air infiltration. Relatively "leaky" windows, lack of storm windows, and typically rather loose frame construction all contribute to air infiltration. The other main cause is the loss of heat by conduction through glass. In this case, there is little daily solar gain to offset losses.

Because heating and cooling loads are so modest, the cost of heating domestic hot water becomes relatively more important in this climate than in more severe climates. Water heating is the second highest energy cost for tenants in this building. This is based on assumptions of average use which, of course, can vary widely depending on occupant habits. This system also has high stand-by losses because storage is decentralized. There are water heaters within each apartment. Also, tanks are located in exterior utility rooms where the benefit of lost heat goes to the outside rather than to occupied spaces.

The third highest energy use is for appliances and receptacles -- due largely to energy used by the refrigerator. Lights are the fourth highest use due to the use of incandescent fixtures in the apartment units.

The owner's greatest energy cost is supplying hot water to the laundry - - averaging over $3.50 per unit per month or over $2,000 per year. This is based on assumptions of average use and average efficiency of laundry equipment. The owner's other main cost is in lighting for the exterior of the building, for halls and corridors, and for storage areas.





In this building, the proportions of the annual energy bill paid for by owner and tenant are significantly different than in most of the other buildings studied. Due largely to the mild climate, the common area energy bill paid by the owner is very low -- about $6 per unit per month or a total bill of about $3,500 per year. Tenant bills from individual meters average $49 per unit per month or about $28,200 per year (see bar chart below). On a per unit basis, tenant bills outweigh owner bills by eight to one.

Who pays the energy bill is important when it comes to paying for conservation improvements. An owner bill of $3,000 leaves little room to achieve good payback without other considerations.

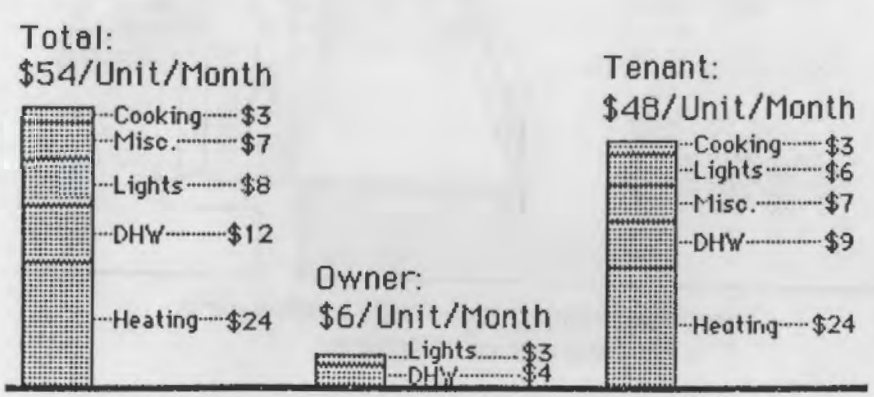
As will be shown in the pages to follow, conservation can save from $5,000 to $11,000 per year on the total building energy bill, but most of the savings benefit will fall to tenants. If owners are going to be expected to pay for energy conservation improvements, they will either have to accept unusually long paybacks or in some way share the benefits of reduced tenant energy bills. Raising rents would be a simple solution. If not, value would have to be found in some other part of the rental equation, such as higher occupancy or lower turnover rates.

In the near term, lower utility bills could be a real market advantage in attracting tenants who are highly sensitized to energy costs. As shown on the graph, the Bellevue area (served by Puget Power & Light) has recently experienced a dramatic increase in electric rates after a very long period with the lowest rates in the country. Although still 30 percent below the national average, electricity rates have doubled in the last three years.

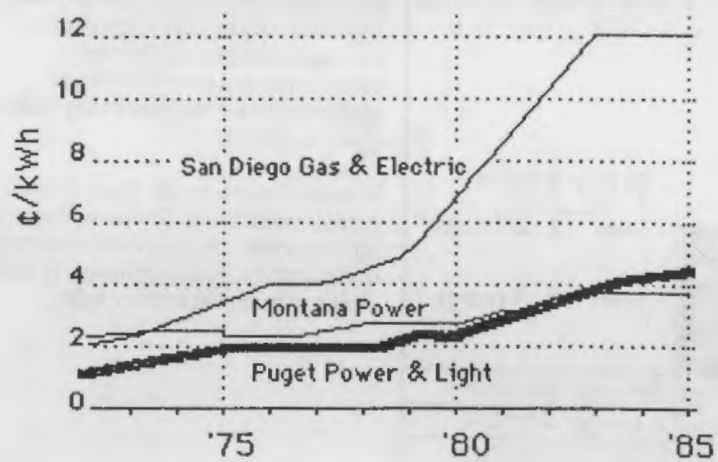
According to comparative statistics, the opportunity for raising rents significantly in this building may be limited. This building rents on average for $6.35 per square foot of rentable space. This is slightly above the high average for the Seattle area, according to a 1984 study of 1,600 apartments by IREM. Nevertheless, a modest 4 percent increase in rents ($17 per unit per month), could raise $10,000 per year. This would be enough to finance a significant conservation improvement program.

Overall shelter costs, including energy costs, are modest in this area. Tenants can qualify for this building with an income that is well below the median income for the nation.

Washington State Lowrise — electricity 5.1¢/kWh



AVERAGE RESIDENTIAL ELECTRIC RATE, 1972 - 1985

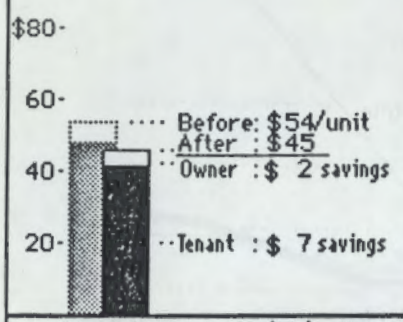


Operations Team A

Bellevue, WA

STRATEGIES & COSTS	
Envelope:	
- Add 4-mil poly to crawl space	250
Infiltration/Exhaust:	
- Caulk all cracks: Floor joists & band board	4,303
- Add adj. crawl space vents	396
Lighting/Appliances:	
- Relamp common area with screw-in fluorescents	870
- Install time clocks on ext. lights	440
- Install high-eff. ranges & refrig.	7,000
DHW:	
- Insulate laundry DHW heater	150
- Reduce DHW temp. to 115°F	-0-
- Install time clocks on laundry DHW	125
- Install high-eff. laundry equip	-0-
TOTAL COST:	$13,534

UTILITY BILLS



Monthly Savings: $9/unit

Annual Savings: $4,936

PAYBACK: 2.7 Years

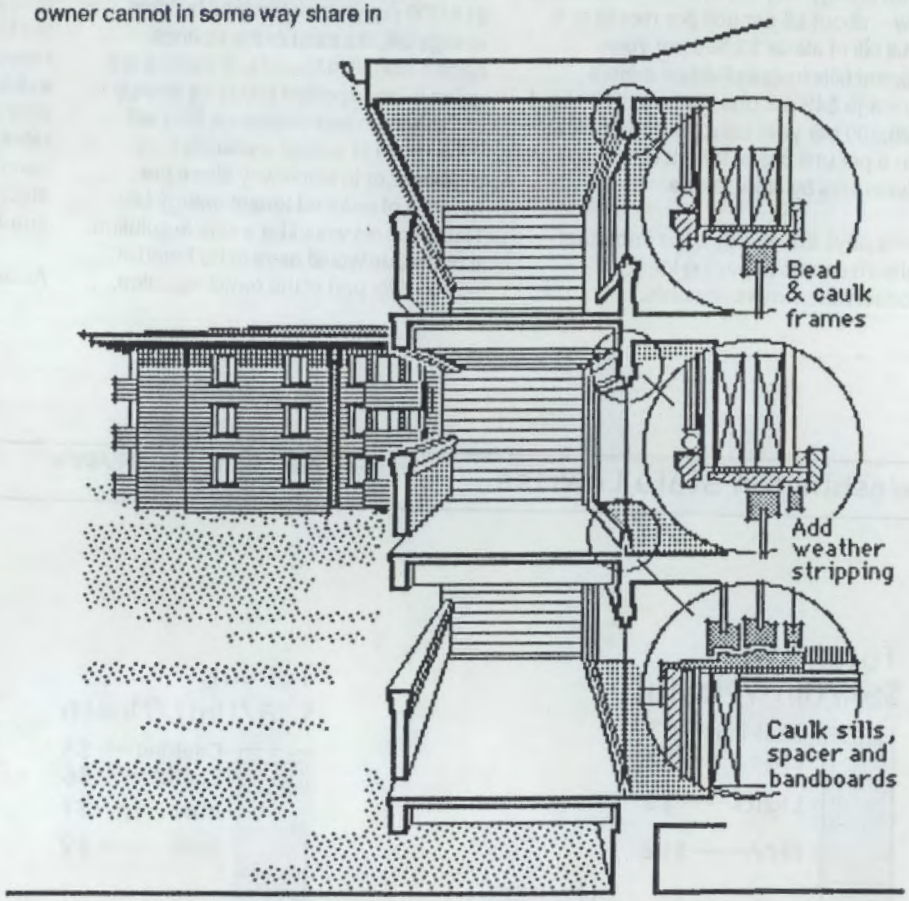
Team A took an aggressive approach to operations improvements, recommending conservation strategies that would reduce energy bills for both the owner and tenants significantly. Total estimated savings of $5,000 per year would reduce annual energy bills 17 percent with an overall payback of 2.7 years.

The team focused on two major strategies to reduce tenant bills. To cut heating costs, Team A recommended three measures to reduce infiltration. The most costly would be major recaulking of the building at all important construction joints. As shown in the illustration, caulking should be applied to door frames, window frames, band boards, and balcony spacer boards. Team A also suggested adding a 4-mil plastic sheet on the ground below the first floor)to reduce moisture migration.

The second major recommendation to reduce tenant bills was to replace standard ranges and refrigerators with high efficiency models at the normal time for replacement. With an incremental cost of about $70 per appliance, this is the most costly item in this strategy set.

To reduce owner costs, Team A focused primarily on lighting. They recommended relamping with screw-in fluorescents in all common areas and installing time clocks to control all exterior lights.

Several low cost improvements were recommended to cut owner DHW costs. The four strategies recommended cost $275, but are estimated to save over $500 per year in owner water heating costs. The distinction between owner and tenant bills is important here. If the owner cannot in some way share in tenant savings, the cost of making all improvements ($13,500) would have a payback of over 13 years.



Thorough caulking at door and window joints will reduce infiltration

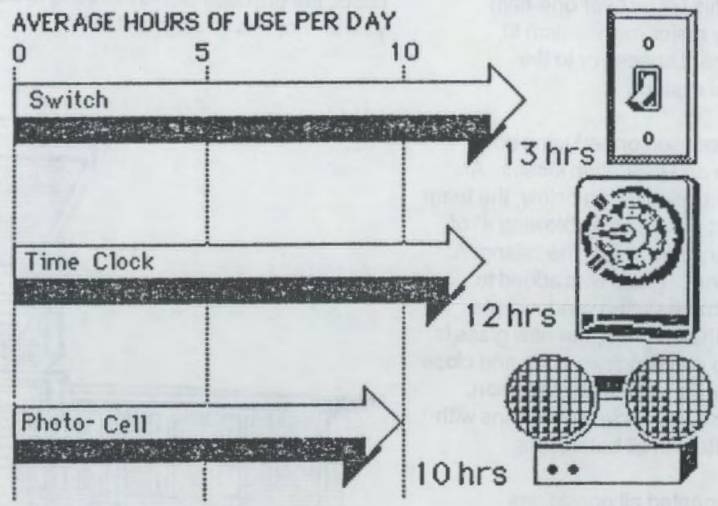
Operations Team B

Bellevue, WA

Team B took a much more restrained approach to operations improvements, focusing primarily on reducing the owner's operating costs. This is the only strategy of the five proposed for this building where the owner would receive a payback under five years from savings on his bill alone.

Starting with the owner's largest annual energy cost, Team B recommended two strategies to reduce hot water heating costs for the laundry. First, the team proposed reducing the temperature of delivered water from 125° to 110° F. The team felt this temperature was sufficient to meet most laundry washing needs.

Second, the team recommended installing high efficiency laundry equipment to reduce both hot water needs and electric drying costs. If the present laundry equipment is owned by the building, this change-over should be made at the end of present equipment life. If the equipment is owned and maintained by a contractor, this change should be made as part of negotiations for the next contract period.



Manual controls for exterior lighting are rarely as efficient as automatic controls

To reduce owner lighting costs, Team B recommended installation of photocell controls on outside stairwell lights. As shown on the illustration, a photocell control can significantly reduce the number of hours when lights are on.

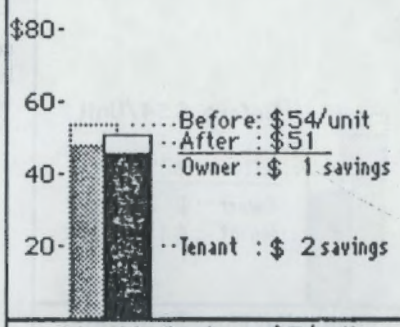
To reduce tenant hot water costs -- the second highest annual cost for tenants -- the team recommended installing flow restrictors in showers and sinks. Although flow rates through these devices are generally acceptable, there can be complaints from those who are aware of "before" and "after" flow rates. For this reason, it is recommended that the owner install these devices at a change in tenancy. The devices are typically very inexpensive and are often available from local utilities as part of a package of conservation improvements. The main cost is labor.

With total building savings of $1,600 per year, a total conservation budget of $1,160 could be repaid in only 9 months. The entire cost of improvements could be paid for with owner savings alone in 2.3 years.

STRATEGIES & COSTS

Lighting/Appliances:	
- Photocells (2) on ext. stair lights	$350
DHW:	
- Reduce laundry DHW temp. to 110°	-0-
- Install flow restrictors in showers and sinks	810
- Install high-eff. equip in laundry	-0-
TOTAL COST:	$1,160

UTILITY BILLS



Monthly Savings: $3/unit

Annual Savings: $1,619

PAYBACK: 8 Months

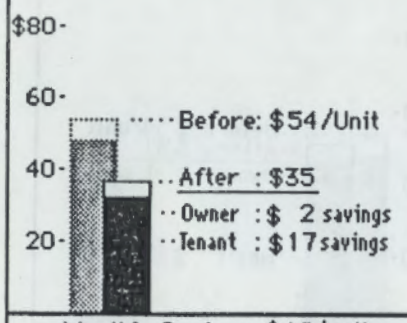
Retrofit Team A

Bellevue, WA

STRATEGIES & COSTS

Envelope	
- Repeat Operations Strategies	250
- Add 4" insulation in ceiling	8,400
- Add second pane of fixed glass to existing windows	9,983
Infiltration/Exhaust:	
- Repeat Operations Strategies	4,699
- Add recirculating fans for baths	4,275
Lighting/Appliances:	
- Repeat Operations Strategies	1,310
- Install high-efficiency ranges & refrigerators at replacement	7,000
DHW:	
- Repeat Operations strategies	275
- Add insulating jacket to individual unit DHW	1,200
Building Site Design/Massing and Solar Control:	
- Landscaping - 4 trees and ivy	2,500
TOTAL COST:	$39,892

UTILITY BILLS



Monthly Savings: $19/unit

Annual Savings: $11,076

PAYBACK: 3.6 Years

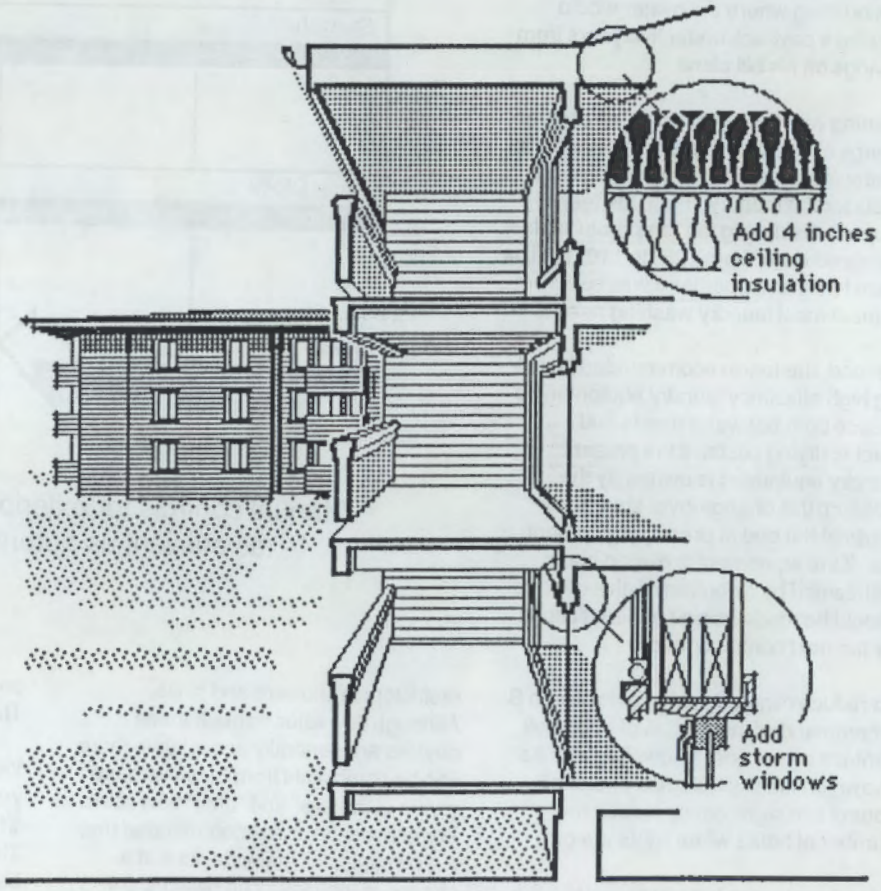
In this strategy set, Team A is able to reduce the total energy bill for the building by one-third (and the heating portion of this bill by over one-half) without any major modification to existing tenant spaces or to the mechanical system.

The team focused on reducing both conduction and infiltration losses. As shown on the illustration below, the team cut conduction losses by blowing 4" of additional insulation into the ceiling. A second pane of glass was added to each aluminum sliding window. (As shown on the diagram, the new glass is secured so that windows open and close as before.) To reduce air infiltration, Team A installed recirculating fans with charcoal filters in all bathrooms.

Team A repeated all operations strategies to reduce owner DHW costs, but also recommended adding insulation "jackets" to all apartment water tanks to reduce stand-by losses and related costs to tenants.

The team recommended adding landscaping to provide shading on the building in the summer while reducing wind loads in the winter.

Overall payback for this strategy set was under five years. However, if owner savings alone had to pay for all strategy costs, the payback would increase to 38 years. For this strategy set to be acceptable, the owner would have to see an advantage in offering tenants lower energy costs and more comfortable apartments.



Added insulation and additional glazing are used to cut heat losses

Retrofit Team B

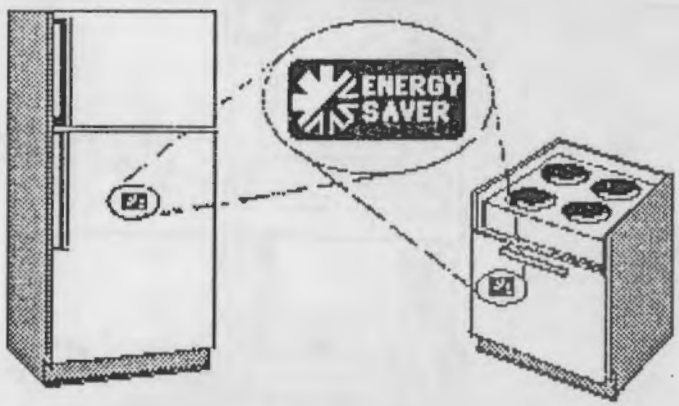
Team B took an approach similar to Team A, but spent the majority of their retrofit budget on adding a second, separate aluminum slider (similar in design to the existing windows) to serve as an operable storm window. Energy results are similar, with a total building energy bill reduction of one-third, but the cost of the summary set is somewhat higher.

In this strategy set it is clear how much more costly it is to purchase and install separate and operable storm windows, about $20,000 more than the fixed glass solution used by Team A. In general, the suggestion of adding additional glazing in this climate may be controversial. Team members argued that a combined strategy to improve the skin of the building should include more insulation, improved caulking, and storm windows. It was believed that major savings can be achieved only with a complete package of improvements. In fact, the whole package of heating-related strategies is estimated to payback in about five years.

To reduce owner lighting costs, the team recommended using screw-in fluorescent lights in all common areas and converting to high pressure sodium for all exterior lights. The conversion to high pressure sodium is relatively costly and should be studied further before implementation.

Team B also recommended converting to high efficiency appliances in the apartment units at the time of normal replacement. This improvement would reduce each tenant bill by about $2 per month with a payback of about 6 years -- much shorter than the life of the appliance. As shown in the illustration, the "Energy Saver" label on all new appliances makes it much easier to identify the most efficient models.

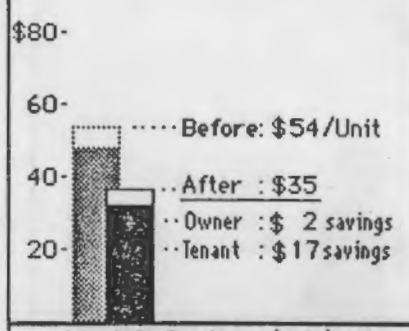
Total building savings of over $11,000 yield a 5 year payback on a total investment of $56,000. However, if owner savings alone had to pay the full cost of improvements, the payback would be unacceptable.



Energy efficient models make a lot of sense. The incremental cost is small compared to years of low-cost efficient operation

STRATEGIES & COSTS	
Envelope:	
- Add roof insul. to (R-30)	8,111
- Add new single-pane slider as storm windows	29,272
Infiltration/Exhaust:	
- Caulk or seal all doors and windows	4,500
Lighting/Appliances:	
- Repeat Operations Strategy	350
- Add screw-in fluor. in common area	870
- Change all ext. lights to high pressure sodium	4,140
- Install high eff. appliances	7,000
DHW:	
- Repeat Operations Strategies	810
- Add insulating jacket to individual unit DHW	1,200
TOTAL COST:	$56,253

UTILITY BILLS



Monthly Savings: $19/unit

Annual Savings: $11,169

PAYBACK: 5.0 Years

Rehabilitation Team A

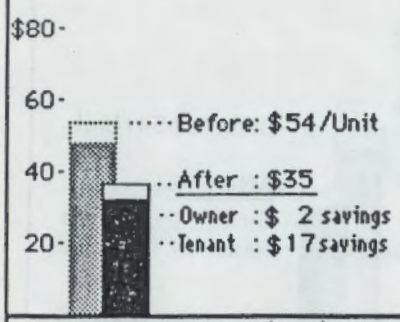
Bellevue, WA

STRATEGIES & COSTS

Envelope:	
- Repeat Retrofit Strategies	25,063
- Insulate carport and crawl space to R-26	2,415
Infiltration/Exhaust:	
- Repeat Retrofit Strategies	8,974
Lighting/Appliances	
- Repeat Retrofit Strategies	8,310
- Add skylights to top floor living room	5,600
- Add 4 corridor skylights and photocell lighting control	1,650
DHW:	
- Repeat Retrofit Strategies	1,475
Building Site Design/Massing and Solar Control:	
- Repeat Retrofit Strategy	2,500
TOTAL COST:	$55,987

Note: Added cost for balcony sunspaces (not paid for with energy savings alone) is $54,720

UTILITY BILLS



Monthly Savings: $19/unit

Annual Savings: $11,065

PAYBACK: 5 Years

Team A began with the assumption that rehabilitation typically occurs at a change in ownership, when there is new financing and a chance to make very big changes.

Team A proposed enclosing existing balconies to create "sunspaces" or, given the climate, "rainless" spaces. As shown on the illustration below, existing handrails are rebuilt to become insulated knee walls with operable windows above. The existing concrete floor is refinished with thin set brick or quarry tile. The wall between the balcony and the living room remains insulated.

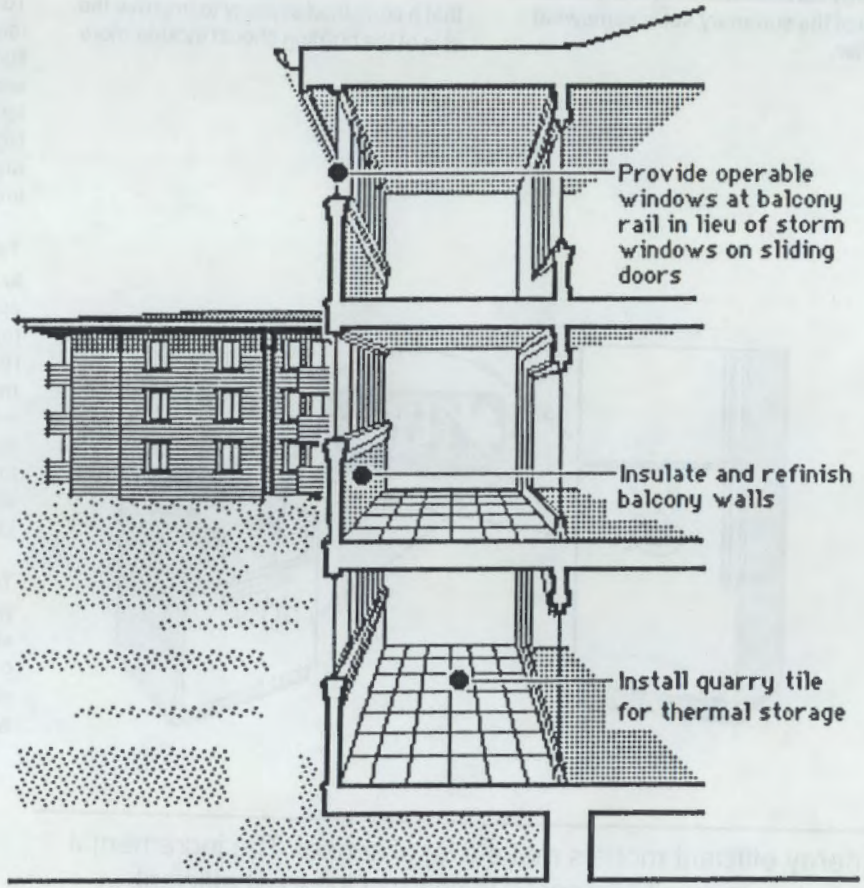
The major values in this conversion are an added amenity for the building and a 5 to10 percent increase in rentable space. The main energy advantage is creation of a thermal buffer between the outside and the living room as well as a reduction in infiltration.

The team also recommended using natural light to further add to the amenities and to cut lighting bills. Skylights are proposed for the top floor of the building in both living rooms and common corridors. Corridor lights would be controlled by photocells to insure sufficient lighting levels at all times.

The crawl space and the joists above the carports are insulated to reduce heat losses and make warmer floors.

Annual energy costs are reduced by $11,000 (about the same as retrofit), for a cost (excluding new balconies) of $56,000 or a payback of 5 years. It is surprising to see that energy savings alone could pay for the new sunspaces in just ten years.

However, added rents from the extra rentable space could pay for all the proposed energy improvements. Paybacks are unreasonable if they are computed only with savings accruing directly to the owner.



Enclose Balconies to Create Sunspaces

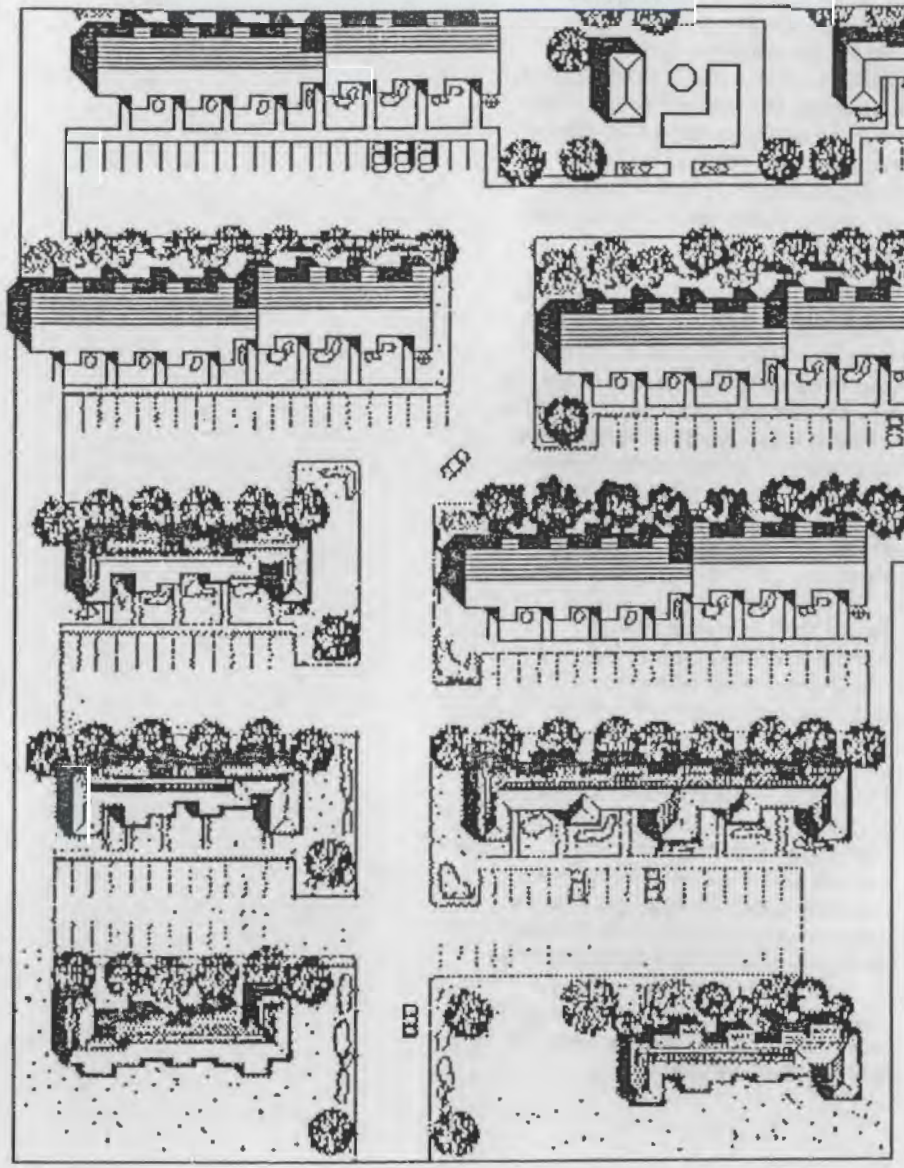
Rehabilitation Team B

Rather than focus strictly on the issue of rehabilitation, Team B chose to do a "sketch problem" on the issue of building orientation. The team believed that highly varied building orientations on the site limited the potential for solar and other building improvements. Their goal here was to see if the same number of buildings could be reoriented on the same site to achieve better north/south exposure and thus create the opportunity for simple solar solutions (to take advantage of what sun is available) and for other site oriented strategies like landscaping and building shading.

The north and south faces of each building are treated differently to take advantage of different climate characteristics. The north face of each building has limited exposure, higher insulation, and a high degree of buffering from prevailing winds. South faces, on the otherhand, have more openings to the sun, roofs situated for active or passive solar applications, and entrances protected from wind.

Other goals for the site were to increase the number of units with views to trees rather than to other units, to reduce the amount of traffic past most units, and to eliminate parking under the buildings.

Doing a precise cost and energy analysis of this full-site study was beyond available resources, so no strategy costs or savings are given.



Site Plan:

North Units:

1. Minimize stairs facing North
2. Views to treed windbreaks
3. Reduce glazing area
4. Higher insulation levels
5. Radiant barriers

South Units:

1. Optimize glazing for passive solar heating
2. Potential for greenhouses
3. Roof slope for active solar systems

Overall:

1. No parking under buildings
2. Taller buildings to north (windbreaks)
3. Open space to south to allow solar gain.

Jury Comments

In the area of operations, the jury complimented Team A for focusing on limiting the use of laundries to tenants only. With the owner supplying all hot water, there is a hidden cost for allowing outside use of the laundries. If the cost of using laundry equipment is kept low to benefit tenants, the amount of outside use can be even higher. As mentioned earlier, one jury member suggested converting coin machines to plastic tokens which are purchased by tenants from the resident manager to control use.

As to retrofit strategies, the jury again questioned the acceptability to either owner or tenants of the color of high pressure sodium lighting on the exterior. Some members felt that mercury vapor or metal halide provided light with more acceptable colors.

One jury member questioned the cost effectiveness of adding 2" of insulation beyond the 2" already in the walls. The team responded that heating is still an issue in this building; the quality of the original insulation job could not be judged; and that should energy costs rise in this area to match the rest of the country, added insulation would become more economical very quickly.

One jury member suggested going to radiant heat panels instead of baseboard electric heaters in the corridors to improve appearances. Baseboard heaters typically "take a beating" in corridors.

As to rehabilitation strategies, one jury member suggested checking the cost effectiveness of heat pumps in this climate, given the new higher electric rates. Heating costs would be reduced and air conditioning would be available for those who wanted to use it. Closer study would be required to see if savings could justify higher first cost and higher maintenance costs for heat pump equipment.

Another jury member pointed out that it is very misleading to compute payback on the proposed new sunrooms based on energy savings alone. There are many economic issues involved and the relatively long payback shown is totally misleading. In this case, energy is only one factor influencing the decision to significantly improve the building and should not be portrayed as the only issue.

Finally, there were a number of comments on the new site design. For one, the new linear arrangement of the buildings was criticized as "visually boring." For another, eliminating parking under the building was questioned. Even though it cut both building costs and energy costs, sheltered parking could be an attractive marketing advantage in this rainy climate. Also, the whole question of trying to improve solar orientation in the Seattle climate was questioned. It would be interesting to see if orientation issues such as reducing wind loads and infiltration could justify the proposed approach without any benefits from solar energy.

Future Boston Highrise

The preliminary design proposed for this highrise apartment in Boston called for a twelve-story structure of about 165,000 square feet situated on a two and one-half acre site. Its broad mix of unit types includes some less conventional designs including a den or a "split" floor plan more attractive to those wishing to share an apartment with an unrelated individual.

For purposes of comparison, the preliminary design met current ASHRAE standards. Subsequent designs proposed by the design teams improved on these basic standards to illustrate what is possible using innovative energy conscious design in the future. The base building as proposed uses 30% less energy than the pre-1973 public housing building in this study, and is 10 to15 percent below average energy use for buildings of this type in the Boston area.

Through design changes, both design teams were able to reduce the energy use in this building an additional one-third -- a savings of over $35,000 per year in both cases. Team A accomplished this by redesigning the building into virtually one large passive solar collector. Team B did it with an innovative atrium design. Team A's changes were made at virtually no increase in first cost and Team B's recommendations were paid for in six and one-half years with energy savings alone -- not including added rents from the extra units they put into the building.

Building Layout

This is a high density project at seventy dwelling units per acre. There is sufficient space on the lot for 148 spaces of surface parking. A garage under the building houses an additional thirty-one cars. Although only one-third of the available parking is covered (beneath the building), there is a 1:1 parking ratio for the project overall.

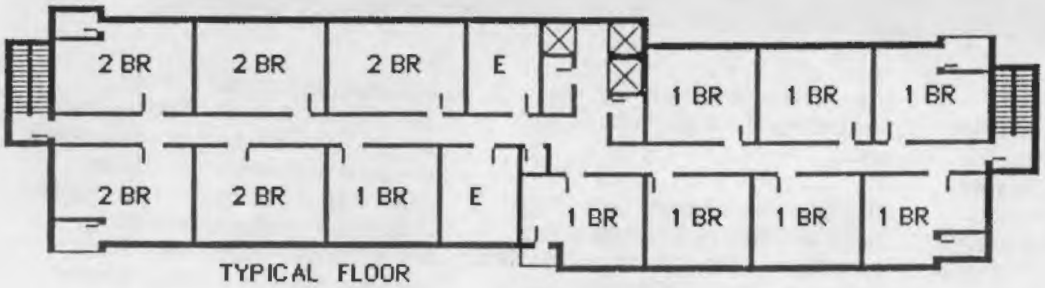
As shown in the table below, there are five different unit types in the building. Most units are one-bedroom (34%), followed by two-bedroom and conventional units. This project uses the same unit designs as the other two future buildings in this study, which have been downsized to reflect current market trends to reduce unit costs. Unit plans for the one-bedroom unit and the more innovative two-bedroom "split" unit are shown on the next page.

The building is laid out with a simple double loaded corridor. The fifteen units per floor are arranged to minimize corridor lengths and to make the building as compact as possible. Glass area in the units ranges from eleven to sixteen percent of floor area -- roughly twice that required by code.

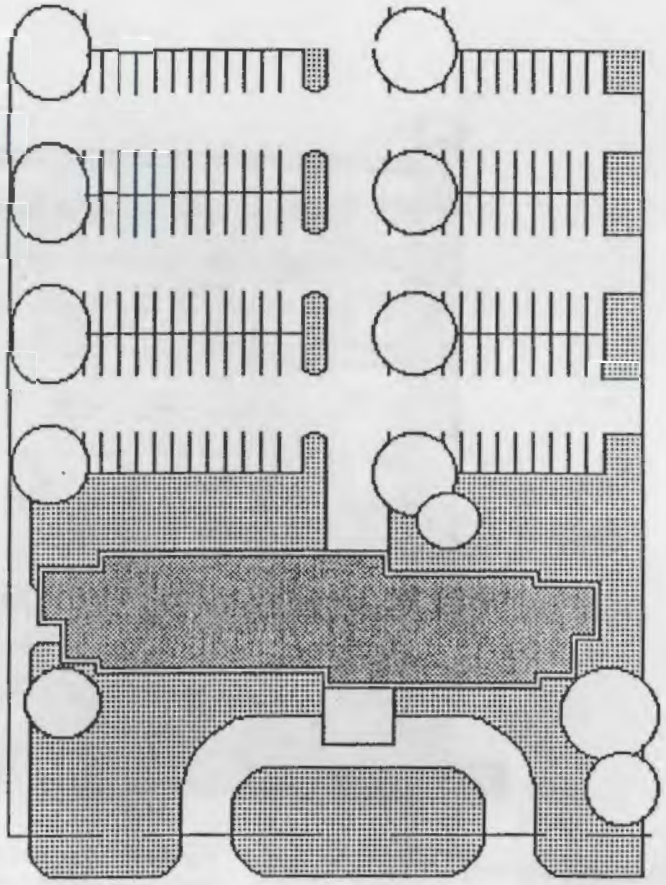
As shown on the site plan, the building has an east-west axis with all units facing either north or south. This orientation presents an opportunity for passive solar solutions, but they were not considered in the base design.

MIX OF UNIT TYPES

Type	Total	Mix	Size
Efficiency	24	13%	480 SF
1-Bedroom	60	34%	648 SF
1-BR and Den	35	20%	708 SF
2-BR Conven.	36	20%	808 SF
2-BR "Split"	24	13%	836 SF
Total	179	100%	



All Units Are Oriented North or South



Site Plan

Building Specifications & Operations

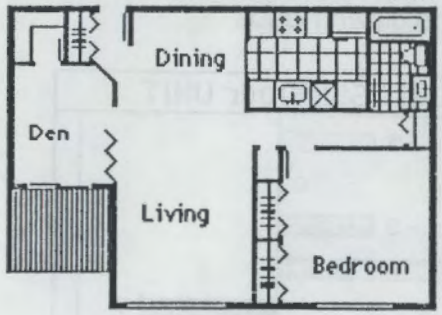
Specifications for this future building represent good practice as of 1986, without exceptional efforts to achieve outstanding energy savings. The roof and walls are insulated to current ASHRAE-90 standards. Windows are double glazed. With good quality windows and with attention to caulking and weatherstripping during construction -- as might be expected today -- it is assumed that infiltration in both the corridors and apartment units of this building will be only 0.4 air changes per hour. This rate is significantly lower than rates for the existing buildings in this study.

Lighting in the units is presumed to be 0.5 Watts per square foot and in the corridors 0.3 Watts per square foot. Both are modest and below the norm for most existing buildings.

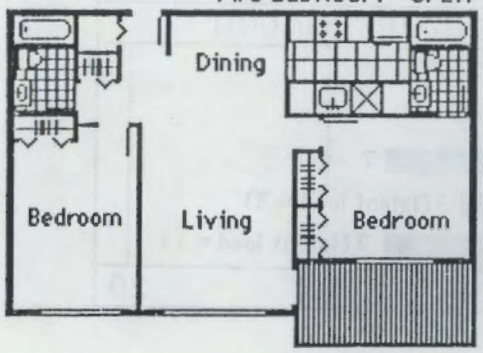
Units are heated and cooled with hydronic heat pumps which are supplied from a "run-around" hydronic loop. During the heating season, supplemental heat is supplied to the loop from two gas-fired boilers (70% efficient). In the cooling season, excess heat is removed from the loop with a cooling tower on the roof of the building. The principal advantage of this system is that excess heat from solar gains on the south side of the building can be "collected" into the hydronic loop (via the heat pumps), and delivered to the cooler northerly side of the building. This process not only reduces overheating and increases tenant comfort but also reduces the amount of supplemental energy that must be supplied to the loop by the owner.

Corridor heating is done with a constant volume packaged HVAC unit located on the roof of the building. It conditions 100% outside air.

ONE BEDROOM - DEN



TWO BEDROOM - SPLIT



BUILDING SPECS

ENVELOPE:

- Exterior Wall
  4" Brick, 4" block, 1-1/2" furring, (R-6) rigid insulation
  1/2" foil back gyp bd.
- Window
  Double pane, 1/8" clear aluminum frame with no thermal break
  U = 0.57; shading coefficient = 0.64 with blinds
- Roof
  Single ply black rubber roofing, 6" tapered polystyrene
  (R-24), conc, deck, sprayed acoustical ceiling finish.

INTERNAL LOADS

- Lights: 0.5 Watts/s.f.
- Appliances: 0.3 Watts/s.f.
- Cooking: 6000 Btu/day (40% latent)
- Infiltration: 0.4 Air Change/hr.

OTHER LOADS:

- Lighting in common areas: 0.3 W/sq. ft. (garage, 0.5 W/s.f.)
- Elevators: 19 kW
- Exterior Lighting: 25 kW operated 12 Hours/day

SYSTEM SPECS

HVAC

Hydronic heat pumps (1 ton units, efficiency and one-bedroom; 1-1/2 ton, two-bedroom) off central "run around" loop, COP=3.0, EER=9.2
(roof-mounted package HVAC, gas heated, for corridors)

TEMPERATURE SETPOINTS

Heating: 70°F, weekdays: 6-8 a.m, 4-11 p.m.
weekends: 7 a.m.- 11 p.m.
65° F, at other hours

Cooling: 78°F, weekdays: 6-8 a.m, 4-11 p.m.
weekends: 8 a.m.- 11 p.m.
82°F, at other hours

CENTRAL PLANT

2 supplemental gas fired boilers
system efficiency = 70%

DOMESTIC HOT WATER

Supplied off boilers
Nominal efficiency = 70%
35 gal./unit/day @125°F

BOSTON, MA

Energy Analysis

Boston is a cold climate, though not as cold as other cities in the same latitude because its climate is tempered by proximity to the sea. As shown on the graph of daily temperatures below, there is less difference between high and low daily temperatures than in many other climates because of this dampening effect. Boston has over 5,600 heating degree days (65° base) and 660 cooling degree days.

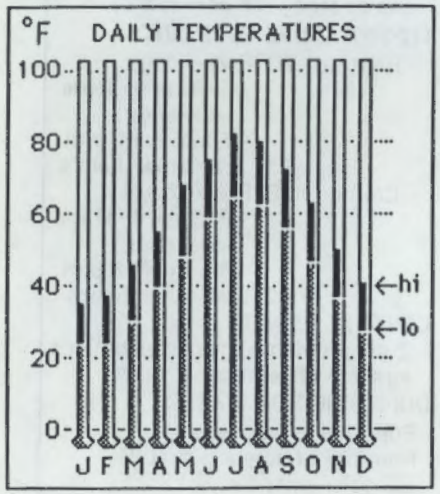
As shown on the bar chart of heating loads, infiltration is the principal cause of heating loads, in spite of the low infiltration rate in this building (only 0.4 air changes per hour). Heat losses through glazing and walls tied as the second most significant cause of heating loads. These losses are offset by internal heat gains from people lights and equipment.

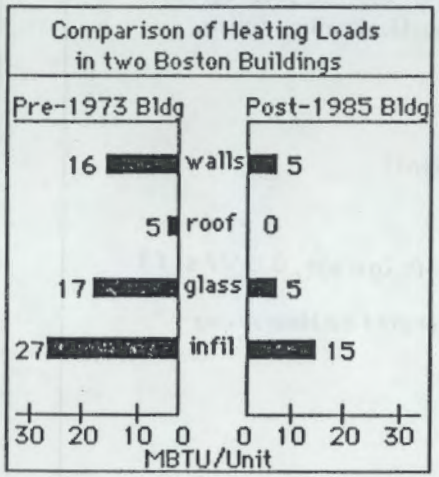
Boston is the only city in the study which is represented by two buildings -- an existing midrise building built before 1973 and this proposed future or post-1985 building. The graph below provides an interesting contrast of heating loads between a pre- and post-energy crisis building.

Infiltration losses in this building are reduced 45% (from the pre-'73 building) by replacing with tighter windows and by making special efforts to caulk and seal the building. Conduction losses through walls are reduced 70% because of additional insulation and the second pane of glass. Heating costs in this future building are further reduced by using a hydronic loop to "capture" heat gains through glass on the south side of the building to offset losses through glass on the north side of the building.

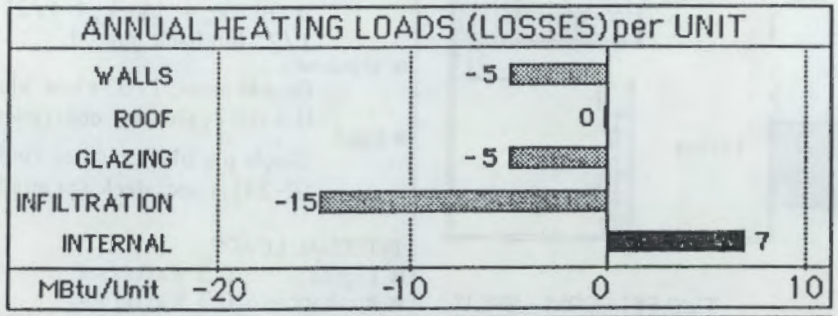
Although infiltration rates have been reduced significantly in the corridors (assumed to be 0.4 ACH), corridor ventilation is still a source of significant energy use -- especially with a constant volume system heating 100 percent outside air. Also, the amount of energy required to heat the garage while ventilating sufficiently to maintain air quality is significant.

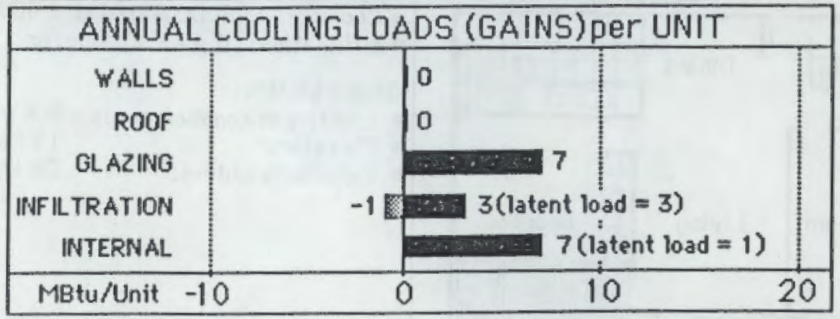
As shown on the bar chart of cooling loads, heat gains through glazing and internal heat gains from people, lights, and appliances are the principal causes for cooling the building. Both can be affected by tenants: heat gains through glazing can be reduced through conscientious use of window shade; and internal gains can be reduced by opening windows whenever possible instead of using air conditioning. These possible tenant savings are not assumed as definitely occurring, however, in the energy modeling of this base design.



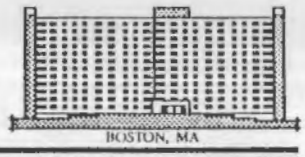


Reduced loads for the post-1985 building are still dominated by infiltration and glazing loads





Economics



As with the other future buildings in this study, all economic variables must be estimates. In this case, computer simulations suggest that the annual energy bill for this building should be about $143,000 or about $67 per unit per month. The owner's portion of this bill is estimated to be $24 per unit per month (32%) and the tenant's portion $43 per unit per month. The total energy cost for this building is about 30% less than the pre-1973 building in this study. At a total energy cost of $1.15 per net square foot of space, this building is about 10-15% below the average for the Boston area (according to a survey by the Institute of Real Estate Management) -- as would be expected for a building better than the average building stock.

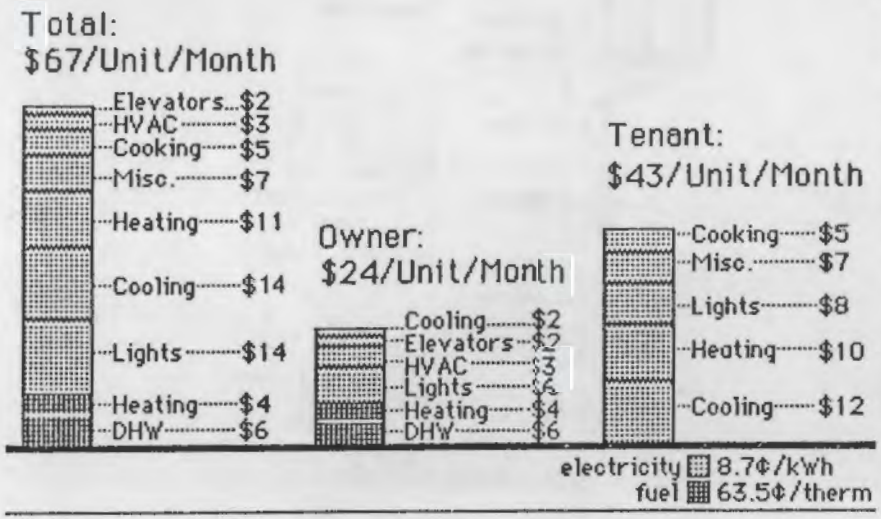
It should be noted that the owner's energy bill would be considerably lower if he or she did not provide supplementary energy into the hydronic loop and did not supply domestic hot water. Domestic hot water is the most significant cost, adding $6 per unit per month to the owner's energy bill. Supplemental heating costs about $5 per unit per month and operation of the cooling tower averages about $2 per unit per month. The owner's bill could be reduced by nearly half if these costs were transferred to the tenants.

Although heating degree days far exceed cooling degree days in this climate, heating and cooling costs are about equal in this building. This is true in large measure because the hydronic loop in the building is very good at "capturing" both solar and internal heat gains and using them to offset heating loads. It is also due to the differential in prices between gas and electricity. The tenant's highest energy bill is for cooling. This is true because the majority of the tenant's heating bill is paid for by the owner via the central boilers and the hydronic loop. The large tenant cooling bill is for electricity to run heat pumps.

The "Energy and Rent Analysis" shown in the box below is also based on assumed figures. According to the Institute of Real Estate Management, the median rent for the Boston area in 1985 was $8.53 per net rentable square foot or $574 for our conventional two-bedroom unit of 808 square feet. Given the energy costs we have estimated, return to the owner at this cost would be $550 and total shelter cost to the tenant would be $617. If rents can be up to 35% of income, the income to qualify for this unit is just over $21,000 -- still well below the median family income for the U.S. of about $26,000.

It should be noted, however, that Boston is a city with rent control regulations that tend to reduce the average rents reported for the area. Several building managers who reviewed this case study questioned whether it would be possible to build this building with the cash flow generated by average rents, unless some subsidy was also included in the economic equation. Although energy cost reduction has improved the income potential for this building, energy savings alone may not overcome other very important economic factors in the decision to build this building.

Future Boston Highrise Utility Costs



ENERGY & RENT ANALYSIS	
Typical Two-Bedroom Unit	
NET RENT TO OWNER	$ 550
OWNER'S MONTHLY ENERGY COST/UNIT	$ 24
TOTAL RENT (IREM Median)	$ 574
TENANT'S MONTHLY ENERGY COST	$ 43
SHELTER COST	$ 617
INCOME TO QUALIFY	$ 21,150

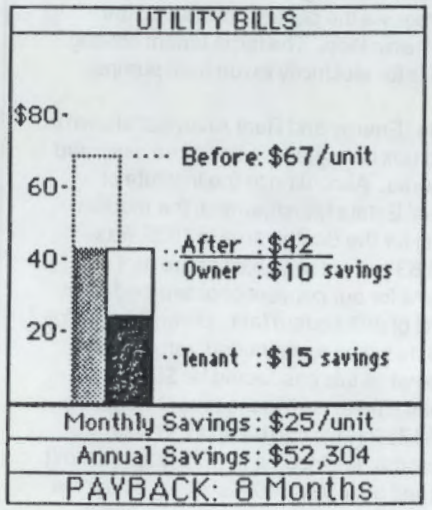
Redesign Team A

STRATEGIES & COSTS

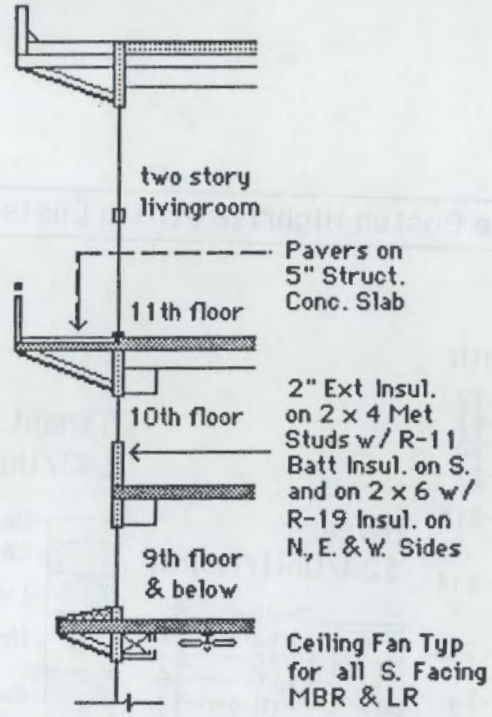
Envelope:	
- Replace masonry skin on south with 2" exterior insulation finish system on gyp. board sheathing on 2x4 metal studs, 3-1/2" batt insul. (R-11), and 1/2" gyp. board interior; on north, east, and west walls use 2x6 metal studs with 5-1/2" insulation	(200,000)
Infiltration/Exhaust:	
- Weatherstrip stairwell doors	1,000
HVAC:	
- Replace apartment heat pump with high effic. units; add through-wall fan and controls	67,000
- Down-size all heat pumps	(20,000)
- Add ceiling fans in MBR and living room - south side only	31,000
- Replace packaged corridor vent system with 2-pipe fan coil	(25,000)
- Improve boiler and chiller effic.	1,500
- Add 10,000 gal. thermal storage	47,000
Lighting/Appliances:	
- Install high efficiency appliances (at replacement)	18,000
- Replace Apt. ceiling fixtures with fluorescent	4,000
- Replace stairwell with screw-in fluorescent	400
- Replace timeclock with photocell control for ext. lighting	(100)
DHW:	
- Install high efficiency laundry equip.	-0-
- Lower DHW temperature to 120° F	-0-
- Improve central DHW boiler efficiency through heat reclaim	2,500
Vertical Transportation:	
- Add microprocessor control	18,000
Building & Site Design/Massing & Solar Control:	
- Move building to north side of lot	-0-
- Delete basement parking	(200,000)
- Reduce glass on north and on most shaded units	(14,000)
- Increase glass on south	40,000
- Add south balcony on floor 11	30,000
- Add soffit overhangs	148,000
- Redesign 16 units to provide 2-story glazing & "split units" on south	88,000
TOTAL COST:	$37,300

The theme of Team A's design is making the building into one large passive solar collector -- increasing insulation on the North, East, and West; reducing glazing on north; and generally opening the building to the south. The net result of many tradeoffs is a building that costs virtually no more to build than the original design but has an annual utility bill that is reduced by 32%.

The team replaced the masonry skin originally proposed with a lighter option consisting of batt insulation between metal studs, gypsum sheathing, and two-inch exterior insulation with a finish system -- similar to the "light" solution used in the future building for Phoenix. Metal studs are two inches wider on the north, east, and west to allow for more insulation. This alternate system reduced building first cost by an estimated $200,000.

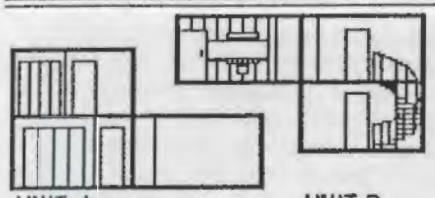


The image of a giant passive collector is carried out over several design changes. First, the building was moved to the north edge of the site to insure solar access to the south. South glass was increased significantly by using wider windows and increasing heights from five feet to six feet. At the same time, north glass was reduced in height from five feet to four feet. Were it not for the hydronic loop, the increased south glass would lead to overheating in the south units. But, with the loop, heat is "captured" in the south units and transferred to the rest of the building. A 10,000 gallon thermal storage tank was added to the basement to provide heat storage for the hydronic loop so that heat collected during the day could be used at night. As shown on the wall section below, the south face of the building was also redesigned to add balconies and overhangs to prevent overheating.



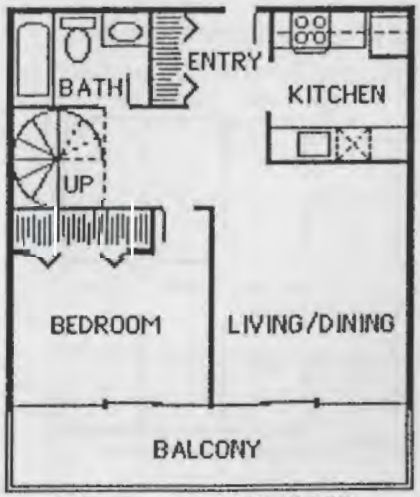
SOUTH WALL SECTION

Redesign Team A



UNIT A UNIT B
SECTION THRU UNITS

UNIT A
12TH FLOOR



UNIT A 11TH FLOOR

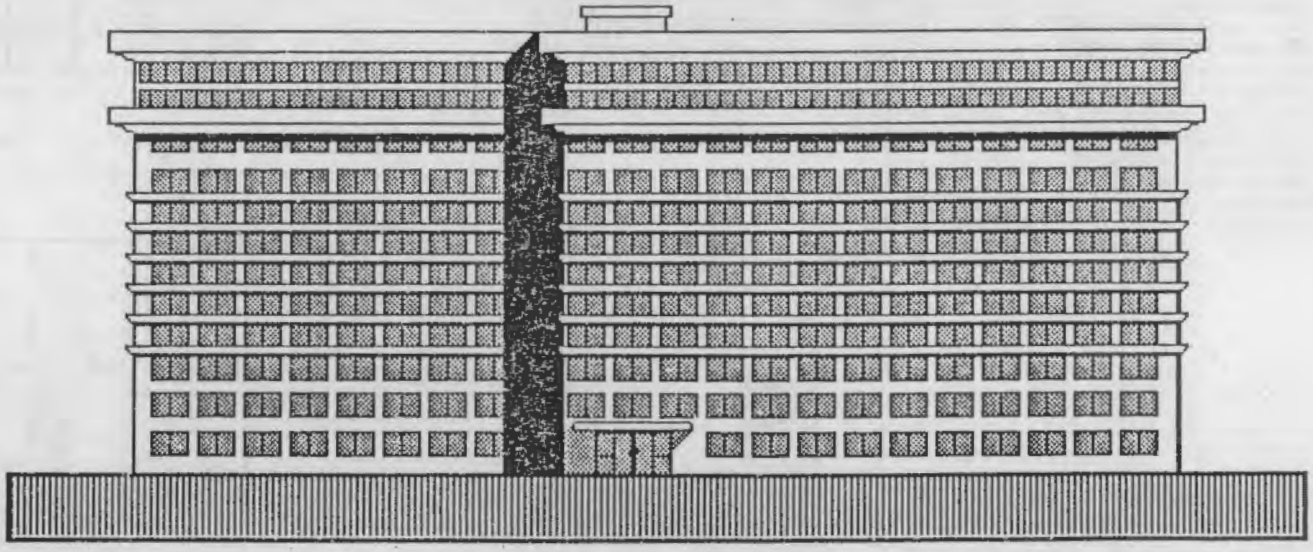
The passive solar theme also inspired a redesign of the top two stories on the south side of the building to create "piggyback" units with two full stories of south facing glass each. As shown on the unit sketches, by alternating the location of the second bedroom in two-bedroom units and adding an internal stairway, sixteen units on two separate floors are transformed into fourteen "split-level" units. This change not only increases the amount of glass on the south side of the building but also makes an interesting modification to the south elevation of the building.

Team A also elimninated basement parking in the building. They argued that even at $50 per space per month the owner would be losing money when capital costs and energy costs of each space are considered. The team felt that if the majority of spaces could be above ground, all spaces could be that way.

As indicated on the strategy list, nearly all equipment was replaced with higher efficiency models. In addition, apartment heat pumps were downsized to meet smaller anticipated loads and modified to have an economizer cycle. More efficient lighting was specified and with better controls. Improved elevator controls which call the nearest car instead of an all-up/all-down cycle were also proposed.

The net effect of very significant increases and decreases in cost from the original design is an overall increase of only $37,000 which can be paid for in energy savings in only ten months.

Team A chose to make the building into one large solar collector with a run-around hydronic heat pump system to distribute the heat and basement water storage to minimize peak loads



TEAM A SOUTH ELEVATION

Redesign Team B

STRATEGIES & COSTS

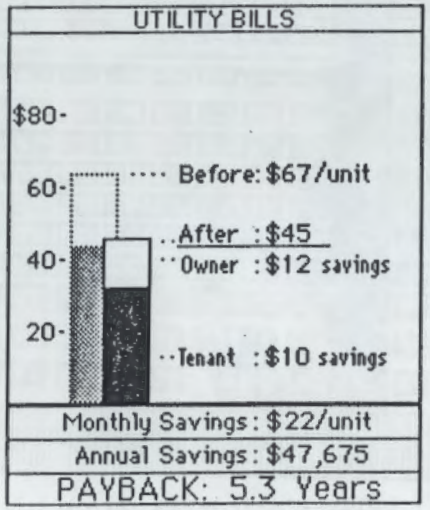
Envelope:	
- Increase roof insulation to R-30	3,000
- Insulate garage ceiling with R-19 batt	44,000
- Add low "E" glass on north	16,000
Infiltration/Exhaust:	
- Add carbon monoxide sensor on garage ventilation system	750
- Add infiltration for atrium	(see below)
Lighting/Appliances:	
- Reduce garage lighting Wattage	-0-
- Install high efficiency appliances	18,000
DHW:	
- Add insulating jacket for central DHW tank	1,000
- Install high efficiency laundry equipment	-0-
- Increase DHW boiler efficiency	2,500
- Lower DHW temperature to 120°F	-0-
- Install flow restrictors for showers	1,200
Vertical Transportation:	
- Install microprocessor elevator control	18,000
Building/Site Design:	
- Reduce exterior wall area & glazing	
- Add covered atrium with operable louvers for ventilation	
- Add balconies and sliding glass door on units	
- Install high efficiency lighting system in atrium, corridors, and other common areas	
- Net of Above	150,000
TOTAL COST:	$254,450

Team B chose to focus on the question of the affordability of housing and creating alternatives to simply making units smaller in order to reduce building costs. They selected two radical concepts for investigation -- (1) moving one bedroom to the interior of each unit and (2) reducing kitchen sizes.

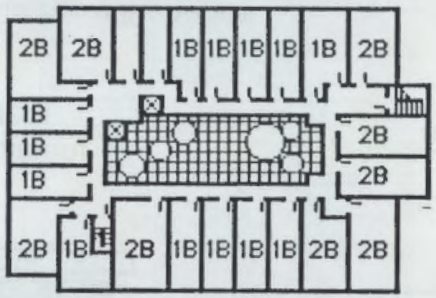
Under most building codes, all apartment bedrooms must have exterior windows. Although originally required for ventilation and as a means of egress in case of fire, the fixed glazing in most current midrise and highrise buildings really provides only light and view. Ventilation is done mechanically and fire protection is provided by sprinklers, the use of non-combustible materials, and other provisions for safe escape. Not only are exterior glazing systems expensive in themselves, but their location tends to dictate minimum unit width, unit layout, and corridor length. If codes were not an issue, Team B argued that tenants might be willing to trade costly windows in one bedroom for a significant increase in space in the rest of the unit.

In the first option, called the corridor redesign below, one bedroom is put in-line behind the living/dining area. This change allows units to be somewhat longer and narrower -- so more units can be located on a given length of corridor.

In this design, the length of the building remains about the same while the width expands from 57 feet to 96 feet. This one change allows the number of dwelling units per floor to increase from fifteen in the original design to twenty-four in this design. Whereas the original design required twelve stories for 179 units, this design puts 192 units in only eight stories. The reduction from 12 to 8 stories in the corridor redesign reduces exterior

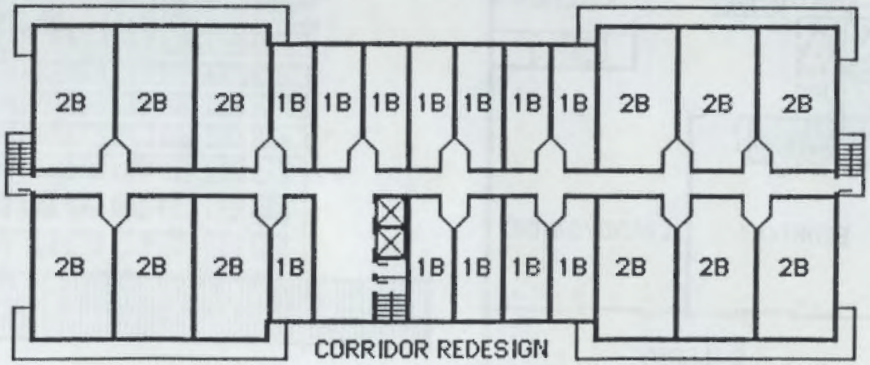


The atrium design offers added common space, and daylight for interior bedrooms



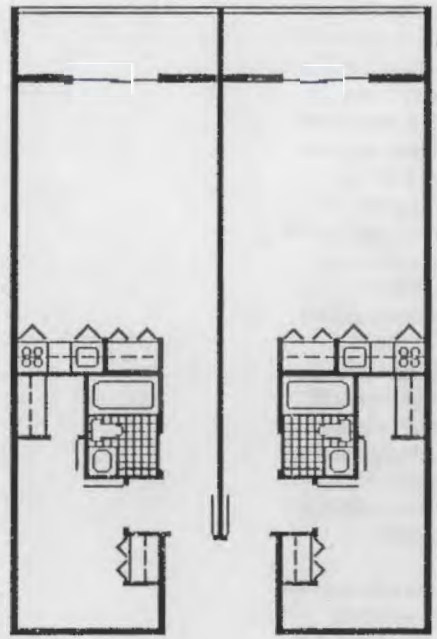
ATRIUM REDESIGN

The corridor redesign maximizes building efficiency and offers up to 20% more space than the base case for the same cost



CORRIDOR REDESIGN

Redesign Team B



wall area by 22% and allows the building to be built of fire-resistive rather than more costly fireproof materials. The building net-to-gross ratio increases from 75% to 83%. From the tenant's perspective, savings in other building costs can be used to increase unit sizes by 20% and to add balconies on all two-bedroom units. The team proposed designing a transom over the closet or kitchen so that light could be "borrowed" from the living area for the bedroom -- making the lack of windows less significant.

The second option proposed by Team B puts an atrium in the center of the building. The main feature of this design is that it allows the bedroom which is not on the exterior of the building to get natural light from the atrium. It also creates the potential for egress, as shown on the unit design. In this case, the building becomes a more compact "cubic" shape. It puts 183 units in eight stories while reducing the exterior of the building by 33 percent. The net-to-gross of this building is the same as the original design (75 percent) after including the atrium.

From the tenant's perspective, unit spaces are increased in size by about 10 percent and all units now have a balcony. It is presumed that the atrium will be as attractive to tenants as it has already become in office and hotel buildings. Not only does the atrium provide an opportunity for plants to decorate the building year-round, but it also enhances the opportunity for natural ventilation.

In their other major proposal to reduce first costs, the team recommended installing smaller "ship's" kitchens in the efficiency and one-bedroom units. A design with less counter and cabinet space and smaller appliances could be fit into one wall. Market surveys have indicated that renters of these smaller units do not use kitchen facilities as much as families who rent the larger units. Larger living rooms, bedrooms, and closets might be an attractive alternative to an unused kitchen.

Team B recommended improving the garage to reduce heating costs instead of eliminating it. They proposed adding insulation and installing a CO sensor to provide ventilation only when necessary. Team B also recommended installing low emissivity glass on the north side of the building. This approach was judged to be more cost effective than triple glazing and more practical than altering window sizes on one side of the building.

After considering all the many tradeoffs in this design, it was roughly estimated that the atrium building could be built for only $250,000 more than the original design, while yielding four more rental units. Energy savings alone (over $48,000 per year) could pay for all the improvements in 5-1/2 years.

Jury Comments

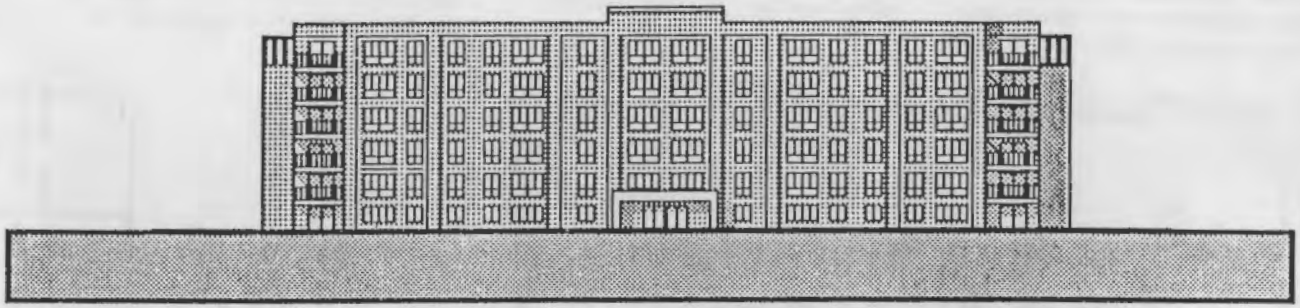
In reviewing the solution proposed by Team A, the jury complimented the team for attempting a truly "solar" solution to the problem, building on much of the innovative work in solar design over recent years. The jury liked the "practical" approach of using a well known technology such as a hydronic loop with heat pumps.

The approach is not without its problems, however. A main concern was whether or not owners would ever even consider building a building where the south face is significantly different from the other three faces. The increased cost of construction supervision alone (to make sure that windows specified for the south side of are actually installed on the south) could overwhelm proposed energy savings. It was also asked whether or not the owner might be creating a marketing problem by building two very different classes of units in the same building -- one very much lighter and more open than the other. A lengthy discussion ensued about the extent to which such owner concerns will be a limiting factor to innovative solar designs in the future.

From a tenant point of view, the jury pointed out that tenants on the south might be asked to experience uncomfortable radiant temperatures and possible overheating so that the system in general would work. For instance, if a unit starts to heat up on a sunny day, a smart tenant might reasonably open the window instead of turning on the air conditioning -- a good solution for the tenant but possibly a bad solution for the building overall.

Needless to say, the concept of an inside bedroom as proposed by Team B was extremely controversial. It was pointed out by one jury member that the Southern Building Code, in response to those building underground homes, now allows bedrooms to "borrow" light from a room with an exterior exposure or from so-called "light wells" or "light shafts." A member of the jury pointed out that at one time all codes required that bathrooms have an outside window but that improvements in mechanical ventilation had changed this view. Still, the main issue may be aesthetic. As one jury member put it, "I never thought I would hear an architect defend such a terrible idea." On the otherhand, a builder in the northeast is now in the process of offering similar units to the marketplace for their opinion on the tradeoffs.

The jury was intrigued by the proposal for smaller or at least less conventional kitchens. They suggested this might be a fruitful area for more study.



The Future in Phoenix: Working with the Climate

This proposed building for Phoenix is one of three "future" buildings in this study. The original, "before", design represents a typical building, on the drawing boards today, which would be built in the next two to four years. It is intended to reflect good current practice and current energy codes, but with no special effort to achieve exceptional energy cost reduction. From an energy point of view, it is better than most existing buildings, but it is still short of what is possible with current knowledge and careful attention to energy issues.

The basic building design has 6 stories with 118 units in 114,000 gross square feet. The building is estimated to cost $3.9 million (1985), which is $34 per square foot or $33,000 per unit.

Unit sizes and designs are particularly interesting, because the design team focused on efforts to "downsize" units by 10 to 15 percent over current practice. This reflects anticipated market trends and builder efforts to keep costs down. The design team also tried to reflect two other market trends by adding a den to a one-bedroom unit and "splitting" a two-bedroom unit, to facilitate sharing by unrelated individuals.

Cooling is the main energy cost in this building, requiring about 1,800 hours of mechanical cooling annually. It accounts for nearly 40 percent of the average tenant bill. This all electric building is estimated to have a total annual energy bill of just over $100,000 per year, 20 percent of which would be borne by the owner and 80 percent by tenants.

As with all three "future" buildings, the design teams were asked to come up with one entirely new design for the building instead of operations, retrofit, and rehabilitation strategies as done for the nine existing buildings. This gave the design teams greater flexibility to investigate more innovative design strategies. The Phoenix climate offers tremendous natural resources for energy innovation. In this particular case, one team agreed to investigate a "light" building where lighter weight building materials, shading, and insulation were the principal elements of the solution. The other team investigated a "heavy" solution using generous amounts of building mass as the principal strategy element.

Both "redesigns" reduced estimated energy bills by one-half with paybacks under six years. Like many of our other buildings, however, these savings fall largely to the tenants. The owner must participate in these savings if paybacks are to be acceptable.

Building Layout

PHOENIX, AZ

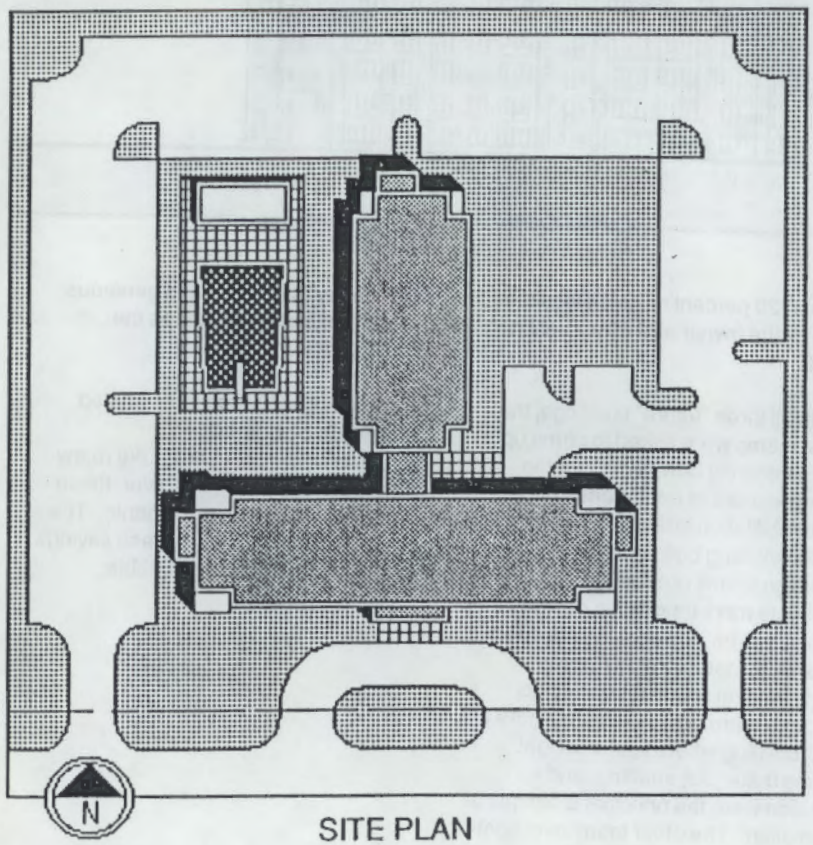
The future Phoenix baseline design assumed a modest 3-acre site with a relatively high density of 40 units per acre and a parking ratio of 1-1/2 cars per unit.

The building is laid out in a "tee" shape with common facilities located at the "knuckle" of the building, giving the building roughly the same surface area in each orientation. With this layout, the farthest unit is only 120 feet, about 50 steps, from the nearest elevator. Only two elevators are used. One stair is located near the elevators as a convenient and low energy alternative for those who don't like waiting.

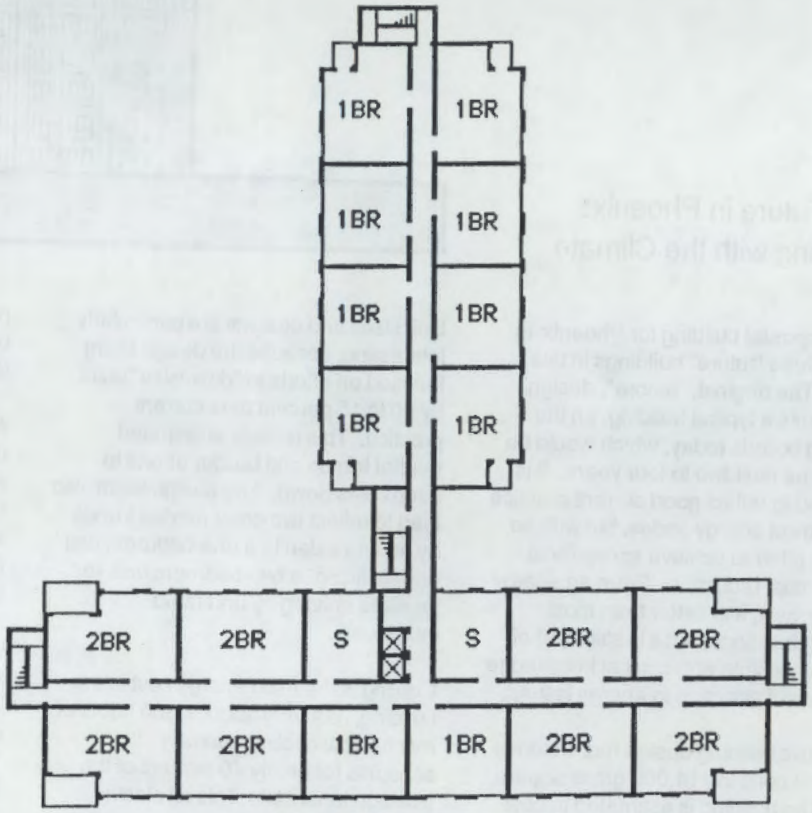
A 24 foot depth for units on each side of the corridor creates the potential for using "quad tees" on bearing corridor walls.

As illustrated on the floor plan below and in the table at right, there are five different unit types. Two less common unit types are illustrated. The one-bedroom unit with a den is designed for tenants (like a young couple) who can't afford a two-bedroom unit, but would like some extra space for a library or computer room. The two-bedroom "split", on the otherhand, is designed for unrelated singles who want individual bedrooms and baths but are willing to share a living room, dining room, and kitchen. Both the mix of units and the design of individual units are done with the possibility of future conversion to condominium ownership in mind.

With a total rentable area of about 85,000 square feet, the net-to- gross for this building is a respectable 75 percent, in spite of down-sizing the units.



SITE PLAN



TYPICAL FLOOR PLAN

Building Specifications & Operations

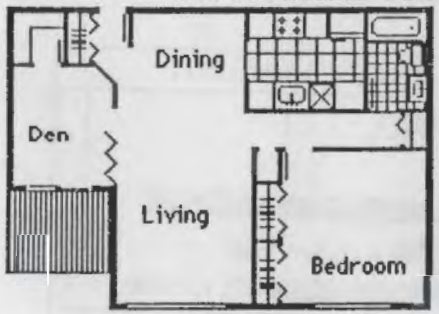
PHOENIX, AZ

The building envelope, reflecting a southwest location, is concrete block with a stucco finish. It has a well insulated roof (R-20) and typical walls (R-7). Windows are steel frame, single pane, with thermal breaks to reduce conduction losses.

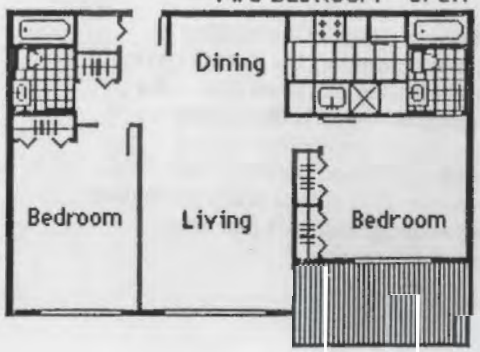
Air infiltration is assumed to be 1.0 ACH for the entire building. This is a good level, but not exceptionally low.

Lighting in the units is a mix of incandescent and fluorescent with an average of 0.5 watts per square foot. High efficiency appliances reduce loads about 30 percent to 0.28 watts per square foot. Exterior lighting is switched. Units are both heated and cooled with good quality "split" system heat pumps -- the compressors for the heat pumps are located on the roof of the building to reduce noise. With an EER of 11.5, they represent good currently available equipment. Corridors are conditioned with a constant volume system. Heating is supplied by electric resistance and cooling by a direct expansion (DX) system. There is a good spread between the heating (70° F) and cooling (78° F) setpoints.

ONE BEDROOM - DEN



TWO BEDROOM - SPLIT



BUILDING SPECS

ENVELOPE:

- Exterior Wall
  Medium weight construction, Stucco on 8" light weight Concrete masonry units--70% solid, 3/4" EPS, 1/2" gyp. bd.
- Window
  Steel sash single pane, clear, U overall = 1.42, shading coefficient = 0.64 with blinds
- Roof
  Light weight construction; built up roofing; 1/2" plywood R-20 insulation with gypsum board on the inside face. U = 0.045, dark color

INTERNAL LOADS

- Lights: 0.5 Watts/s.f.
- Appliances: 0.3 Watts/s.f.
- Cooking: 6000 Btu/day (40% latent)
- Infiltration: 1.0 Air Change/hr.

OTHER LOADS:

- Lighting in common areas: 0.35 W/sq. ft.
- Elevators: 18 kW
- Exterior Lighting: 4.5kW operated 12 Hours/day

SYSTEM SPECS

HVAC
Air-to-Air heat pump, split system with auxiliary electric heat; COP = 3.10 ; EER=11.5 (corridor: Forced-air constant volume with electric resistance heating & DX cooling; EER = 8.5)

TEMPERATURE SETPOINTS
Heating: 70°F
Cooling: 78°F

DOMESTIC HOT WATER
Individual Electric Water Heaters with 85% efficiency; Nominal efficiency = 60%
35 gal./unit/day @125°F

Energy Analysis

PHOENIX, AZ

The most outstanding feature of the Phoenix climate is its very clear sky. It allows for both intense sunshine in the daytime (creating high cooling loads) and radiation to the night sky (creating heating loads). This is a climate where cooling is clearly the principal energy issue.

Shown on the graph below, the average temperature in Phoenix doesn't go below 30° F in winter, although record low temperatures are significantly lower. What is impressive, however, is the spread between the average daily high and low temperatures -- the diurnal swing. As shown on the graph below right, the temperature swing on an average July day can be nearly 30 degrees.

By comparison, Los Angeles, which is only 375 miles away on the same latitude, has only a 13 degrees diurnal swing -- largely a result of less clear sky conditions and ocean influences.

Intense daily sun is the principal cause of high cooling loads. Cooling degree days (3,500) are more than double heating degree days (1,550).

As illustrated on the bar charts of building loads, the principal cause of cooling loads are heat gains through glazing. Most of this cooling load results from direct sunlight. Although glass is generous in this building (11 to 16 percent of the floor area), it is not excessive. The balance of the cooling load comes from internal gains (largely lights and people) and from infiltration.

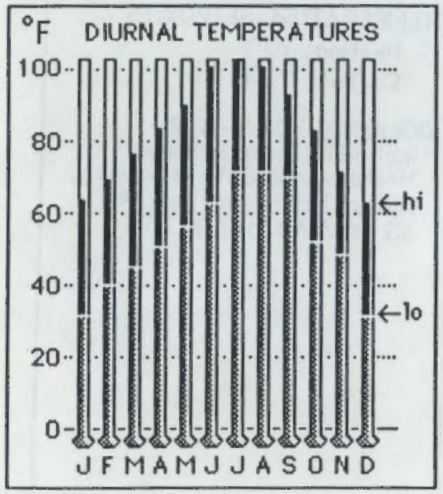
Heating loads are only one-tenth the size of cooling loads. Infiltration is the principal cause of heating loads. Conduction through glass is second.

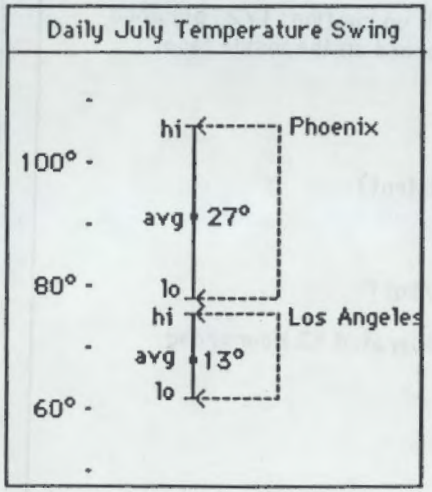
As with other buildings in relatively mild climates, because this building is already "energy-efficient", as defined by current design practice, heating and cooling loads are modest. The cost of heating domestic hot water is relatively significant for this building. It is the second highest cost for tenants and the highest cost annually for the owner.

Lighting is the next highest cost for both owner and tenants.

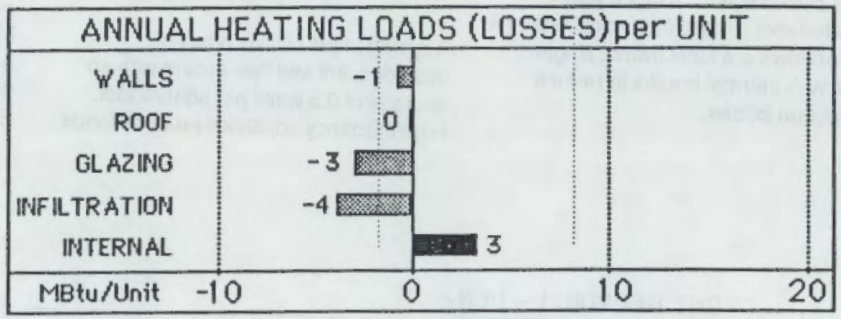
The basic design of this building is energy conserving, but does not go to any lengths to take advantage of the tremendous opportunities offered by this climate. Evaporative cooling, shading, and load shifting are all possible in this climate and were studied by the design teams as part of the redesign exercise.

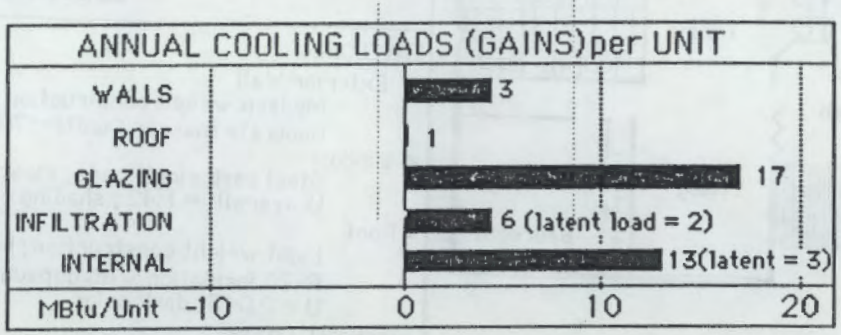
Phoenix temperatures vary widely during the day





Heating loads are small. Large cooling loads are dominated by glazing loads caused by strong solar gains





Economics

Because this is a future building, there are no existing energy bills for comparison. Instead, the design team estimated an annual bill using the DOE-2 computer energy analysis program.

The annual energy bill is estimated to be just over $100,000 per year. Because all units are individually metered, tenant bills are significantly greater than owner bills. Tenants pay roughly 80 percent of the annual bill or about $59 per unit per month. The owner pays about 20 percent of the annual bill or about $16 perunit per month. With an annual owner bill of $22,000, there is room to pay for building improvements with energy cost savings. However, the owner must either share in tenant savings (by an increase in rent) or get some other market advantage if reasonable paybacks are to be achieved on major improvements.

The rent and energy analysis, shown in the box at right, is also based on assumptions. The rent for a typical two-bedroom unit is based on the median rent for the area as reported by the Institute of Real Estate Management, adding 15 percent to represent inflation from 1984 to the date of occupancy some 2 to 4 years hence. With an estimated shelter cost of $639 per month, a renter could qualify for this unit with an annual income below the national median in 1985.

Both design teams were able to to reduce annual energy costs by 50 percent, over $50,000 annually, giving attractive paybacks between 5 and 6 years.

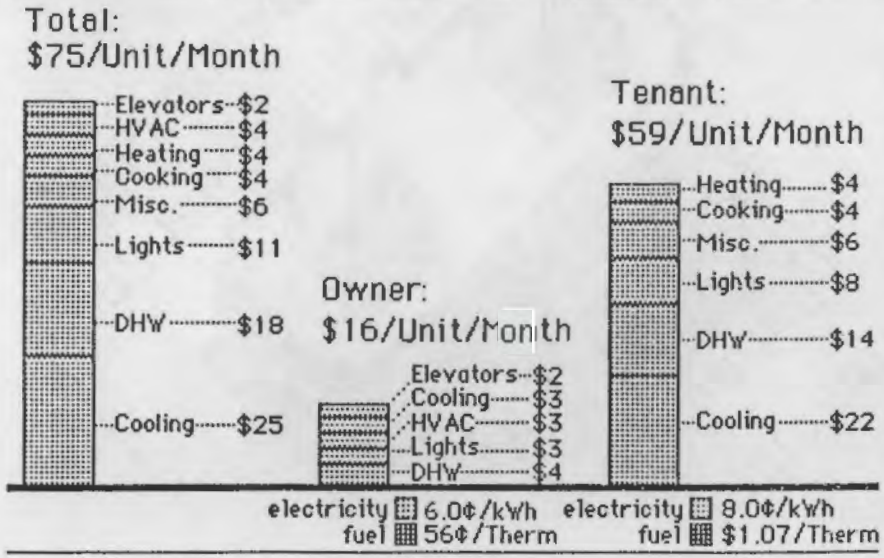
Energy and Rent Analysis

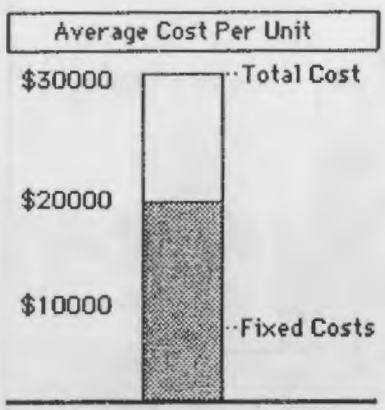
(Typical Two-Bedroom Unit)

Net Rent to Owner	$564
Owner's Monthly Energy Cost/Unit	$ 16
TOTAL RENT	$580
Tenant's Monthly Energy Cost/Unit	$ 59
SHELTER COST	$639

INCOME TO QUALIFY: $19,900

Phoenix Midrise Utility costs





It is a common assumption that in order to cut housing costs in the future, apartment sizes must be reduced. To test this theory, the design team conducted a simple sensitivity analysis. If all space related building costs (foundations, substructure, superstructure, roofing, and interior partitions and finishes) are removed from the building cost estimate, the cost per unit drops by about 35%. It appears that the majority of costs (plumbing, wiring, HVAC, etc.) are fixed.

This analysis suggests that reducing unit sizes by 10% will actually reduce construction costs by only about 3%. Would the market be willing to accept reductions in fixed costs (fewer appliances, simpler kitchens, fewer amenities) to preserve larger unit sizes? An interesting question worthy of further study.

PHOENIX, AZ

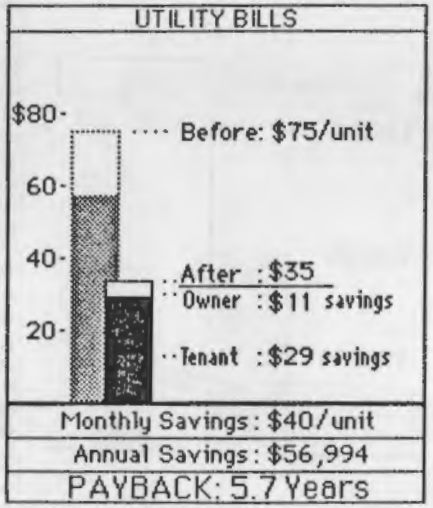
Redesign Team A

STRATEGIES & COSTS

Envelope:	
- Go to 1-1/2" ext.. insul. system	13,200
- Go to 4" load bearing metal studs walls with R-11 insulation	(22,000)
- Insulate to R-30 on steel roof deck	24,000
- Tyvek on courtyard walls	3,000
Infiltration/Exhaust:	
- Weatherstrip and caulk all exterior	5,800
- Go to Ducted range exhaust	-0-
HVAC:	
- Lower heating set points	-0-
- Downsize with higher eff. heat pumps	(42,000)
- Delete corridor mech. sys.	(8,000)
- Add ceiling fans in bedrooms and living rooms	19,720
Lighting/Appliances:	
- Replace all inc. lights with fluor.	4,000
- Add photocell control on common & exterior lights	-0-
DHW:	
- Go to heat-pump DHW in each unit	76,800
- Add wter saving fixtures	2,000
- Use high eff. laundry equipment	-0-
- Add active solar DHW for laundry	25,000
Building Site Design/Massing & Solar Control:	
- Go to concrete slab on grade	26,000
- Floor: 2-1/2" conc. topping on deck & bar joists	44,000
- Go to 4" load bearing metal stud partitions	10,000
- Unit E: add SF and reduce deck	(18,000)
- Unit B: delete balcony & patio door	(see above)
- Unit A: add SF to perimeter	56,000
- Add two 12" fountains	60,000
- Add 1' fixed glass clerestory	17,000
- Add courtyard overhang	29,000
TOTAL COST:	$325,520

Team A redesigned the Phoenix building using a "light weight" or low-mass design approach. The team used light weight building materials, insulation, shading, and evaporative cooling (from a courtyard fountain) as the principal strategies to reduce cooling costs. The result is a building that is very reminiscent of the Mediterranean -- another hot and very sunny climate.

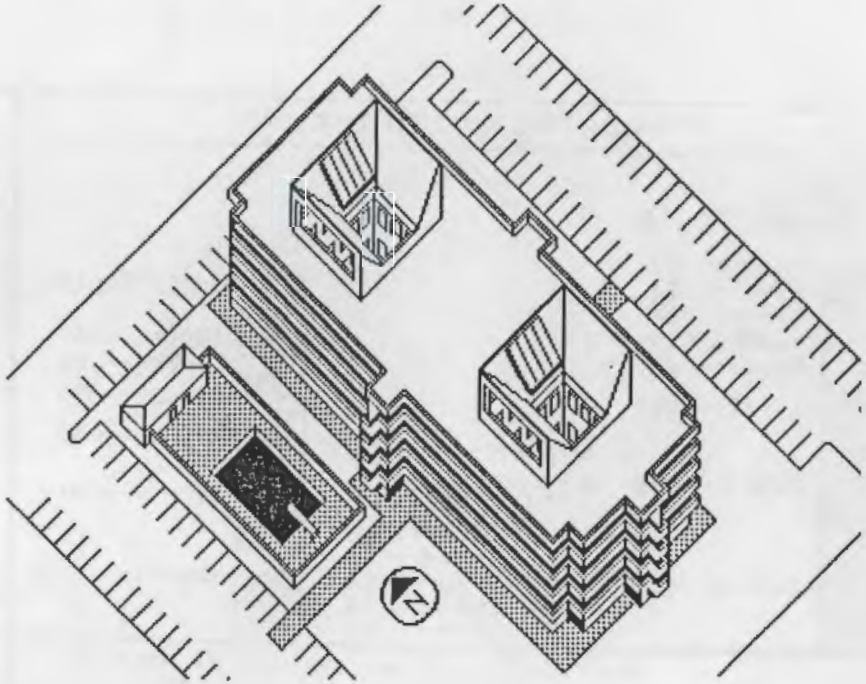
As shown at left, the net cost of all Team A strategies was about $325,000, but annual savings are an impressive $57,000 per year -- a 5.7 year payback including the added amenities of a courtyard, fountains and single loaded corridors.



Team A began by totally reconfiguring the building. Whereas the original design in a "tee" shape had equal exposure in all directions, the redesign has a north/south axis with units surrounding two courtyards.

To accomplish this, both the basic building floor plan and the site plan had to be redone. The building was reduced from six to five stories without altering the site or the basic unit mix. As illustrated on the site plan below, the building fits on the same site with only modest alterations. The pool is moved slightly, parking is reduced to a single row on the north, and the entry drive is changed to the east side of the building. As illustrated on the table on the next page, the size of the units did not change (except studio units, 20 percent larger), but the mix of units was altered significantly. The number of one-bedroom and two-bedroom "split" units was increased.

TEAM A AXONOMETRIC SITE PLAN

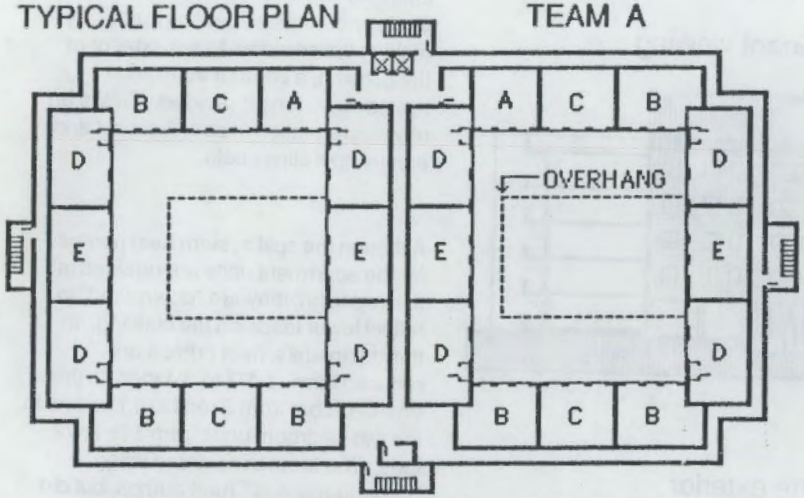


The "Light" Solution

PHOENIX, AZ

As part of an overall shading strategy, the apartment units were "reversed" so that corridors were moved to the exterior of the building and living room and bedroom windows moved to face inward onto two courtyards. This approach is much like the use of courtyards with adjacent living spaces found in the Mediterranean areas of Africa and Italy where the sun is also very hot and dwellings shade themselves in order to maintain comfort.

TYPICAL FLOOR PLAN TEAM A



Overhangs and exterior corridors shade the windows and the exterior wall

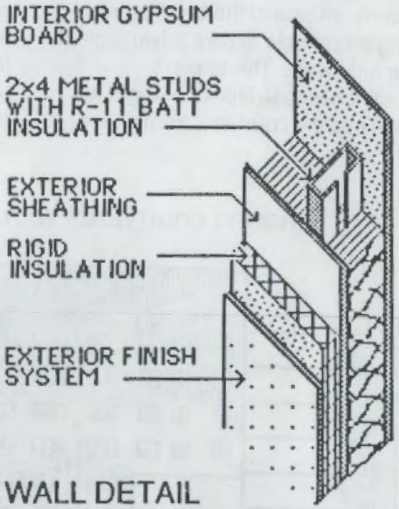
COMPARISON OF UNIT TYPES AND SIZES - Team A						
Type	Number of Units			Size of Units (sf)		
	Base	Redesign	Change	Base	Redesign	Change
A Studio	12	10	-17%	480	576	+20%
B 1-Br.	34	20	-41%	648	648	-0-
C 1-Br. W/Den	24	30	+25%	708	708	-0-
D 2-Br. 2 Bath	24	20	-17%	808	808	-0-
E 2-Br. "Split"	24	40	+67%	836	860	+ 3%
	118	120				

Principal features of the courtyard are two very large fountains and a roof open to the sky. Each fountain, with four water sprays, is used to cool the courtyards by evaporation. It is estimated that these fountains can lower the ambient temperature in each courtyard by roughly 15° F. This not only lowers the ambient temperature on one-half of the exterior skin of each unit, but also creates the potential for ventilation with cool air through the units.

The courtyard roof is open to the sky to allow for ventilation and also to allow the entry of diffuse light. A large overhang is used to reduce direct beam sunlight and attendant cooling loads. As illustrated on the axonometric drawing of the building, this rooftop shading device is designed in response to sun angles and does not have a symmetrical shape.

The net effect of these strategies is to create a building in which the exterior skin of most units (except the top floor) is shaded from the direct rays of the sun during most hours of the day. In addition, ambient temperatures in the courtyards are reduced, further reducing cooling loads on the units. All other building systems are redesigned to act in concert with this approach to the intensely sunny environment.

As shown on the detailed section, walls are of light construction, consisting of 4" load bearing metal studs with batt insulation (R-11). The exterior has sheathing, 1-1/2" rigid insulation, and a continuous plastic infiltration barrier.



Team A's lightweight wall section minimizes cost while it maximizes insulating values

The interior is gypsum board applied directly to the metal studs. All exterior walls are painted glossy white to reflect as much of the sun's energy as possible.

The roof has rigid insulation (R-30) on steel deck. It also has a light color to reflect the sun.

The "Light" Solution

Alterations to the building envelope include a revised approach to glazing and strategies to reduce infiltration. On the courtyard side of the building, all glazing is operable to take advantage of cooler atrium air. This glass is unshaded because little direct light is allowed into the courtyard from above.

On the corridor side of the building, glazing is limited to a one-foot strip, a clerestory, at the top of the wall. This glass is high and inoperable for both security and privacy reasons. It is intended only to raise ambient light levels in the dining areas. It is not used in the closet, bath, or kitchen (because of cabinet work).

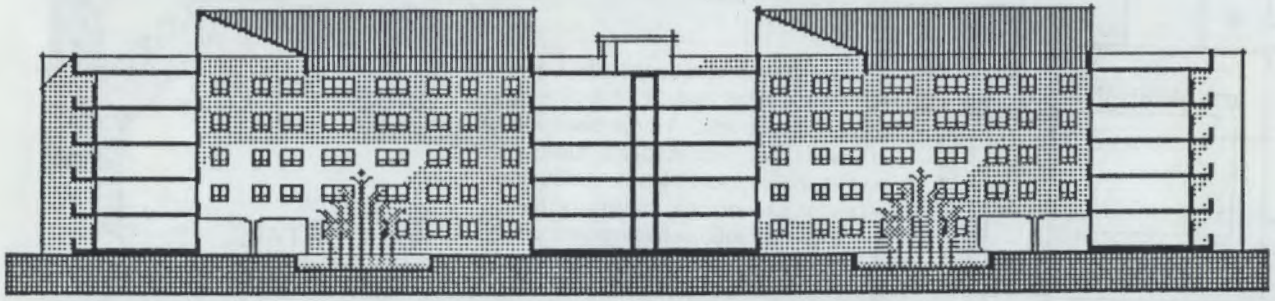
Because fixed glass makes cross-ventilation impossible, the team specified a range hood and fan with ducting to the outside (over the top of the corridor). As shown on the schematic design of a typical unit (next page), it is possible to "pull" air through the unit from the courtyard and exhaust it through the kitchen vent.

Infiltration control is accomplished by specifying expert application of caulking and weatherstripping on all exterior doors, windows, sill plates, and band boards. A plastic film is also used in the exterior walls beneath the gypsum wallboard.

The original mechanical system is also changed significantly to complement the strategy of reduced cooling loads. By moving the corridors to the exterior of the building, a corridor ventilation system is no longer needed. This is an obvious reduction in both first cost and annual operating costs.

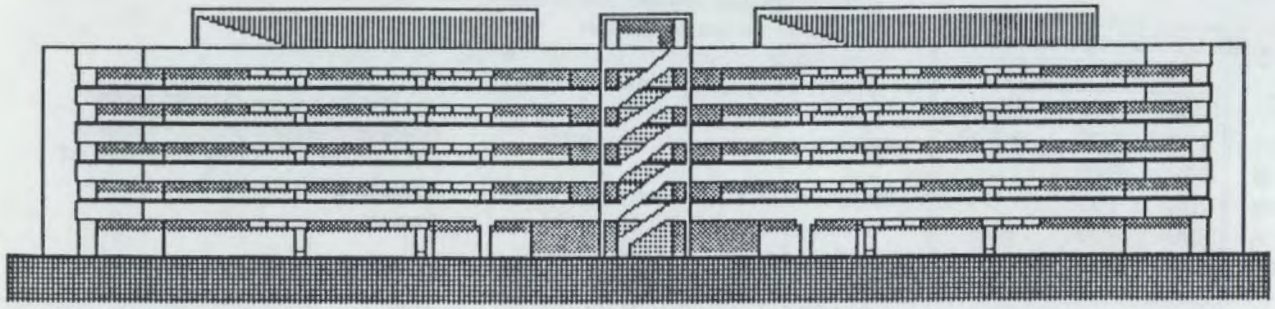
Although the split system heat pumps for the apartment units are retained in this redesign, they are "downsized" to reflect lower loads on the building. In the studio units, heat pumps are reduced from 1-1/2 to 3/4 tons, in the one-bedroom from 2 tons to 1 ton, and in the two-bedroom units from 3 to 1-1/2 tons. The team considered using "through-the-wall" heat pumps, but did not because of the added noise in an otherwise very pleasant courtyard. They also considered eliminating air conditioning altogether, but felt this would be too radical a recommendation until the basic theory of the building is proven.

Shaded courtyards with water fountains offer cool oases for tenant viewing



SECTION

Exterior glazing is mounted high against the bottom of the exterior corridor for shade and privacy



WEST ELEVATION - TEAM A

The "Light" Solution

PHOENIX, AZ

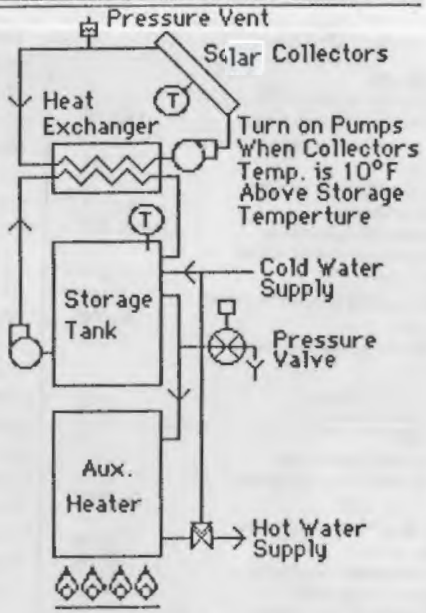
Heat pump water heaters replace standard electric water tanks and support the design approach of eliminating air conditioning altogether. A 3/4 ton heat pump water heater in the conditioned space (with a 40-gallon tank) would cool the apartment while heating domestic hot water.

Economizer controls were considered to operate the heat pump fans for unit ventilation. They were eliminated as not being cost effective over what tenants could do with existing controls if instructed on how to use them properly. Programmed thermostats were not recommended for use with the heat pump systems because they can actually lead to higher energy use than by simply holding temperatures within a reasonable "deadband" -- in this case a low of 70° F and a high of 78° F as in the original design.

Ceiling fans were added to further enhance tenant comfort while reducing energy costs. A 48" ceiling fan is installed in each living room and a 36" fan in each master bedroom. In a dry climate, the movement of air created by a fan moving 150 feet of air per minute can make 83° F air feel like 78° F. Therefore, with the use of ceiling fans, the setpoint in the units can actually be increased from 78° F, as originally specified, to 82° F. Ceiling fans are also seen generally as an added amenity and could support the owner's need for modestly higher rents to support energy improvements.

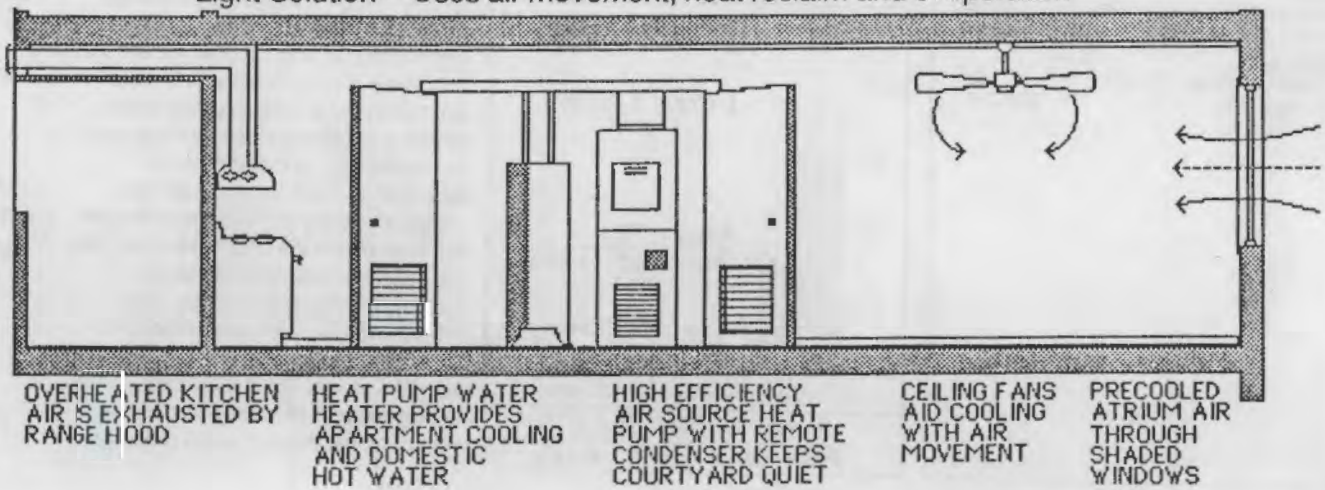
Lighting loads were reduced by specifying fluorescent light fixtures in all the units. For fixtures where tenants might want an option, screw-in fixtures could be specified so the tenant could use either incandescent lamps or screw-in fluorescent lamps. All corridors, stairs, and parking lights are on photocell control to insure use only when needed.

The team assumed that units would already be supplied with high efficiency appliances. To reduce the owner's DHW bill, they recommended installation of front loading washers in the laundry and high efficiency dryers which automatically turn off with humidistats. The team also recommended installing a solar domestic hot water heating system (see schematic design at right) in this nearly perfect climate for solar technology.



Solar DHW System

Light Solution -- Uses air movement, heat reclaim and evaporation



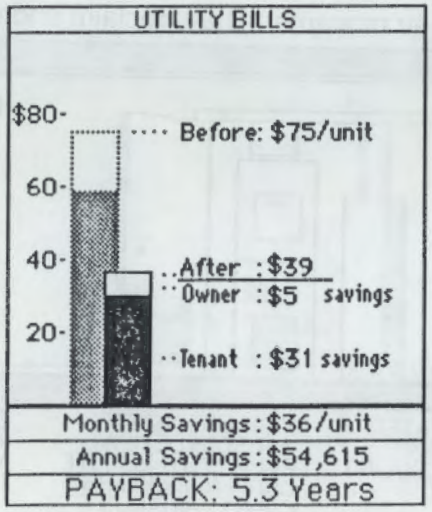
Redesign Team B

PHOENIX, AZ

STRATEGIES & COSTS	
Envelope:	
- Go to 8" x 16" semi-solid concrete block with stucco	140,000
- Go to exposed concrete plank ceiling	98,000
- Add balconies and sliders on more units	55,136
- Add window overhangs	26,500
- Reduce window glass area (more units)	11,000
- Revise floor plan; add exterior skin	30,000
- Aluminized plastic mopped on roof	6,000
Infiltration/Exhaust:	
- Caulk and seal joints	6,000
HVAC::	
- Replace split sys. with downsized high eff. air-to-air heat pumps	(42,000)
- Add economizer package on HVAC	3,500
- Add ceiling fans (2/unit)	19,720
Lighting/Appliances	
- Add fluorescents where possible	4,000
- Add photocell control	450
- Install high eff. appliances	12,000
DHW:	
- Reduce DHW temp. to 120°F	-0-
- Add solar domestic DHW	140,000
Training:	
- Tenant ed. on night - flushing	-0-
TOTAL COST:	$288,306

Team B redesigned the Phoenix midrise using a "heavy" or high- mass approach. The basic strategy was to reduce cooling loads by using extra mass in the external wall to reduce skin loads and exposed mass on internal walls to shift heat gains to times of the day when they can be eliminated by ventilation instead of mechanical cooling. Additional strategies focused on reducing cooling loads from glass.

As shown in the summary, a total redesign cost of $290,000 will produce estimated savings of about $55,000 per year, or a payback of 5.2 years. In comparing Team A's and Team B's results, note that totally different design approaches produced roughly equal savings and paybacks.

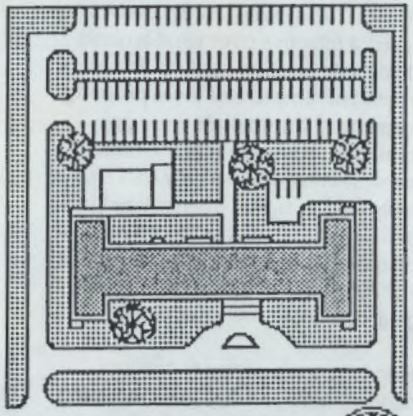


Unlike Team A, Team B felt that the building should be reoriented on an east/west axis, facing most units either north or south. Inspection of the computer model for the original design confirmed that east and west units with glazing experienced significantly greater daily loads than north and south units.

On the revised floor plan, shown on the next page, all but four units face either north or south, where shading strategies can more easily be applied. The design team was able to accomplish this new layout with the same unit mix per floor and virtually the same square footage per unit (see table). The layout is actually more efficient because the number of required stairs has been reduced from four to two.

The team did, however, revise the proportions of all the units except the studio apartments as shown on the typical floor plan at right. By moving closets and altering room shapes somewhat, the team subtracted two feet from the width of each unit and added two feet to the length -- reducing the exposed exterior surface for most units in the building. In the process of redesigning the units, the team also added a balcony to the 72 units that did not have one in the original design. This not only improved shading for the building but also added value. This added value was not accounted for in computing the payback for this strategy set. At a cost of about $290,000, energy savings of about $55,000 per year can bear the cost of the redesign improvements with an acceptable 5-year payback.

As shown below on the revised site plan, modifications are modest to accomodate this new building on the same relatively constrained site. The pool is moved slightly and parking is removed from the east and west sides of the site to the north.



SITE PLAN – TEAM B

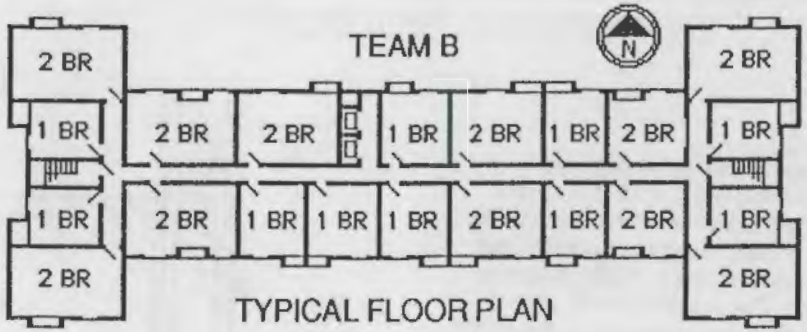
The redesigned building has minimized exterior exposure and oriented most units north or south

The "Heavy" Solution

PHOENIX, AZ

The main focus of this strategy set, however, is the use of building mass. Building mass is used instead of insulation to prevent conduction of heat through the exterior walls of the building.

After reviewing preliminary research in this area by the Lawrence Berkeley Laboratory (LBL), the team proposed two options which could be built with readily available building materials -- a 16" block wall (the "mass only" solution), and a 12" block wall with 2" of exterior insulation (the "mass plus insulation" solution). Both options are detailed at right.

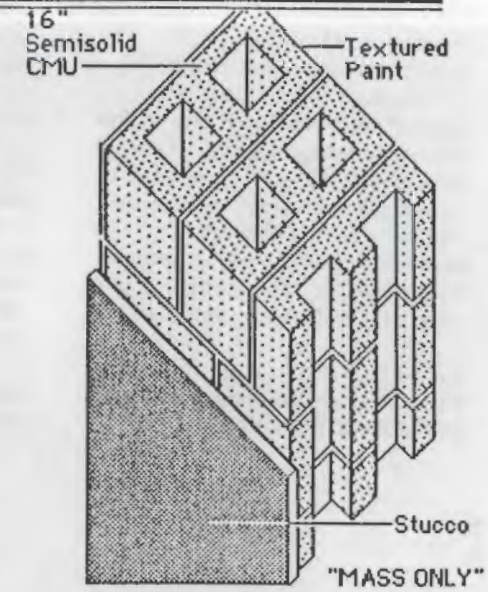


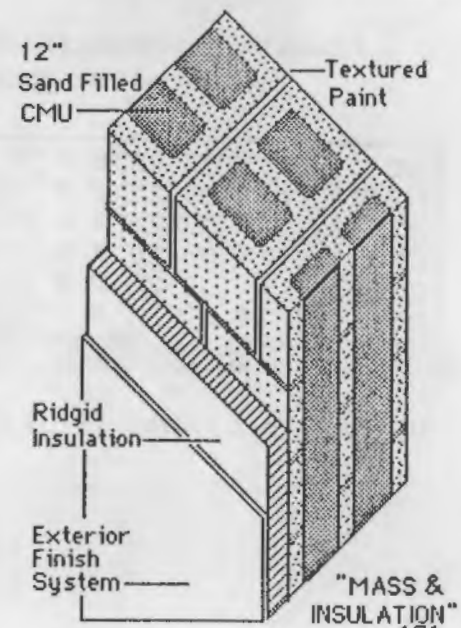
COMPARISON OF UNIT SIZES - Team B			
Type	Size of Units (sf)		
	Base	Redesign	Change
A Studio	480	480	-0-
B 1-Br.	648	630	- 3%
C 1-Br. W/Den	708	720	+ 2%
D 2-Br. 2 Bath	808	800	- 1%
E 2-Br. "Split"	836	860	+ 3%
(no change in unit mix)			

From the LBL work, the team estimated that either approach would very nearly eliminate the penetration of heat to the interior of the building. If modest amounts of heat did penetrate, it would arrive with sufficient "lag time" so that it could be eliminated by ventilating with cool night air instead of by expensive mechanical chilling.

The 16" block wall (made from 8" x 16" semi-solid block laid side by side instead of end to end), was chosen because it would cost 15 percent less to build than the 12" sand filled block approach. A simple stucco finish applied to the exterior is low cost and gives the building a massive or "earthy" look which is very much in keeping with local architecture and its adobe themes.

The other basic strategy is to leave mass exposed on interior spaces so that it can absorb internal heat gains and "shift" them to a time of day when they can be removed by ventilation. According to LBL, about 30 percent of the interior surface of a unit needs to be exposed mass in order for a strategy (called "night refreshing" by the team) like this to work. The team exposed the interior side of the massive exterior wall (painted with a sand finish) and exposed the ceiling (or underside) of hollow core floor planks. This approach means ceiling fixtures must be kept to a minimum or eliminated, but the floor can be carpeted and remaining walls can have standard finishes. Ceiling wiring can be run in the hollow cores where necessary. The ventilation system must be redesigned to work with this strategy.

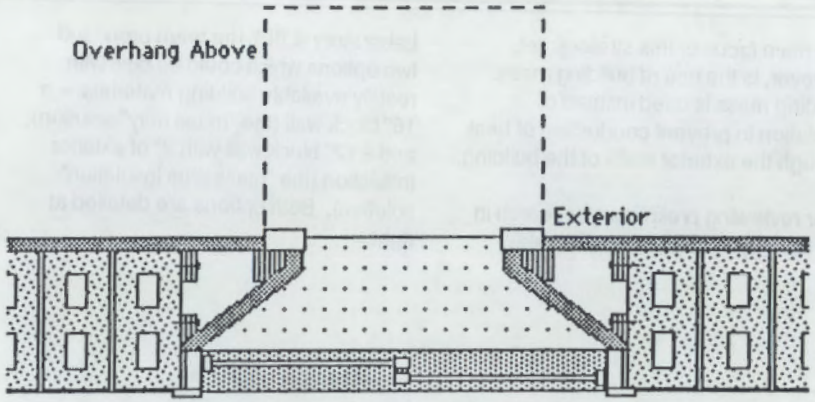




The "Heavy" Solution

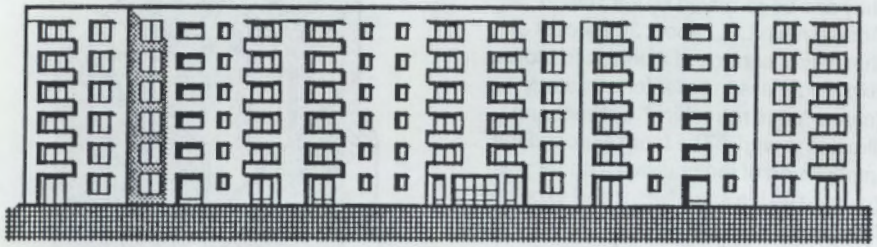
The next most important set of strategies focused on reducing heat gains through glass -- the principal cause of the largest load in the original building. Whereas the Team A design focused inward toward a courtyard, Team B felt that outward views were important. Over twenty different mountain ranges completely encircle Phoenix proper -- an important natural resource with marketing potential.

The addition of balconies to 72 units in the building not only enhanced views and access to the outside, but also provided direct shading of most living room glass. On all other glass, the team reduced glass area and significantly increased shading. In bedrooms, glass is used principally for light and ventilation instead of views. For this reason, glass areas were reduced to a standard 4' x 4' window. As shown on the window details at right, windows are set on the inside of the mass wall and shaded by angled "fins" on each side. Although the net effect is to reduce the window aperture, it creates a pleasing transition of diffuse reflected light from dark inner walls to intensely bright sky.



Window Jamb Detail

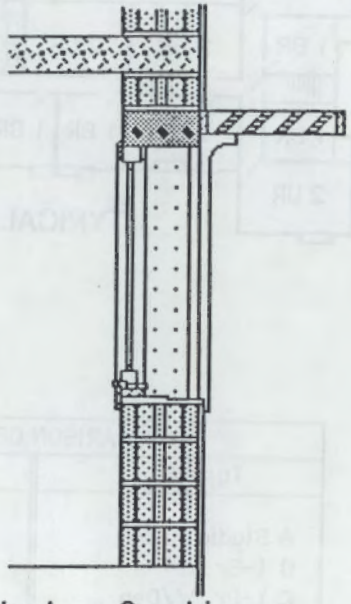
All windows are protected with deep recesses and overhangs to minimize solar heat gain



SOUTH ELEVATION - TEAM B

Shades above the windows are fixed timber slats which block direct beam sunlight, but allow air movement up the side of the building which prevents hot air from being trapped against window heads. The use of timber for shades and other trim features complements the building mass in creating an indigenous appearance for the building.

The team considered using either a second pane of glass or "low emissive" glass to further reduce heat gains through windows. Both strategies were eliminated because they were not cost-effective. In this climate, major cooling loads are caused by direct solar gain rather than by conduction of heat through the glass. In this climate shading is far more effective than strategies to reduce conduction.



Window Section

The "Heavy" Solution

PHOENIX, AZ

With loads on the building significantly reduced, and with "night refreshing" as a key strategy, the HVAC system also had to be modified. First, the team recommended installing "through-the-wall" heat pumps instead of split systems. By adding a mechanical closet adjacent to the new balcony to house the heat pumps, compressors could be moved from an intensely hot roof to a shaded environment thereby improving efficiency.

With reduced loads, the heat pumps can also be downsized significantly from the original design. In all but the studio apartments, cooling equipment was reduced by one full ton over the previous design.

An economizer is used on each heat pump to automatically blow cool outside air through a unit when conditions permit instead of using mechanical air conditioning. The theory of "night refreshing" is that internal heat gains from lights, appliances, and people are absorbed into building mass during the day and then "flushed" out of the building at night by ventilation with cool night air. This flushing process also cools (charges) the mass, making it ready to accept heat from the unit the following day.

Two ceiling fans are added to each unit to increase air flow and to achieve air movement. Fans help the transfer of heat from the building mass to the air and vice-versa.

Although the building is designed to enhance air flow through the units at night when desired, there is also a strong effort to reduce infiltration of hot air during the day when it is not wanted. The team specified an aggressive program of caulking and weather-stripping. It is estimated that caulking and weatherstripping in combination with the thick mass walls and smaller windows will reduce infiltration from 1.0 ACH to about 0.4 ACH.

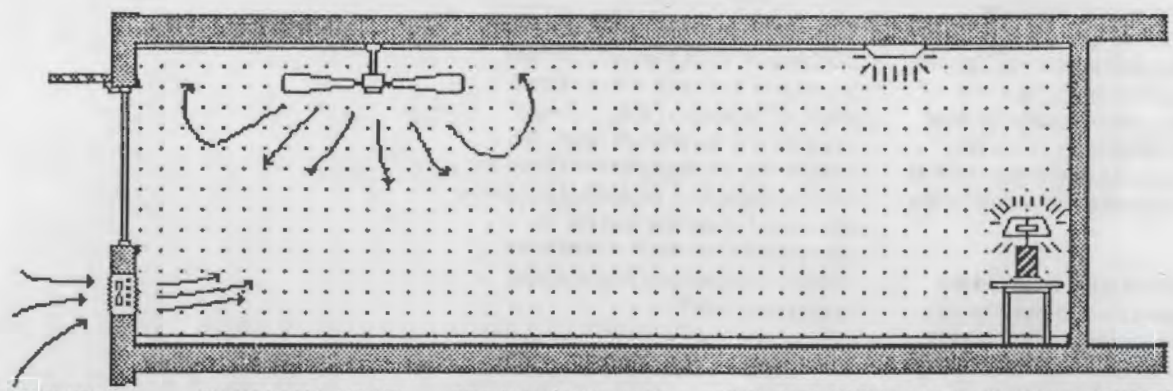
The net effect of these strategies is dramatic. Tenant cooling bills are estimated to drop from over $22 per month, on average, to less than $5. In fact, without other changes, the cost of heating domestic hot water would be twice cooling costs.

To significantly reduce DHW costs for tenants, the team recommended going to a central distribution system with 4,000 square feet of solar collectors as the principal heating source. Although a costly solution (about $140,000) it would reduce monthly water heating costs for tenants from over $13 to less than $6.

Owner hot water bills would be reduced to virtually nothing. The system is estimated to have an eight year payback, assuming no tax credits.

As an alternative, the team suggested using a conversion device that would allow pre-heating of DHW from the heat pumps. This solution is attractive because it allows the use of individual water heaters and the assigning of individual costs.

HIGH MASS BUILDING STORES NIGHT COOLING FOR DAYTIME USE



ECONOMIZER COOLS BUILDING MASS WITH LOW NIGHT TEMPS

THRU WALL HEAT PUMP PROVIDES HIGH EFFICIENCY HEATING AND COOLING

CEILING FANS COOL OCCUPANTS AND IMPROVE THERMAL TRANSFER WITH THE BUILDING MASS

EXPOSED HIGH MASS CEILING AND WALL SURFACES STORE DAYTIME HEAT AND RELEASE AT NIGHT

FLUORESCENTS LIGHTS PRODUCE MORE LIGHT WITH LESS HEAT GAIN THAN INCANDESCENT LIGHTS

Jury Comments

Starting with the "light" solution, the jury questioned the amount of water to be used by the two courtyard fountains. How much water would be consumed by evaporation and at what cost? This cost would have to be subtracted from energy savings and might be an issue in the water-short southwest.

Another question arose concerning the window strategy. As the design now stands, living rooms and bedrooms would receive only indirect light from the courtyard. As one jury member put it, "no one will ever see the direct light of day."

In spite of these questions, the jury complimented the team and was especially pleased that the team had attempted to see into the future and recommend truly different design strategies.

The jury liked the match with the indigenous architecture embodied in the "heavy" or massive solution by Team B. They also liked the simplicity of the bearing wall structure and the general efficiency of the building. They did, however, question whether the building, as laid out required another stair for fire egress.

One jury member complimented the team for moving closets from the side walls to the end walls of the unit and thereby reducing unit widths by two feet. However, he viewed this not as an innovation but an error in the original design. "Closets should be perpendicular to the building face only when used as a sound barrier between units in garden apartments or other light frame buildings where sound transmission is more of a problem" he said.

As an alternative to 8" x 16" blocks set side by side on the exterior wall, one jury member suggested using 16" x 16" blocks with grout. Another jury member pointed out that corridor walls could also be used if additional exposed mass was required in the building.

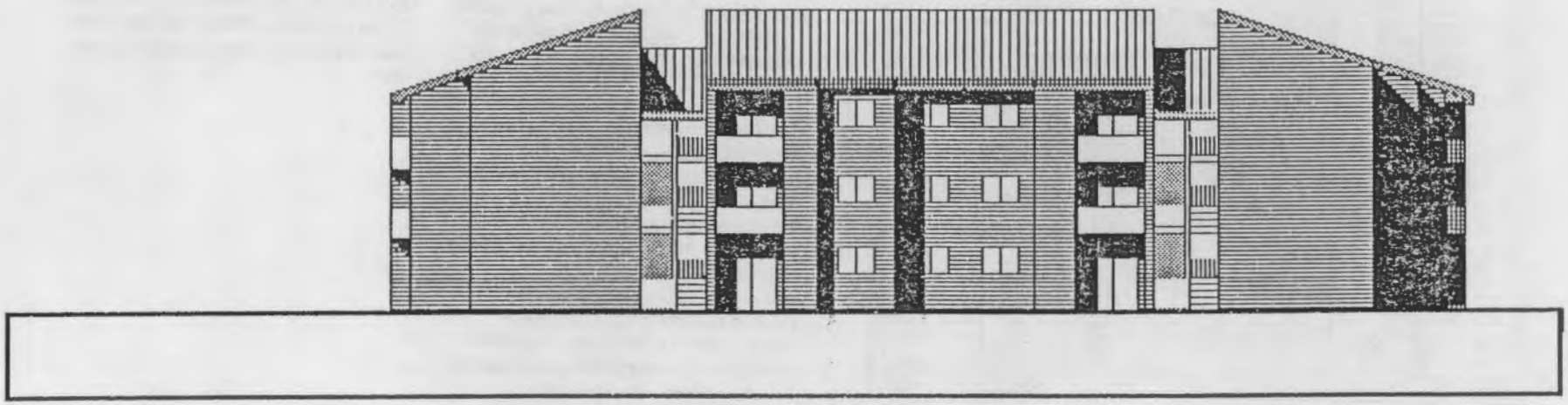
The jury questioned how easy it would be to use the hollow cores of the floor planking for electrical wiring. They felt there would be some added cost for this approach which should be counted against the cost-effectiveness of this solution. The jury also emphasized the need for the designer to pay added attention to sound transmission issues with this solution.

The jury had two comments affecting both teams. First, they felt that both teams had so significantly reduced loads in the building that they were approaching the limits of small heat pumps. If loads really turn out to be as small as expected, could heat pumps be eliminated altogether and still be acceptable to tenants? Could even smaller units be used than are now readily available?

The jury also pointed out that both teams were calling for special efforts to make the building "tight." They agreed that this is possible with the techniques specified, but only with close construction supervision.

Future Houston Lowrise

HOUSTON, TX



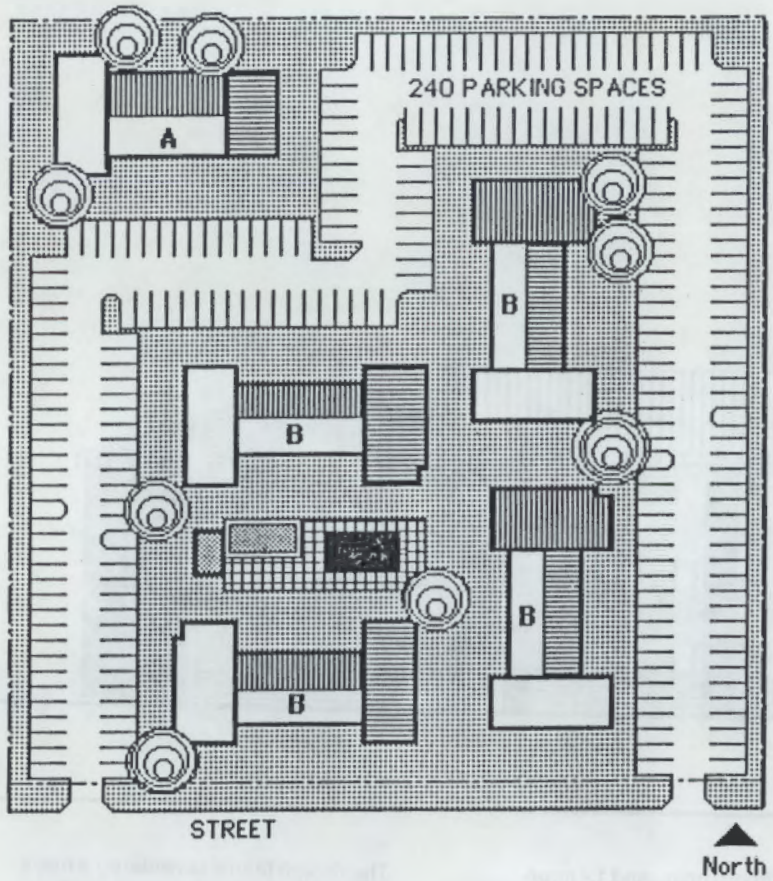
The proposed building for Houston is one of three prototypical buildings in this study. The design reflects good current design practice and current energy codes, without a special effort made to achieve exceptional levels of energy conservation. It is representative of designs that could be built within the next 2-4 years. The total annual energy bill is estimated to be $69,000. Although the building is more efficient than most exising buildings, much more can be done to further reduce energy use and cost.

The design features five separate three-story buildings, located on a four-acre lot. A total of 120 apartments are included in two distinct building types. The plan contains 48 one-bedroom apartments, 30 two-bedroom/two-bath ("split"), 30 two-bedroom /one-and-one-half-bath units, and 12 three-bedroom units.

Each team redesigned the project with a specific focus on cutting expected energy costs while enhancing the amenities of the project. Both teams achieved cost savings of over 40 percent, with paybacks of 18 and 33 months, respectively -- well worth a developer's consideration.

The design teams considered a major marketing trend in designing the three-bedroom and two-bedroom split apartments to allow sharing by unrelated individuals. As with the other future buildings in our work, the design also incorporates smaller units than are generally common in current projects.

Building Layout



SITE PLAN

A total of 240 parking spaces have been provided on the site. Due to the restricted nature of the site, units are oriented in all directions.

Reflecting the relatively efficient design, the major energy problem in this climate proved to be space cooling, followed closely by lighting and appliances. Approximately 1,900 hours a year require cooling. Although extended periods of the year are within the comfort zone, high levels of relative humidity limit the potential for natural cooling. The annual energy cost for the design is approximately $69,000. Roughly 85 percent of this cost would be borne by the tenant and the remaining 15 percent by the owner.

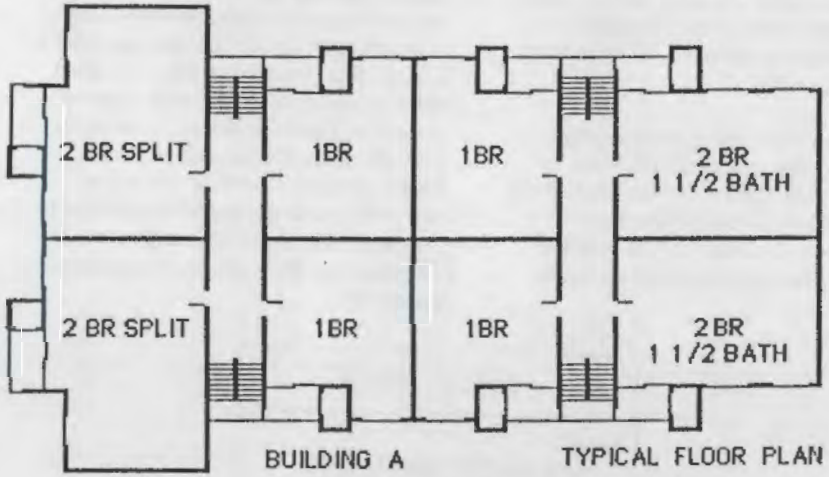
The two design teams each developed an entirely new design for the building, instead of separate packages of retrofit, renovation and rehabilitation strategies. This greater flexibility allowed the teams to evaluate more innovative strategies to reduce energy use and cost. Both redesigns feature reduction in the number of separate buildings, and developement of alternative insulation strategies. Greater differences appear in the choice of mechanical systems.

Energy costs in the redesigned building were reduced by between 40 percent and 45 percent. Considering total savings, payback periods were under 3 years. These dollar savings fall largely to the tenants. While the owner's energy costs have been reduced by between 70 percent and 80 percent from the level of the basecase design, greater participation by the owner in these savings is necessary to ensure that payback periods are adequate from his perspective.

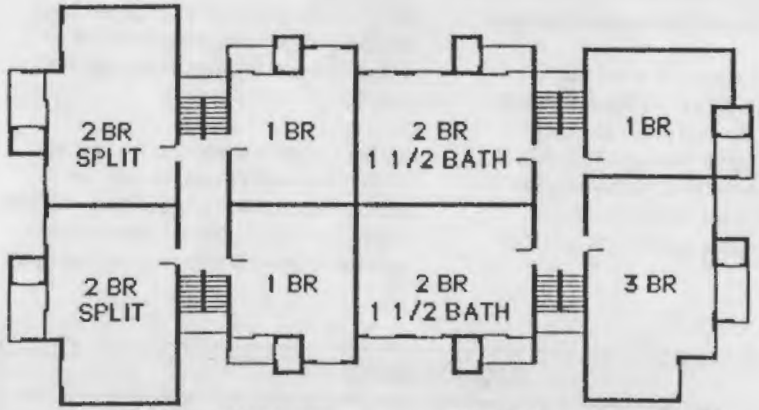
In creating the building, the design teams assumed a four-acre site, with a density of 30 units per acre and a parking ratio of 2 cars per unit.

The 120 apartments are located in five separate 3-story buildings, laid out in blocks, with apartments facing all cardinal points. The common services, including the swimming pool, are located in the main group of four buildings. All vertical movement in the buildings is by stair.

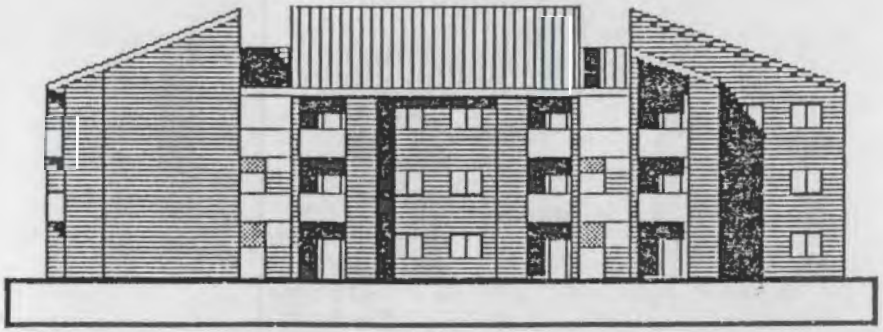
Building Layout

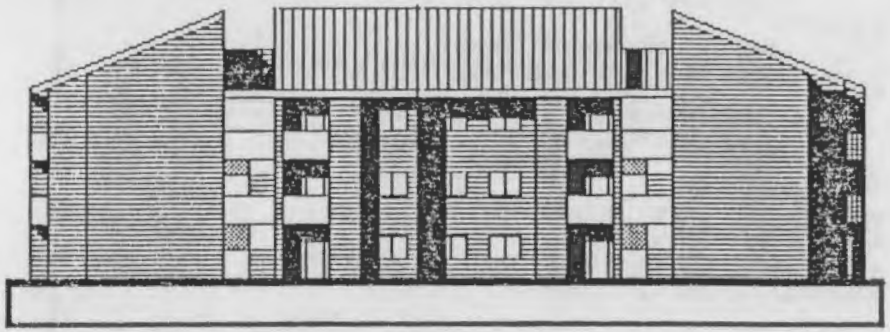


BUILDING A TYPICAL FLOOR PLAN



BUILDING B TYPICAL FLOOR PLAN





Four separate types of units are included in the complex, including a mix of at least three unit types in each building. A separate exterior mechanical room saves space in the apartment that would otherwise be taken by this function. A two-bedroom, two-bath "split" unit is designed for unrelated occupants (like students) or elderly individuals who desire separate bedrooms and baths, but are willing to share kitchen and living facilities. A two-bedroom, one-and-one-half bath apartment, and a three-bedroom, two-bath "split" unit is also available for families or tenants desiring more space. The layout of the buildings is compatible with eventual conversion of the housing complex to condominiums.

The gross area per building is 34,848 square feet. The net-to-gross for each building is 85 percent in spite of the relatively large proportion of one-bedroom units equaling 40 percent of the total.

Building Specifications & Operations

HOUSTON, TX

The architectural and mechanical specifications for the base case building are based on current accepted practice.

The exterior walls are wood frame construction, with R-11 fiberglass batt insulation. The roof is composed of asphalt shingles over plywood, with R-19 batt insulation. Windows are single-glazed with steel sash and thermal breaks to reduce conductive heat gain and loss.

Standard-quality construction is assumed, with an air-infiltration rate of approximately one air change per hour. While this is a reasonable rate, further reductions and savings in energy use are possible.

A mix of incandescent and fluorescent lighting is used in the units, with an average level of 0.5 watts per square foot of power consumption during occupied periods. Standard-efficiency appliances are used, producing a load of approximately 0.4 watts per square foot. Exterior lighting is controlled by photocell, reducing the "on" time to ten hours per day.

Heating and cooling is provided by through-the-wall air conditioners (EER=8.2) sized at 500 square feet per ton, and 74 percent efficient gas furnaces. Outside air is not supplied mechanically. All kitchens and baths have recirculating fans with charcoal filters. Corridors are open to the exterior, so mechanical ventilation is not required. A programmable thermostat regulates the temperature in each apartment, to avoid unnecessary space conditioning during unoccupied periods. Water is heated by high-efficiency (80 percent) gas water-heaters located in each apartment. A separate gas heater supplies hot water to the central laundry facility, and high-efficiency laundry equipment has been specified.

BUILDING SPECS

ENVELOPE:

- Exterior Wall
  Light weight construction, cedar siding, 1/2" plywood, R-11 batt insulation, 2x4 wood stud @ 16" o.c., 1/2" gypsum board; U=0.071
- Window
  Steel sash single pane, clear, U overall = 1.42, shading coefficient = 0.64 with blinds
- Roof
  Asphalt shingles, 1/2" plywood, air space, R-19 insulation, gypsum board; U=0.045

INTERNAL LOADS

- Lights: 0.5 Watts/s.f.
- Appliances: 0.4 Watts/s.f.
- Cooking: 6000 Btu/day (40% latent)
- Infiltration: 1.0 Air Change/hr.

OTHER LOADS:

- Lighting in common areas: 2.7 kW
- Exterior Lighting: 1 kW HID operated 10 Hours/day; 1.3 kW incandescent operated 10 Hours/day

SYSTEM SPECS

HVAC

Thru-wall air conditioners for space cooling; cooling EER=8.2; gas furnace for space heating with 74% nominal efficiency (no heating or cooling in corridors)

TEMPERATURE SETPOINTS

Heating: 70°F, weekdays: 5 p.m. - 8 a.m.
weekends: 7 a.m.- 11 p.m.
65° F, at other hours

Cooling: 78°F, weekdays: 6-8 a.m, 4-11 p.m.
weekends: 8 a.m.- 11 p.m.
80° F, at other hours

DOMESTIC HOT WATER

Individual gas DHWs
Nominal efficiency = 80%
35 gal./unit/day @125°F

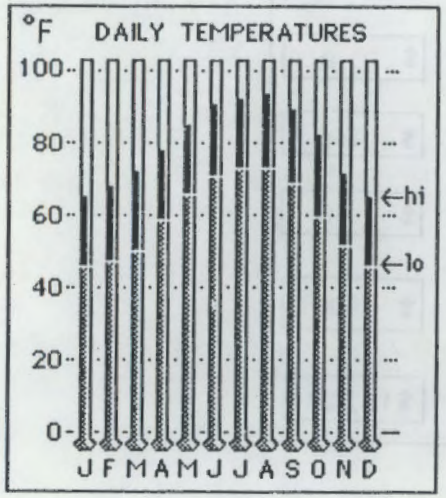
The climate of Houston is marked by high levels of relative humidity throughout the year. Although the temperature on over 40 percent of the hours of the year falls between 65° F and 78° F the average level of relative humidity (75 percent) requires air movement to maintain comfort. Many natural cooling strategies involving ventilation are not possible in this location.

Energy costs in Houston are relatively low. Cooling is the major problem, accounting for 24 percent of energy use, and 35 percent of total energy cost. While water heating requires slightly more energy than cooling (26 percent of total use) it makes up only 9 percentt of energy cost, because gas is used as the fuel. Space heating is the third most significant cause of energy use (19 percent of total use,) followed by lighting (12 percent) miscellaneous loads (12 percent) and cooking (6 percent).

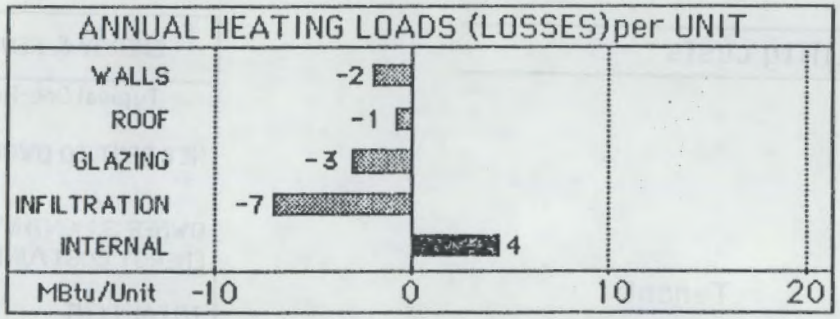
All of the above uses and costs deal with the tenant's bill and energy used within each apartment. The owner pays only for exterior H.I.D. and corridor fluorescent lighting, plus any gas used in the common laundry.

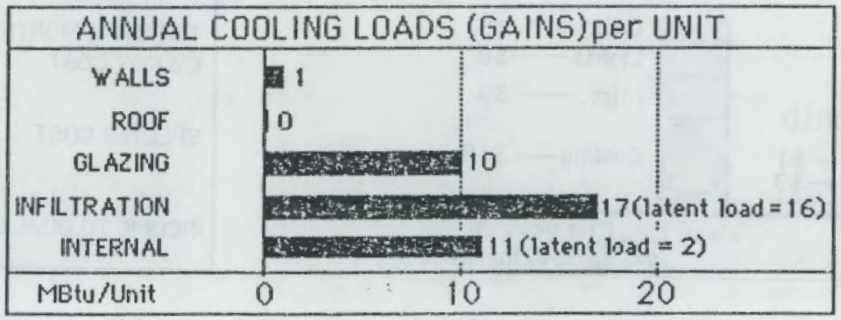
Infiltration is the major contributor to heating loads, followed by conduction through windows. They make up over 75 percent of the total heating load. Greater control of these areas is thus an essential part of any energy management plan. Sensitivity studies indicate that reducing the air-infiltration rate of one ACH would reduce the cooling load by 24 percent and the heating load by 53 percent. Window areas are approximately 12 percent of the floor area. East-and west-facing units use 26 percent more energy for heating and cooling than north or south facing units, suggesting that orientation and shading are important factors in controlling energy use, given the relatively high levels of solar radiation in Houston. Part of the problem with infiltration is that in the design of the buildings, some units have three exposed sides, providing more surface and crack area, through which air may enter. Within these apartments, the major contributor to cooling loads is cooking followed by lights and body heat. These same sources also offset approximately 30 percent of the heating load caused by envelope losses.

A reduction in lighting energy use of 50 percent, achieved through replacing incandescent lights in kitchens and bathrooms with fluorescent, would reduce the cooling load by 4 percent. Reducing the shading coefficient of the window glass reduces the cooling load while increasing the heating load by roughly the same percentage.



Infiltration and glazing are the two major causes of heating and cooling loads





Economics

HOUSTON, TX

As this is a future project, there is no utility billing history that may be used as a basis for evaluating the performance of energy-conserving strategies. Therefore all energy costs were derived from the base case energy analysis and rents are estimated by using the Institute for Real Estate Management (IREM) average rents for typical two-bedroom units in Houston in 1985. It should be noted that current local micro economic effects have caused apartment rental costs to remain well below the national average for the last several years.

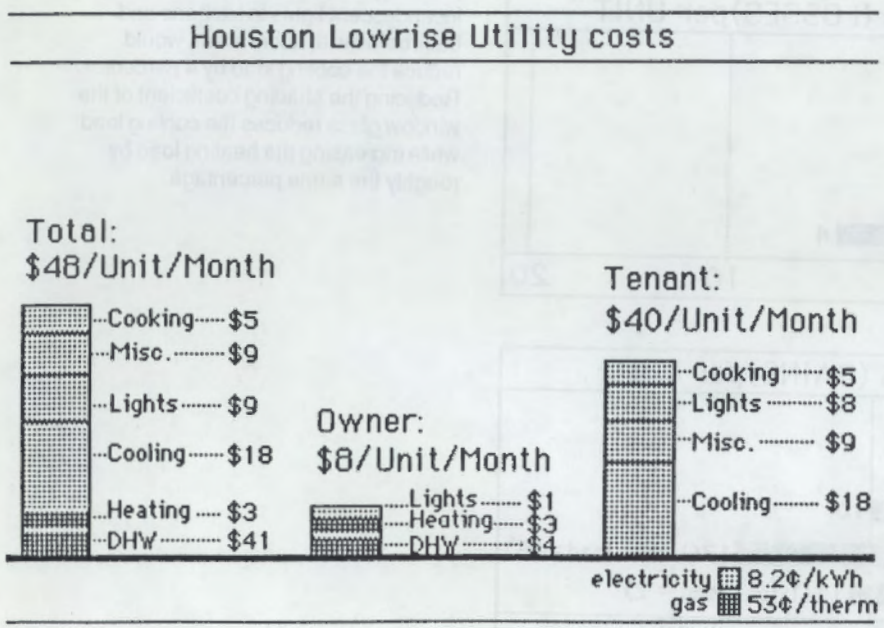
In the hot-humid climate of Houston, the calculated annual energy bill for the entire 5 building complex is just over $69,000 per year using 1985 electric and gas rates. Dividing this total energy cost by 5 for the number of buildings, then by 24 (the number of units) we find the average utility cost per unit to be $575 per unit per year.

With 24 units per building the average unit size is 1,234 square feet. By dividing the annual average energy costs per unit of $575 by the average unit size of 1,234 square feet the average energy cost per square foot is calculated to be $0.46 per year of $0.03 per month. These energy costs are considerably lower than comparable energy costs of similar buildings in the Houston area.

Because of the metering arrangement for electricity and natural gas, energy bills are significantly higher for the tenant than for the owner. Tenants pay roughly 83 percent of the total monthly bill per apartment, or about $40, while the owner pays the remaining 17 percent (or about $8). There is some room in the owner's annual energy bill of $11,722 to pay for some modest design changes with energy cost savings. The owner's position will be greatly improved however, if he can share in the tenant's savings, through charging higher rents.

This greater cash-flow will ensure reasonable paybacks on major design changes to the buildings.

The rent and energy-cost analysis presented at right uses the Institute for Real Estate Management (IREM) average rent for a typical two-bedroom unit in Houston in 1985. An inflation factor of 5 percent is used to increase costs concurrent to the assumed date of occupancy, some 3 years hence. With an estimated shelter cost of $400 per month, a renter could qualify for this unit with an annual income of $13,920.



ENERGY & RENT ANALYSIS	
Typical One-Bedroom Unit:	
NET RENT TO OWNER	$ 358
OWNER'S MONTHLY ENERGY COST/UNIT	$ 8
TOTAL RENT (IREM Median)	$ 366
TENANT'S MONTHLY ENERGY COST	$ 40
SHELTER COST	$ 406
INCOME TO QUALIFY	$13,920

Redesign Team A

HOUSTON, TX

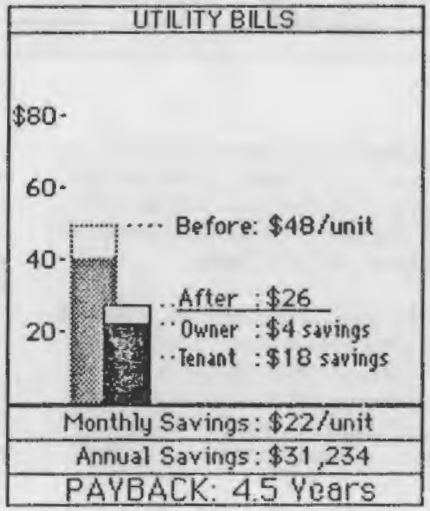
STRATEGIES & COSTS	
Infiltration/Exhaust:	
- Switched range fan	-0-
- Wrap exterior side of sheathing with monolithic plastic	7,400
- Expert caulk and weatherstrip, foam window & door frames	6,000
HVAC:	
- Install ceiling fans in living & bedrooms	18,000
- Downsize mechanical units	(55,200)
- Install high-efficiency air-to-air heat pumps	60,600
Lighting/Appliances:	
- Replace stairwell/corridor inc. with fluorescent	500
- Replace all apartment built-in inc. w/screw-in fluorescent	5,040
- Install high efficiency appliances	16,000
DHW:	
- Install high eff central DHW syst.	19,500
- Install insulating jacket on central DHW tank	900
- Lower DHW supply temp. to 115°F	-0-
- Install water restrictors in shower heads	600
Building & Site Design/Massing & Solar Control:	
- Reduce bldg. numbers from 5 to 4	(43,000)
- Plant trees on east & west sides of all buildings	20,000
- Install tinted glazing with white venetian blinds	14,592
- Paint exterior walls white	15,000
- Move east & west bedroom windows to north &south when possible	-0-
TOTAL COST:	$141,132

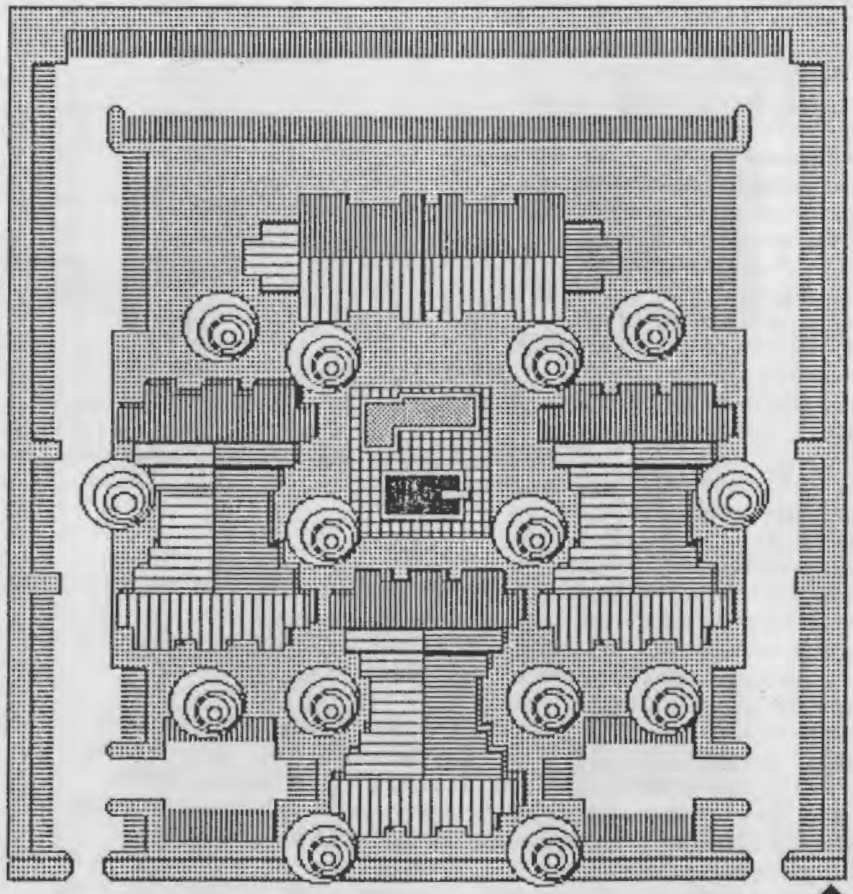
Team A emphasized conservation in its redesign effort. Strategies were identified to reduce the amount of solar heat gain entering the apartments through the windows by lowering the shading coefficient, and by providing better protection from solar radiation. Careful attention was also given to tightening up the units to reduce infiltration, and improving the efficiency of the appliances and lighting systems. Amenity value was sought through the addition of ceiling fans and carefully placed landscaping features.

Team A also studied the substitution of alternative fuel types, to lower energy costs, even where energy use may have remained the same or increased slightly.

Evaluation of the building indicated that lower levels of energy use are obtained through orienting glass areas either due north or south, and reducing window areas on the east and west. Several building configurations were evaluated as means to achieve this objective.

The most energy efficient site design - four linear, parallel buildings with their long axes oriented east-west was rejected, because the buildings appeared overly regimented and lacking in visual interest. The creation of long, unenclosed open spaces, and the loss of the enclosure for the pool area would have decreased the amenity value within the complex.





Team A Site Plan N

Redesign Team A

HOUSTON, TX

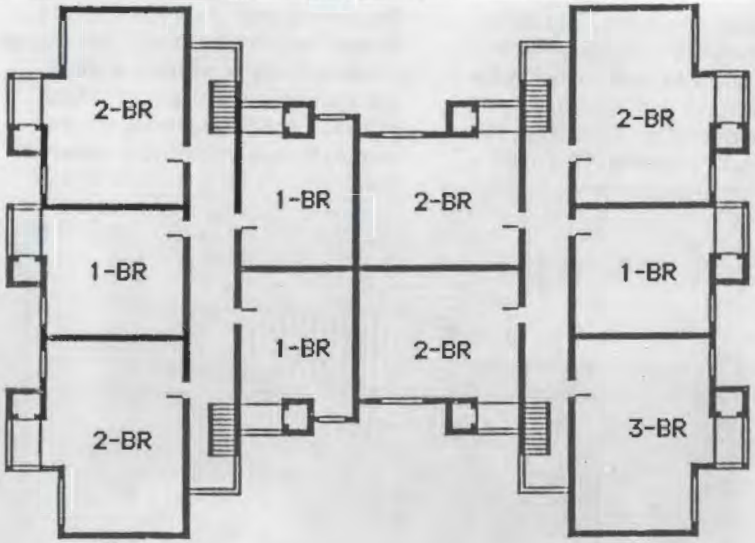
The site design ultimately selected (see illustration) increased the amenity value and marketability of the project. The major change is the reduction from the original five buildings on site to four. Two separate buildings were developed to accommodate the desired number of units on site. This organization creates many irregular exterior spaces between the buildings, increasing visual interest in the complex, and providing a sense of place for the tenants. The sense of enclosure for the pool courtyard is also enhanced. Large deciduous trees were placed throughout the site to provide general shading, particularly in front of east and west glass. Combined with a dark ground cover, the landscaping offers substantial reductions in air conditioning costs, while increasing the desirability of the complex. The placement of the buildings themselves also affords additional shading of exposed windows by adjoining building forms.

The same fundamental energy conscious design principles were used to develop both building forms used in the redesign. Resource efficiency is enhanced in the redesigned buildings through a reduction in the number of east and west oriented units, and a corresponding reduction in the number of stairwells and corridors. A significant change in the layout of the remaining east and west (end) apartments was the repositioning of glazing to the south or north walls where possible. The only east or west glazing remaining has been carefully protected. Short through building circulation patterns have also been maintained, both for energy considerations (the circulation spaces are unconditioned and daylit, and ventilated naturally) and for improved security through high visibility.

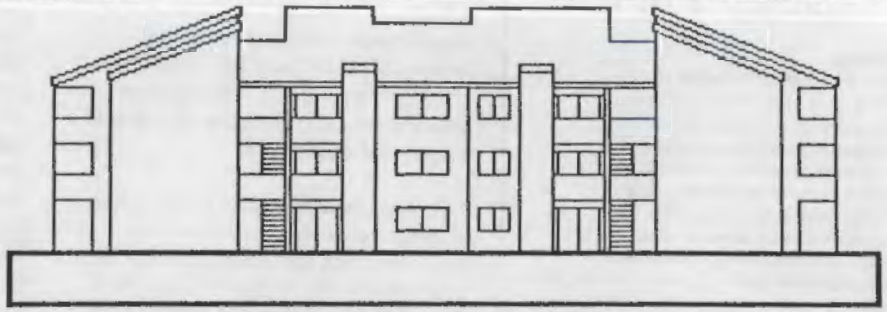
Remaining east and west glazing is protected by being recessed into the envelope of the building, between projecting shading fins and beneath a large overhang. This is particularly important for the large sliding doors at the balconies. Solar gain, the largest single contributor to sensible cooling loads, was also reduced by replacing the clear, 1/8" inch glass in all windows with dark tinted, 1/4" inch glass. Medium-color blinds were replaced with white blinds.

Similar low-cost, but effective, measures to control infiltration were used in both buildings. A continuous plastic film was installed beneath the exterior sheathing to seal the walls. Infiltration through windows, doors, and their frames was reduced by caulking, sealing, and weatherstripping.

Several strategies, investigated for their potential to reduce exterior surface temperatures due to solar heat gain and cooling loads, were rejected as too expensive. These included a standing-seam, reflective (white) metal roof, and an aluminum-foil radiant barrier in the exterior walls. In both cases, the energy cost savings did not compensate for the



Building B



EAST/WEST ELEVATION

higher first cost of the measures. The redesigned buildings use the same asphalt-shingle roof as the base case, but have painted exterior walls instead of walls coated with a medium-dark opaque stain.

Cooling loads were reduced by the siting and envelope strategies. A problem was encountered, however, when high-efficiency gas water-heaters and furnaces were evaluated as a means of reducing gas use. The local gas utility rate structure discourages the use of more efficient gas appliances, because the tenant is required to pay a minimum monthly charge already in excess of the average heating and hot water cost with standard appliances. There is thus no economic incentive for the tenant to improve the efficiency of his or her gas use. After this realization, the team concentrated on all-electric solutions for lowering energy use and cost.

The space-conditioning system ultimately chosen by team A was an air-to-air heat pump. Due to the reductions in cooling loads, it was possible to specify units of significantly lower capacity than in the original design. This system offers relatively high efficiency for heating due to Houston's mild winter weather. A heat pump water-heating system was rejected because the team felt that, with significantly reduced cooling loads due to other strategies, this strategy might not be cost effective. The team eventually selected a conventional electric-resistance water heater with an extra insulation jacket.

Ceiling fans were installed in the apartments to assist the mechanical cooling system. While ceiling fans are perceived as amenities that can be converted into higher rents or a marketing advantage, the air flow that they create also allows comfort to be maintained at higher interior temperatures. The conventional mechanical system provides dehumidification; combined with 48" diameter fans in the living areas and 36" fans in the master bedrooms, the interior cooling setpoint temperature was assumed to be as high as 82° F.

The team proposed changing from individual gas water heaters to a central gas fired system for each building. All tenants now pay a minimum monthly fee for gas that is higher than their actual use. Going to a central system would cut total DHW costs in half, but would shift these costs to the owner. It is an irony that minimum fees have made the most energy conserving approach (individual heaters) significantly more costly than necessary.

The net effect of this redesign has been to lower first cost in some areas lower energy costs, and increase amenity values in the project as a whole. Major savings were also achieved through the downsizing of cooling units. While all strategies adopted into the final redesign pay for themselves through a combination of first-cost and operating-cost savings, their major value to the owner and tenant may be the increase in the perceived amenity value of the project. Higher value has been obtained at lower monthly cost.

The incremental cost of $196,332 required to implement the desired modifications to the base case design produces annual utility cost savings of $31,234. The overall payback for these measures is approximately 6.3 years. Since 85 percent of these savings go directly to the tenant, the owner will have to carefully evaluate his rental pricing structure, to ensure that his share of the savings is adequate to justify the increased first cost.

Redesign Team B

HOUSTON, TX

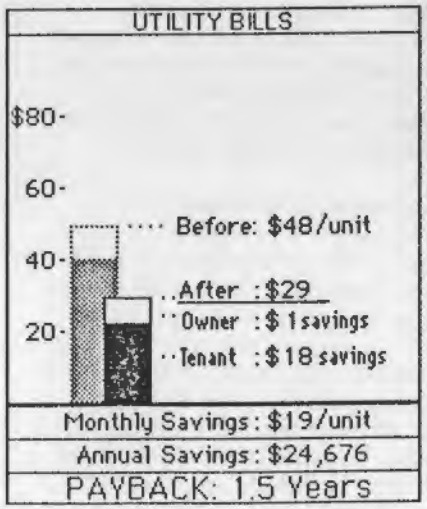
STRATEGIES & COSTS

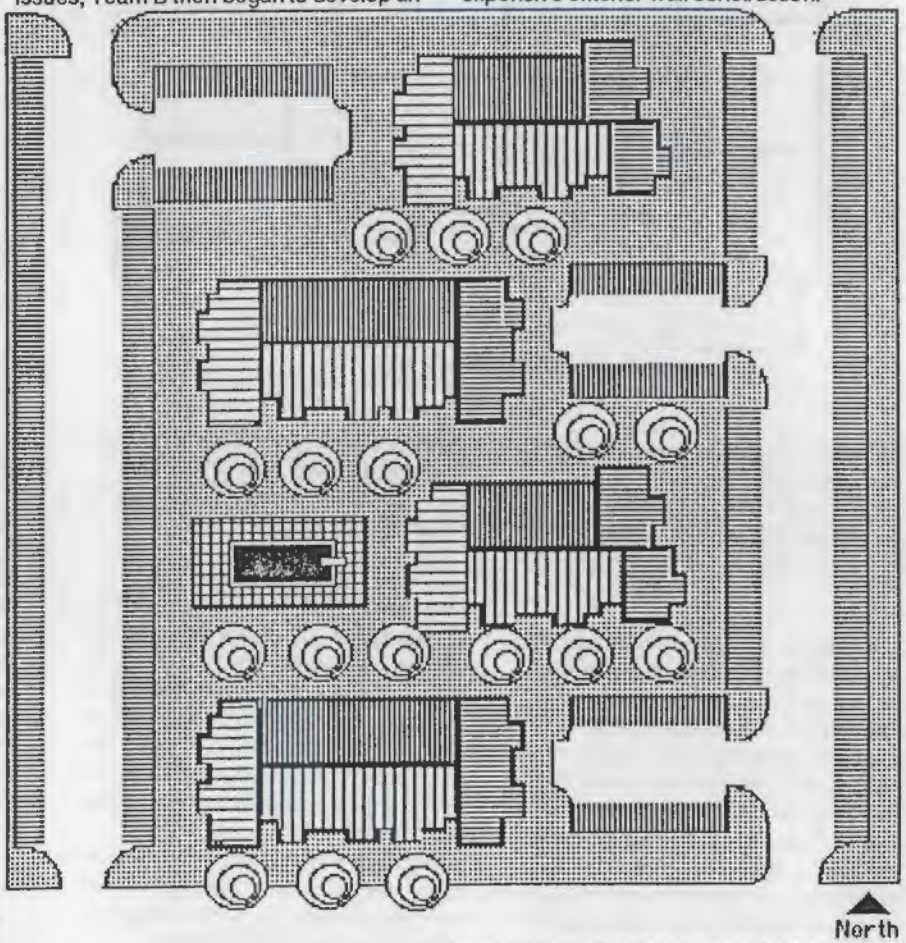
Envelope:	
- Install 1/2" gyp. bd. 2x6 studs at 24" O.C. R-11 ball insul., 2" airspace for raceways 1/2" reflective face polyisocyamurate rigid insulation 1/2" plywood; plywood clear siding Foam window & door frames; caulk bank boards & toe plates; trim & caulk duct entries, tape ext. insul. joints; Add ridge vents; Increase insul. jacket on DHW tank	47,000
HVAC:	
- Install high efficiency gas/elec.. split forced air system	50,000
Lighting:	
- Install fluorescent lighting in corridors	600
- Install fluorescent lighting in units	5,040
- Install high efficiency appliances	18,000
DHW:	
- Install high efficiency individual DHW units	4,500
- Reduce DHW temp to 115°F	-0-
- Install low-flow shower heads	600
Building & Site Design/Massing & Solar Control:	
- Reduce bldg. number to 4; Reduce number of stairs, exposed exterior walls, east/west facing units; Extend side fin on balcony to shade sliding glass doors; Plant trees on east & west to shade units; Inset windows on inside face of 2x6 walls; Lower overhang on south, east, and west windows; Extend side fin to shade east and west windows; Reduce bedroom windows from 3-1/2'x6' to 3-1/2' x 4'	(90,000)
TOTAL COST:	$35,740

Like Team A, Team B began its investigations on the premise that conservation, by reducing infiltration and controling solar gains, was the most effective way to reduce the cooling load and overall energy use.

The refinement approach included the development of improved shading strategies, and the reduction of window areas on the east and west. Apartment floor plans were analyzed to determine locations where windows could be shifted to either the north or south elevation, without significantly altering living conditions in the units. This led to an approximate reduction of 20 percent in the amount of east and west glazing. The mechanical closets on the balconies were also repositioned where appropriate to provide better shading of bedroom windows and balcony siding doors.

Window sizes were also reduced by approximately 20 percent. The smaller window sizes (3'6" x 4') also provide additional space for furniture below the sills. The balcony door was similarly reduced to a standard 6'-wide unit. With this basic understanding of the major issues, Team B then began to develop an alternative design. The major feature of this redesign was the reduction of the original five buildings to four. This change allows for better positioning of glass, and a smaller surface area to reduce infiltration. Building costs will also be lowered by a reduction in the amount of expensive exterior wall construction.





TEAM B REDESIGN SITE PLAN

Redesign Team B

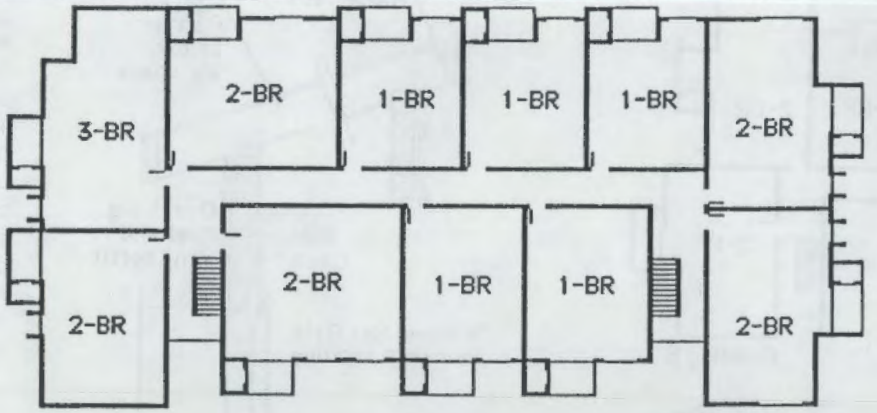
HOUSTON, TX

In this redesign, Team B maintained the same mix of apartment units in two A-type buildings with 33 units and two B-type buildings with 27-units. A benefit to the owner of these redesigned buildings was a reduction in the amount of common area from 105 square feet per living unit in the base case design, to 70 square feet in the redesigned buildings.

Additional dwelling units were inserted into the corridor spaces in the original designs, causing the deletion of some staircases and the creation of an interior access corridor for some of the apartments. The desirability of this arrangement was enhanced by lower construction and operating costs, as well as the possibility for the owner to increase the range of rents within the complex. For example, smaller units on the interior corridor could be rented at slightly lower rents.

As many units in these buildings as possible were placed with their glass areas oriented north or south. The remaining east and west apartments retained the strategy of reorienting windows where possible. Only minor windows or balcony doors in these units now face east or west. This adaptation, combined with the effect of the balcony overhang above and a fin wall to the north of the balcony doors on the west side, results in the very significant reduction of direct solar gain into the units.

Deciduous trees were planted on the east and west sides of the buildings to provide additional shading for windows and doors and to increase the amenity value of the project.



Building A

SOUTH ELEVATION

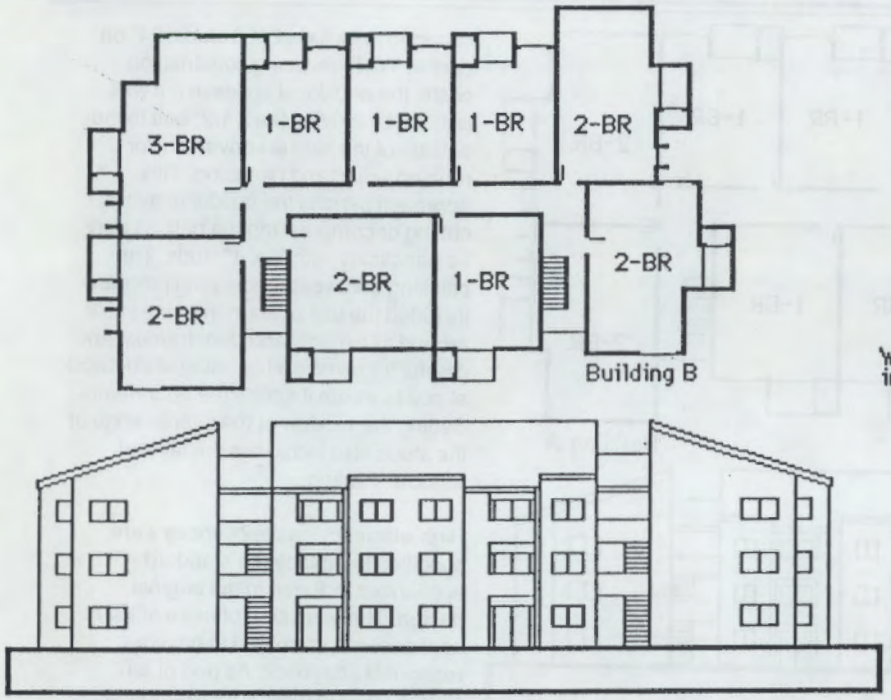
After heat gain through windows, the largest sensible component of cooling loads in Houston is heat buildup in attics and on wall surfaces. Team B specified a radiant barrier in the walls, in the form of foil-faced rigid insulation board, used as sheathing. The team also specified that all sheathing joints be taped to provide additional resistance to air infiltration. Battens were nailed to the sheathing prior to the installation of the exterior plywood finish to maintain the necessary air space in front of the radiant barrier surface. A radiant barrier was placed in the attic by installing builder's foil beneath the roof deck. Continuous ridge vents were added to the roof construction to maintain a positive flow of air through the attic space and decrease heat buildup.

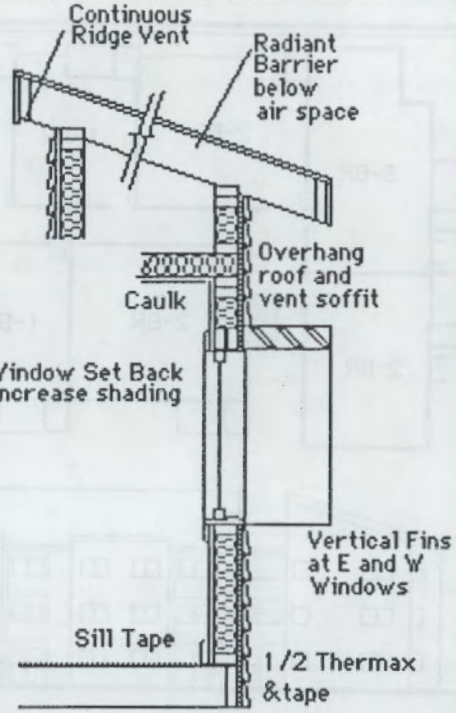
Several strategies were used to reduce infiltration by 50 percent, to 1/2 air change per hour. Wall construction was changed to include 2 X 6 studs, 24" on center. While reducing construction costs, the additional space in the wall created by moving the 3 1/2" batt to the outside of the stud is convenient for running wiring and plumbing. This approach permits the builder to avoid cutting or compressing the batt, as may be necessary with 2" x 4" studs. The caulking and weatherstripping program included the use of foam-in-place caulk around all window and door frames, and careful trimming and caulking of ductwork at points where it enters the apartments. Setting the window at the interior edge of the studs also increases the level of window shading.

High-efficiency gas appliances were specified to replace the standard appliances included in the original design. The extra cost of more efficient appliances is estimated to have a reasonable payback. As part of an overall effort to reduce internal loads, screw-in fluorescent lamps were used to replace incandescent lamps in the apartments where possible.

Space heating was provided by a high-efficiency gas furnace with an efficiency of 74 percent. The mechanical air-conditioning systems selected were electric DX split systems with energy efficiency ratings (EER) of 11.5 and a performance coefficient (COP) of 3.37. This equipment replaces the standard-efficiency gas-fired furnace and DX air-conditioner specified in the original design. Reductions in cooling and heating loads enable corresponding reduction in equipment sizes. An

Redesign Team B





Typical Wall Section

average cooling reduction of approximately one-half ton capacity was achieved for each unit.

The team retained the concept of individual gas water heaters, but recommended adding gas cooking appliances to increase the gas load within the minimum $8 per month fee charged for gas service. Better insulated tanks and low-flow shower heads were also recommended to reduce water heating costs.

Team B also considered, but later rejected, several additional concepts. A central heating and cooling system was evaluated to determine if the greater efficiency of the central heating and cooling prime equipment, combined with the capability to store either chilled water or ice for peak-shaving, was cost-justified. Due to the lower first cost of the heating and cooling equipment, and the relatively low utility bills, it was determined that this strategy would not be cost-effective in the Houston climate.

Another strategy tagged for further development is the use of a split damper system in the apartment units that would allow directing conditioned air to specific parts of the apartment without conditioning the entire apartment. The bedrooms could be conditioned during nighttime hours, while temperatures in the living spaces are allowed to "float," and vice-versa during daytime hours. This would reduce the conditioned zone by one-third to one-half, and permit corresponding reductions in the required capacity of mechanical heating and cooling equipment. This could become an attractive strategy as pressures to reduce first costs and operating costs increase, in the effort to make housing more affordable.

Double glazing was the last feature evaluated. While it provides some comfort advantage, its higher first cost is not likely to be repaid in a reasonable time by a reduction in energy cost. This is because of the relatively small contribution that conductance through windows makes to the total heating and cooling loads.

The incremental cost of $35,740 required to implement Team B's desired modifications to the base case design will yield annual utility cost savings of $24,676. The overall payback for these measures is only 18 months.

As with Team A's package, the owner will have to carefully evaluate his rental pricing structure to ensure that his "share" of the savings is adequate to justify the increased first cost. Due to the lower cost of this package, the owner may have additional latitude in setting rents, further enhancing any marketing advantage that may result from his investment in energy conservation.

The one factor that greatly affects both strategies is the financial condition of the rental market in Houston. Where rents for a two-bedroom unit averaged $530 eighteen months ago, they now average $320. Payback lengths are affected greatly as rents in Houston have plummeted. The jury felt that more consideration must be placed by both teams on first-cost as owners have less latitude to adjust rents. While Team A's strategies were generally well founded, Team A's redesign, with a $196,332 price tag, makes it an unlikely choice for an owner in the current Houston climate, in spite of a decent 6-year payback. This strategy set does, however, provide significantly higher annual savings than does Team B's set, and may be of interest to builders in similar mild climates and more typical economic factors.

Team A's decision to paint the exterior walls a bright white, while energy efficient, is not necessarily a good idea. One jury member felt that the amenity value would suffer with an all white complex. Regarding the lack of incentive for installing energy efficient gas water heaters, consideration might be given to switching more appliances and the air conditioning system to gas, thereby using less of the more expensive electricity, making the minimum monthly gas charge of no consequence. To be especially commended in both team strategies is the downsizing of the originally specified HVAC units due to the tightening of the envelope.

In team B's strategy of using a split damper system, tenants will surely not want the HVAC system to be undersized to a point of not being able to condition the whole apartment.

Chapter V: Conclusions

Cutting energy costs is a key to more affordable housing for tenants and significantly increased profits for building owners. As shown in the previous chapters, this conclusion applies to all types of multifamily housing regardless of location, ownership, utility rates or bill paying arrangements.

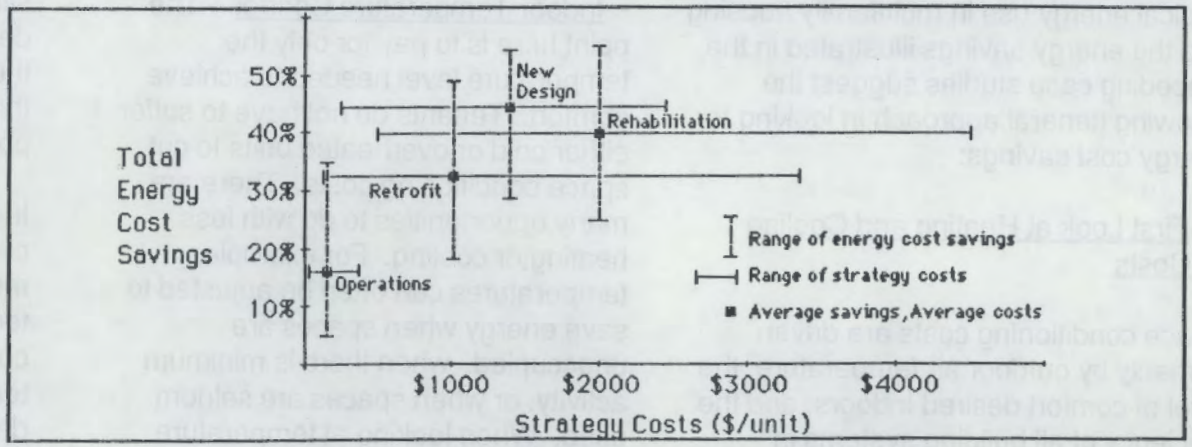
Energy bills can be reduced -- cost effectively -- in every multifamily building we studied. Older existing buildings typically waste more energy, and consequently have higher energy bills than newer buildings. Energy costs can be cut most in these older buildings. Significant energy cost savings are possible, however, even in new buildings which meet or exceed current ASHRAE standards. More savings are possible in harsher northerly climates than in more southerly or temperate coastal climates.

Energy cost savings typically increase with greater investment. The law of diminishing returns does come into play however. Low-cost operations strategies, taken separately, are much more attractive than high-cost rehabilitation strategies, but investment beyond low-cost strategies will be required to achieve large impacts on your energy costs. You should look at substantial investment in energy cost-cutting to maximize your total dollar return.

Our recommendations do not stop at low-cost, low-impact approaches. As shown on the graph below, in order to achieve cost savings on the order of 30% to 35% we found it necessary to spend $1000 to $2000 per unit. The results you achieve in your cost-cutting efforts will depend entirely on the special circumstances of the building or project you are working on, but several general conclusions about energy use in multifamily housing can be drawn from the twelve case studies in this report.

- Space conditioning (heating or cooling) is the most important energy cost in apartment buildings, and should be looked at first in cost-cutting efforts. Across all existing buildings, heating and cooling taken together accounted for 31 percent to 65 percent, averaging 52 percent of total energy costs. In future buildings, the range lowered to 43 percent to 45 percent, but was still the predominant cost factor by a substantial margin.

- Lighting is the second ranking energy



cost in most buildings, ranging from 8 percent to 24 percent (16 percent average) of total energy costs for existing projects and 15 percent to 23 percent in future buildings.

• DHW costs typically rank third, averaging 12 percent in existing buildings and 14 percent in future buildings.

• All other energy costs, including appliances, vertical transportation, and miscellaneous receptacle use, together account for about 20 percent of the energy bill. These each merit modest attention, but only after the larger energy issues, above, have been addressed. Typical energy use in multifamily housing and the energy savings illustrated in the preceding case studies suggest the following general approach in looking for energy cost savings:

1. First Look at Heating and Cooling Costs

Space conditioning costs are driven primarily by outdoor air temperature, the level of comfort desired indoors, and the efficiency of all building systems in delivering comfortable conditions. Four principal factors, each with a variety of conservation options, should be reviewed for opportunities to reduce space conditioning costs. The factors, roughly in order of cost effectiveness and ease of implementation, are:

- Indoor Temperature Control
- Infiltration and Ventilation Air Control
- Equipment Efficiency Improvement
- Building Shell Improvement

The following paragraphs discuss each of these factors and summarize strategies which the design teams found effective for dealing with them.

• Indoor Temperature Control -- The point here is to pay for only the temperature level needed to achieve comfort. Tenants do not have to suffer either cold or overheated units to cut space conditioning costs. There are many opportunities to do with less heating or cooling. For example, temperatures can often be adjusted to save energy when spaces are unoccupied, when there is minimum activity, or when spaces are seldom used. When looking at temperature control, the first thing to do is to make sure neither heating nor cooling are provided when not needed or when the outside environment could be used to meet the comfort needs of tenants instead (for example, by opening windows in spring or fall instead of turning on air conditioning). Further savings are possible with temperature setback (for heating) and setup (for cooling) which can be done manually or automatically on a daily basis.

Operations strategies to control temperature settings should start with the education of building personnel or tenants, depending on who has control of temperature settings. In a retrofit situation one should consider more decentralized controls, individual thermostats for tenants, or programmable thermostats to allow closer and more positive scheduling.

In retrofit, rehabilitation, and new design, ceiling fans can be considered as a means to expand the range of temperatures that are considered comfortable. Ceiling fans allow heating temperatures to be lowered two to four degrees, and cooling temperatures raised two to four degrees while

maintaining occupant comfort.

Indoor temperature control is a very effective first step in cutting energy costs. The costs of these strategies are low and the relative savings are very high. Temperature control strategies were recommended by the design teams for every building in this study.

• Infiltration and Ventilation Air Control is the second most important factor to consider in cutting heating and cooling costs in apartments. There are two ways in which unconditioned outside air is introduced into a building: by infiltration, the seepage of air into a building through cracks and other openings in the building shell; and by ventilation, the supply or exhaust of air by mechanical systems.

In controlling infiltration the goal is to minimize leaks. Weatherstripping and caulking are the most typical means of closing air pathways and lowering infiltration rates. In these situations, the more professional the installation the better. In new design, close attention should be paid to construction details such as vapor barriers and construction quality control around all doors, windows and other openings. In this study, infiltration control was recommended for all twelve buildings.

Control of ventilation air in buildings is more straight forward. Here the goal is to minimize ventilation within acceptable limit when external conditions are unfavorable and to maximize ventilation when conditions are favorable. Ventilation is controlled through scheduling the operation of equipment and adjusting the amount of air introduced into the building. Strategies include: adding time clocks to run fans for pre-set periods only, reducing damper openings, downsizing fans, and varying fan speeds. In some cases, ventilation may be eliminated entirely or cut back drastically. For example, recirculating kitchen and bath fans with charcoal filter to clean recycled air were selected by both design teams for several buildings in this study. This particular strategy is very effective in cutting energy costs and is accepted by most building codes. The noise of operating these fans and the fact that some users feel indoor air quality is reduced, makes their use controversial.

Ventilation air control was recommended as a strategy in a majority of the buildings in this study.

With all strategies that affect indoor air, keep in mind that indoor air quality is an important area of public concern and research is in progress that will lead to a better understanding of the problem and ways to deal with it. Reduction of infiltration and ventilation beyond a certain point is probably not a good idea. The measures that were recommended in this work were intended to reduce infiltration to a level that would maintain health and ensure a pleasant indoor environment.

• Equipment Efficiency Improvement is the third most important factor to consider. The general goal of equipment strategies is to increase efficiency. Some low cost actions can be effective, such as consistent maintenance and careful adjustment of equipment, but many strategies can be costly.

In older buildings, equipment strategies typically focus on improving the central plant. In retrofit, rehabilitation and new design consider new, more effective controls (decentralized controls provide advantages over centralized systems), high efficiency replacements (the marginal cost for higher efficiency is often low compared to returns), or entirely

new systems. In rehabilitation and new design, depending on what other energy cost-cutting actions you take, it may be possible to substantially downsize equipment. For instance, in several future buildings, design teams were able to cut already small heat pumps capacities in half -- saving both energy costs and first costs in the projects.

Equipment strategies were recommended for all buildings in this study.

• Building Shell Improvement is the fourth factor which can be used to cut space conditioning costs. The goal should be to reduce conduction losses and gains through all parts of the exterior wall section. Reducing conduction losses through glazing received a good deal of attention from the design teams. Most strategies to control building shell losses and gains involve substantial additions of materials and construction time and are therefore fairly expensive.

Operating strategies are limited, but include better window management (e.g. tenant education on use of blinds), the addition of interior blinds, and the addition of storm windows (either exterior or interior) which can also be seen as a retrofit strategy.

In retrofit and rehabilitation consider adding insulation, adding better glazing (tinted or reflective to cut solar gains; Low E to cut heat losses), installing new exterior shading devices (overhangs, awnings, etc.), or even replacing old windows with new window assemblies.

In new design, more innovative approaches can be taken. For example, the storage capacity of building elements can be used to store heat for later use or to delay unwanted heat gains until natural cooling can be used to remove them. Building configuration can also be altered to minimize losses and gains or to take advantage of natural resources.

It is important to re-check the sizing on all HVAC equipment after all shell strategies have been applied. The net effect of many strategies is to reduce building loads which, in turn, means that smaller HVAC equipment can be used.

Use of building shell strategies was mixed in our work. Heat loss through glazing is fairly easily dealt with by storm windows, which were recommended for several of the buildings. Window shading to reduce solar gains was found to be effective in several other buildings, as well; particularly in the future buildings where cooling is a much larger proportion of total energy costs.

2. Second, Investigate Opportunities to Cut Lighting Costs

Lighting is a significant energy cost in all apartment buildings. This is an area where easy cuts can be made, particularly in common space and exterior lighting. The approach is simply to reduce light levels whenever and wherever possible (using photocell or time clock controls, delamping, education, etc.) without compromising vision or safety, and to use the highest efficiency lamps available. Quality of light is an important issue, however. Do not consider low pressure sodium lamps ("the color purple") for hallways, but do consider color corrected fluorescents everywhere.

Lighting strategies have effects beyond cutting lighting costs. Reducing lighting can substantially reduce cooling loads. However, the loss of heat from lights can also raise heating costs modestly during

the heating season. However, the net result of using the heating fuel rather than inefficient, or "wasted", electric heat is still a reduction in energy costs.

Lighting strategies were selected for all of the buildings in this book.

3. Third, Reduce Domestic Hot Water Costs

Domestic hot water (DHW) is used for bathing, dishwashing, laundering, and general cleaning. Each of these areas provides opportunities for modest energy cost savings. For DHW, the goal is simple: use the lowest temperature that will do the job (be careful, however, not to go below minimums for sanitation and dishwashing detergents), minimize storage losses (a major part of DHW cost is maintaining the tank temperature), and reduce flow rates to the extent possible.

The design teams recommended DHW strategies for all buildings in the study. In several cases replacement of particularly inefficient configurations was recommended -- for example, when a central DHW system required year-round operation of heating system boilers.

4. Finally, Reduce Remaining Miscellaneous Energy Costs

The remainder of the annual energy bill is made up of appliance use (stoves, ranges, refrigerators, dishwashers, clothes washers, dryers, etc.) elevators, and miscellaneous receptacle use. Cutting these costs in any systematic way is difficult, but can be fruitful.

In particular, installing high efficiency apartment appliances can produce substantial cost savings. Older, less efficient appliances should not be replaced until they have served their normal service life. At the time of normal replacement, the marginal cost of an efficient model is low and can easily pay for itself in energy savings. In most cases, these savings continue long after the incremental cost for efficiency has been recovered. In the case of central laundries, look at the opportunity to have the laundry concession contractor switch out existing equipment for more efficient models at contract renewal.

# # #

In summary, savings from a thoughtful approach to energy conservation for multifamily housing can be substantial, as shown in the table summarizing our results, below....

SAVINGS (%)	EXISTING BUILDINGS						FUTURE BUILDINGS	
	Operations		Retrofit		Rehabilitation		New Design	
	range	Average	range	Average	range	Average	range	Average
Space Conditioning	3%-51%	23%	30%-61%	45%	36%-70%	51%	36%-70%	55%
Lighting	1%-34%	10%	1%-53%	14%	35%-62%	17%	35%-62%	44%
DHW	4%-38%	17%	10%-60%	28%	16%-72%	32%	16%-72%	40%
TOTAL ENERGY COSTS SAVED	5%-35%	16%	18%-49%	32%	28%-55%	40%	28%-55%	44%
STRATEGY COSTS ($/unit)	$5 to $340	$135	$130 to $3350	$1040	$460 to $4500	$2010	$220 to $2440	$1220*
PAYBACKS	1mo. to 4yr.	1.2 yrs.	1yr. to 7yr.	3.8 yrs.	1yr. to 14yr.	5.7 yrs.	8mo. to 6yr.	4.1 yrs.

*includes substantial amenity improvement

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