THE ENERGY CRISIS:

AN ARCHITECTURAL CHALLENGE

BY

PEER GERLACH

B. S., New York Institute of

Technology, 1972

THESIS

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Master of Architecture

in the Graduate School of

The University ofNew Mexico

Albuquerque, New Mexico

May, 1976

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Committee Chairman

Keith W. Haggard	Visiting Lecturer and NMSEA Chairman

Committee Members

Don P. Schlegel, Professor	School of Architecture and Planning, UNM
Craig G. Andrews	Architect, Albuquerque, New Mexico

Reader

Wybe van der Heer, Associate Professor	School of Architecture and Planning, UNM

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ABSTRACT OF THESIS

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The depleting reserves of natural resources and energy and their escalating cost have vitalized serious interest in conservation. Perhaps one of the nation's most sensitive economic indicators is the building industry, which has been deeply affected by the energy crisis.

While numerous procedures for conserving energy and materials in buildings exist, correct implementation of these methods is the real issue. It is therefore essential that the architect, together with allied professionals, plan buildings as efficiently as possible, if the future of this vital industry is to be secured.

Consequently the following study is intended to serve as a guide for alternative design considerations with respect to the deepening energy crisis that confronts the architect. This survey represents the latest research available, with a large portion of the data having been collected through correspondence with universities engaged in conservation projects. Furthermore, reports, nationwide newspapers, and interviews with professionals in the building industry have yielded pertinent information on problems faced by the practicing architect and his related attitudes.

Although the worth of many conservation techniques in building design is a source of much debate among experts, there are certain basic principles, which should be applied in all planning. Most of the information that follows, however, has been more specifically directed toward building in hot-arid climates. Nevertheless, it is hoped that the suggestions presented herein will be of practical benefit when adapted for individual design needs.

Chapter I traces the development of energy systems through history and analyzes the major factors that have led to the current energy crisis. Present and future problems of the building industry and related professionals are also discussed.

Chapters II and III represent the handbook portion of this study and present designers and planners with alternate design proposals that will save energy and materials, based on current technology.

The concluding chapter takes an in-depth look at the status of the building industry and the architect's role therein. Trends, changing priorities, and relationships among building professionals are the topics analyzed to determine future courses of action the industry might -follow to alleviate problems caused by the energy crisis.

Appendices at the end categorize in outline form additional conservation procedures, with an extra supplement on saving energy in residential construction.

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Chapter 1 THE ENERGY CRISIS

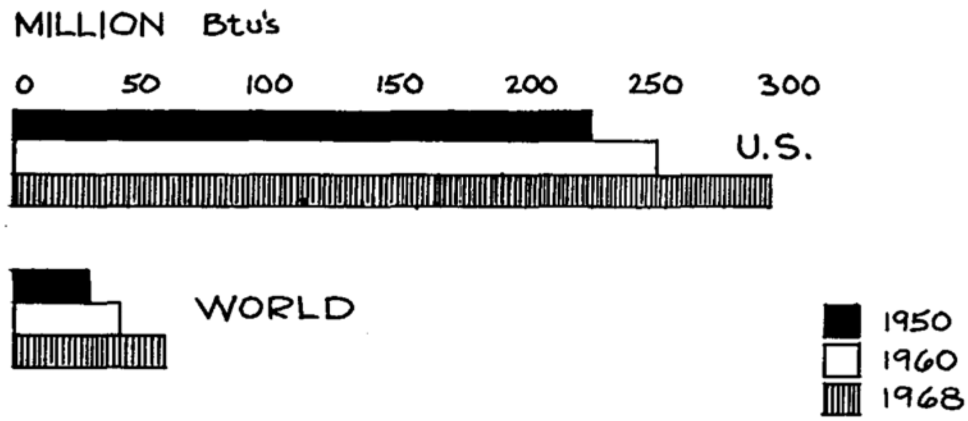
Man has always relied on the Earth with its abundance of natural resources to supply the energy that will fulfill his needs and desires. Recently he has had to face the grim reality that his planet is running short of such resources. To make matters worse, the tremendous increase in population has overturned earlier predictions of how long our natural resources would last. Another factor contributing to the deteriorating outlook is the increased industrialization of undeveloped countries. Finally there is the growing waste factor coupled with a spiraling increase in pollution.

With respect to energy resources there are two types of systems used: (1) man-organized energy systems; and (2) man-made energy systems.[1] Before the middle of the 19th century, man-organized systems were the dominant factor in converting natural processes into usable energy. This use of water power, wind power and animals, reorganized the natural forces without extracting the Earth's resources permanently. However, for the past 100 years man-made energy systems have been using up the Earth's nonrenewable resources at an alarming rate.

From the end of the 19th century through the middle of the 20th century our nation witnessed a sudden and vast expansion of industry, science, communications, and population unparalleled in history. Unfortunately, this growth was accompanied by a devastating lack of responsibility or foresight regarding future consequences or needs. As a result, we find ourselves at the close of the 20th century in the midst of a forbidding situation commonly referred to as the "energy crisis." This energy crisis has manifested itself in the disproportionate growth rates between consumption and domestic production. To illustrate the point let us examine some of the actual figures presented in the graphs that follow (Figure 1).

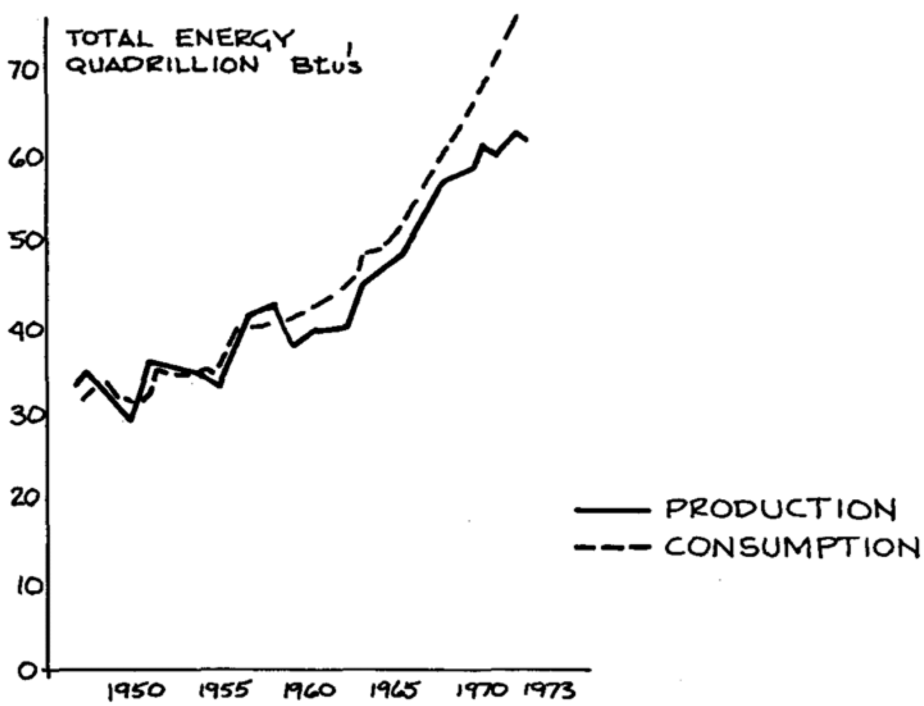
The total energy used in the United States has more than doubled in the last 2S years, while the population has increased by one-third.[2] In the last 5 years energy consumption has increased at the rate of 4.5% annually, whereas the rate of domestic production has remained relatively unchanged.[3] Moreover, to meet the growing energy needs the United States has found it necessary to become an importer – 15% of its oil – in striking contrast to its role as an oil exporter in the past. Finally, with only 6% of the world's population, the United States consumes one-third of all the energy produced.[4]

COMPARATIVE ANALYSIS OF ENERGY USES



a. ENERGY USE PER CAPITA, U.S. AND THE WORLD

(Source: Exploring Energy Choices, Ford Foundation, 1974)



b. U.S. ENERGY PRODUCTION AND CONSUMPTION

Figure 1

Clearly then we are already in an energy deficit, with production falling steadily behind consumption. Over the past few years we have continued patterns of growth in housing, transportation, and industry, totally oblivious to future needs, spurred on by profiteers and a public seeking more comforts at any cost. Compounding the problem further is the emergence of environmental policies. Whereas these policies were designed to protect our limited energy resources and reduce pollution, one of their negative effects has been to polarize even further the interests of users and producers through resulting economic pressures. Partially to blame for the dilemma of how to maintain current and future energy needs without destroying the environment and exhausting all of our resources is the government. Rather than committing themselves to a national energy policy and uniting fragmented local policies, many federal agencies are contending for the decision-making authority and budget control of environmental and energy legislation.

It is becoming increasingly apparent that we cannot continue to double our total energy consumption every 15 years using the philosophy "more is better."[5] Nevertheless several options still remain at our disposal to achieve an energy equilibrium:

1. Increase energy production.
2. Rely more on foreign sources.
3. Decrease consumption.

As the first possibility is basically a technological matter, and the second an increasingly expensive and doubtful source, this paper will focus on the third choice. But even more specifically, it will concern itself with those alternatives currently available for reducing energy consumption in the building industry, with some of the consequent ramifications for the parties directly involved, especially the architect. Regardless of which choice our nation decides upon however, we will see major changes in the American lifestyle that has traditionally operated on the premise that waste is natural.

In order to propose any viable solutions it is necessary first to understand the nature and scope of the problem. Therefore we must begin our study with a preliminary analysis of the facts and statistics relating to energy consumption in the building industry. For instance, an investigation conducted by the Stanford Research Institute revealed that the consumption of natural resources such as petroleum, gas, and coal can be traced to: industrial – 41.2%; transportation – 25.2%; residential – 19.2%; commercial – 14.4%[6] (Figure 2). It is a fact that buildings expend one-third of all the energy in the United States, whereas the automobile, at a 14.3% usage, has attained the most notoriety as a leading cause of wasted energy. Obviously then, the time has come to conserve energy in buildings, not only in the space heating, ventilating, air-conditioning and lighting, but in the manufacture and transportation of building materials.[7]

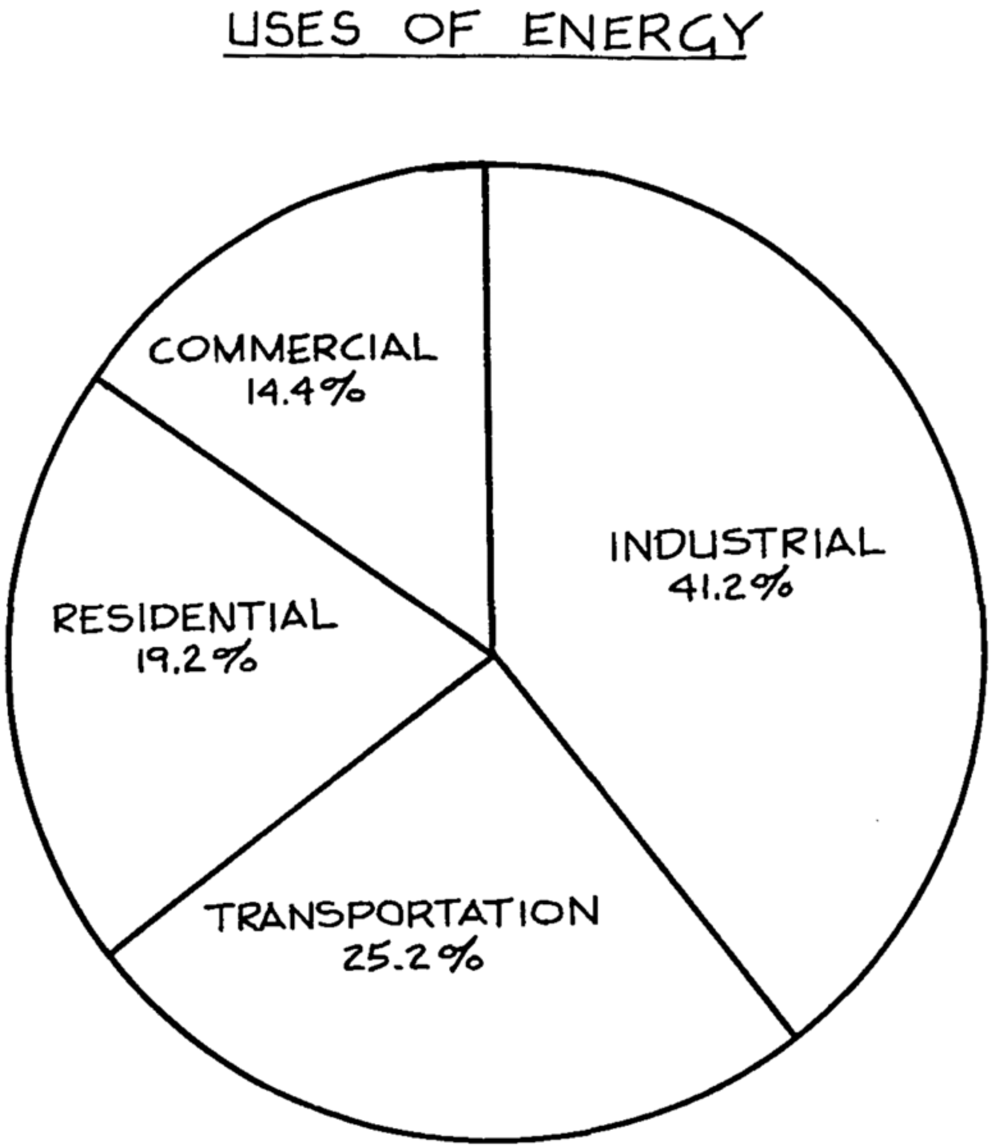


Figure 2

In the past energy was abundant and relatively inexpensive, so it was not economically feasible to conserve energy with high-priced additions to the initial cost of buildings. However, now that we are faced with depleting resources and increasing competition in the world market for both energy and materials, the building industry must be reevaluated. It has been estimated that energy consumption can be reduced up to 50% with no penalty to the quality of life within buildings, and that existing structures can be renovated to save up to 25% of the energy needed for operation and maintenance.[8]

The present consumption rates of natural resources can serve only to raise the cost of building materials drastically in the near future. Aluminum, for instance, has a 100-year life expectancy in world reserves according to the U.S. Bureau of Mines. However, if the consumption is considered exponentially increasing by 6.4% a year, aluminum reserves would last for only 31 years. The book, Limits to Growth, (Figure 3) designates the exponential limitations, in years, for nonrenewable resources at five times the known reserves, which implies that aluminum has 55 years before exhaustion at the present consumption rate. For all practical purposes, the claim in Figure 3 is not that materials will be totally depleted at the years given, but that some consideration and awareness be directed to the possibility that resources will no longer be available in quantities to which we have been accustomed.

For every million dollars worth of building, about 1,250,000 kilowatt hours, or the equivalent of 736 barrels of oil goes into the materials used in construction. The process begins with the collection or reclamation of raw materials such as stone, mining ore, etc., and continues with the transportation of raw materials into finished building components rolled steel, cut stone, cut lumber, e.g. These must then be transported to the site by rail, truck, or some other form of transportation to be assembled into a building by a construction company, all involving an elaborate range of energy-consuming machinery. Furthermore, every year the building is in operation it requires about a million kilowatt hours of energy for operation and maintenance. By 1970, for instance, the total energy consumption for building operation and maintenance in the United States was 69,000 trillion Btu's.[9] The primary outlay of energy was attributed to lighting. Air circulation was secondary, with remaining demands traced to heating, air-conditioning, water heating, and appliances.[10]

NONRENEWABLE NATURAL RESOURCES

RESOURCE	KNOWN GLOBAL RESERVES	STATIC LIMITS (YEARS)	PROJECTED RATE OF THE (% PER YEAR) HIGH	AV.	LOW	EXPONENTIAL LIMITS (YEARS)	EXPONENTIAL GROWTH CALCULATED, USING 5 TIMES KNOWN RESERVES (YEARS)
Aluminum	1.17×10^9 tons	100	7.7	6.4	5.1	31	55
Chromium	7.75×10^8 tons	420	3.3	2.6	2.0	95	154
Coal	5×10^{12} tons	2300	5.3	4.1	3.0	111	150
Cobalt	4.8×10^9 tons	110	2.0	1.5	1.0	60	140
Gold	353×10^6 troy oz.	11	4.8	4.1	3.4	9	29
Iron	1×10^{11} tons	240	2.3	1.8	1.3	93	173
Lead	91×10^6 tons	26	2.4	2.0	1.7	21	64
Manganese	8×10^8 tons	97	3.5	2.9	2.4	46	94
Mercury	3.34×10^6 tons	13	3.1	2.6	2.2	13	41
Molybdenum	10.8×10^9 lbs.	79	5.0	4.5	4.0	34	65
Natural Gas	1.14×10^{15} cu. ft.	38	5.5	4.7	3.9	22	49
Nickel	147×10^9 lbs.	150	4.0	3.4	2.8	53	96
Petroleum	455×10^9 bbls.	31	4.9	3.9	2.9	20	50
Platinum Group	429×10^6 troy oz.	130	4.5	3.8	3.1	47	87
Silver	5.5×10^9 troy oz.	16	4.0	2.7	1.5	13	42
Tin	4.3×10^6 lg. tons	17	2.3	1.1	0	15	61
Tungsten	2.9×10^9 lbs.	40	2.9	2.5	2.1	28	72
Zinc	123×10^6 tons	23	3.3	2.9	2.5	18	50

Figure 3

As the figures illustrate, the energy cost of a building reaches much further than one would expect.

To no one's great surprise office buildings constructed in recent years use far more energy, on the average, than older buildings of equal floor space. Most of the differences can be attributed to higher lighting levels, sealed windows, glass curtain walls, and to the increasing use of computers, elevators, and electric office machines. It has been estimated that many high-rise buildings so-called glass towers – have an energy waste factor of 75%. Analyses of such structures reveal that frequently interior rooms are not related to the exterior, thereby requiring artificial cooling year round – even in cold climates. The current use of mirror glass does reduce the heat buildup within a building, but the material can reflect glare and heat into the street or adjacent structures.[11] Studies have shown that 50% of the energy used for buildings is wasted, and that energy consumption in such structures is rising exponentially – doubling every ten years.

Perhaps the most controversial energy-wasting glass tower is the World Trade Center in New York City. No windows can be opened in the Center's two 110-story towers, and most occupants cannot turn off their own lights. The Center requires 80,000 kilowatts of generating capacity.[12] In other words this figure represents as much electrical power as is needed for a city twice the size of Santa Fe. Because of the structure's height the power requirements for elevators, pumps, and other systems are proportionately greater, thus adding to the energy drain.

This paper will deal primarily with the sources of waste in such typical commercial buildings, which have had an increasing annual energy consumption rate of 5.4% since 1960.[13] Nonetheless, while a million square foot enclosure may deserve a different treatment for energy conservation than an apartment complex or residence (Appendix H), some of the suggested techniques will apply to all building types. However, it should be emphasized here that any energy impact study must be determined on a regional basis since policies that are effective in hot-arid climates, such as those stressed in this analysis, may be ineffective in humid or temperate climates.

Finally, the last and conceivably the most difficult phase of the architectural challenge is how to create new incentives for conserving energy in both old and new buildings with a program that will capture the greatest long range monetary savings. As the price of energy escalates, perhaps the need for action to reduce energy consumption will become more evident.

One of the major obstacles in energy conservation for the building industry is that in most cases the architect/engineers and builders have no follow-up program on the operation and maintenance of the completed building. Therefore they must rely upon data, which mayor may not be relevant to their design needs, compiled by research institutes analyzing experimental structures. Thus, the designer is left with too many trial and error alternatives instead of exact figures on how to modify his future structures for energy economy.

For some of the aforementioned reasons there appears to be a strong possibility that government policies, requiring builders to make economically feasible investments to save energy, will become a reality. Regulations could manifest themselves in the form of rules established by public service commissions directing all new construction to meet demanding energy conservation standards before utility service would be available. States such as New Mexico, California, Florida, and New York already have laws governing energy use.

Another form of regulation that could be instituted is that buildings would have to meet an energy conservation policy before the government would guarantee a loan by the Federal Housing Administration, Veterans Administration, Small Business Administration, or any other agency for new or existing home or commercial construction. Moreover, the benefits of life-cycle cost programs for buildings seems to be of growing interest to the government. The Commission on Government Procurement has suggested that, "when feasible, proposals for AE contracts exceeding $500,000…should include estimates of the total economics – i.e., life-cycle costing."[14]

It seems inevitable that architects and related professionals will have to cooperate with the government to legislate solutions. Otherwise, the resulting decisions on conservation standards may not be to the architect's liking. Consequently, many architects, the AIA, ASHREA and research groups are developing energy-conscious design procedures as indicated in the following chapters.

FOOTNOTES

[1]Energy and the Built Environment, AIA, (Washington, D.C., 1974), p 2.

[2]Ford Foundation, Exploring Energy Choices (Washington, D.C., 1974), p. 1.

[3]Ibid.

[4]Ibid., p. 3.

[5]David Freeman, Energy: The New Era (New York, 1974), p. 8.

[6]Ford Foundation, p. 125.

[7]Richard Stein, "Architecture and Energy," Forum, (July/August, 1973), p. 53.

[8]Ibid.

[9]Ibid., p. 3.

[10]__"Its Metabolic Use of Energy Determined Building Worth," Austin American, (May 12, 1974). (Unsigned, microfiche)*

[11]Ibid.

[12]Peter J. Brenstein, "Energy Crisis Spells End of Glass-Tower Era in Design," Long Island Press, March 31, 1974, microfiche.

[13]Ford Foundation, p. 5.

[14]C. W. Griffin, Energy Conservation in Buildings (Washington, D.C., 1974), p. 160.

*Where microfiche references are cited, no page numbers were shown.

Chapter II BUILDING WITH THE NATURAL ENVIRONMENT

> "For the style of buildings ought manifestly to be different in Egypt and Spain, in Pontus and Rome, and in countries and regions of various characters. For in one part the earth is oppressed by the sun in its course; in another part the earth is far removed from it; in another it is affected by it at a moderate distance." – Vitruvius 27 B.C.

One possible approach to the energy problem is to design buildings in relation to the environment. As a matter of fact, this concept of building with the climatic conditions in a particular region has been an age-old procedure. For example, hot-arid zones imposed extreme demands on the structures of tribal dwellings. The climate, characterized by excessive heat and glare of the sun, required vernacular architecture to be designed to reduce heat impacts and provide shade. Structures such as the pueblo of San Juan were constructed of massive adobe roofs and walls, which have good insulative value and the capacity to delay heat impacts for long hours, thus reducing the daily heat peaks. The utilization of very small windows and the placement of buildings in close proximity greatly reduced the amount of exposed facade. In addition, pueblo structures were usually extended on an east-west axis, thereby reducing morning and afternoon heat impacts to the two end walls in the summer and receiving a maximum amount of south sun in the winter months.

By utilizing the information from vernacular architecture along with modern technology, it is entirely possible for architects to design structures that are appropriate for local climatic conditions. In fact there are numerous techniques for incorporating the natural environment into the building design process to further the cause of energy conservation at our disposal today. However, the problem is that too few financiers, builders, or owners know enough about the environment and its various effects on structures. Furthermore, until the specter of an energy crisis compelled professionals to reevaluate natural elements and building systems, there was little incentive to learn.[1]

Climate is perhaps the single most important factor that influences building form. Choice of materials, structural system, and the energy required for heating, cooling, ventilating, and lighting run a close second. For example, outdoor temperatures that remain close to the indoor design temperature have a direct effect upon the heat loss or gain, and the magnitude of temperature peaks. Likewise the amount and direction of sun and wind have a direct bearing upon the heating and cooling loads. Thus, data relevant to heating and cooling degree days does not provide sufficient information to design an envelope appropriate to the climate, nor to determine the most efficient type of mechanical and electrical equipment.

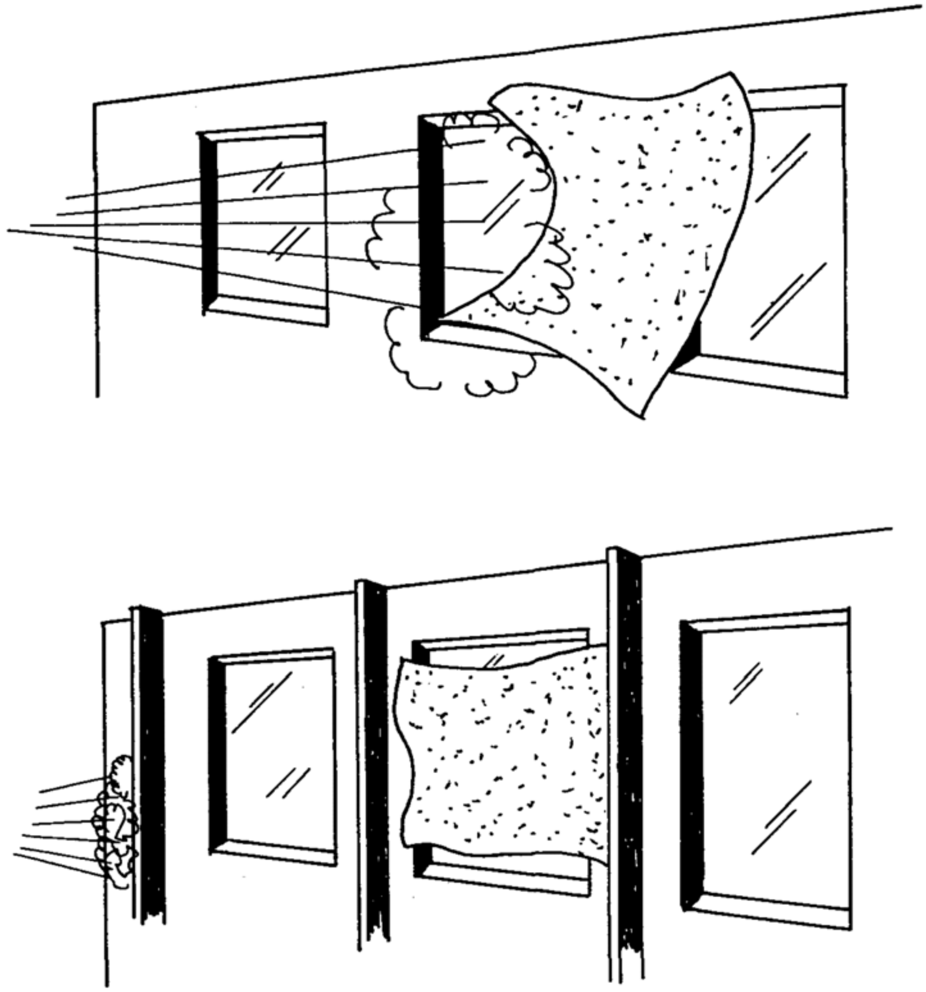
Wind and Solar Analysis

The prevailing direction and velocity of the wind on a given site should determine the shape and orientation of a building. For instance, winter winds cause great heat losses from building envelopes, especially at windows and thinly insulated walls. The impact of such air currents upon a structure reduces the still air film around a building and will substantially affect calculations of the insulating U-values, depending on when the readings are taken. Furthermore, winds also dissipate the solar heat impact upon a structure or evaporate moisture on wet surfaces, thereby cooling the building lower than the ambient temperature. One simple way to minimize the undesirable wind impacts is to place fins at strategic locations on a building, especially at windows (Figure 4).

On the other hand, the same wind may prove to be advantageous for natural cooling when properly directed into the building (Figure 5). Just as wind velocity is calculated in the structural analysis, it also should be a consideration in energy costs for the mechanical system.

A wind analysis study undertaken by Princeton University researchers has revealed that townhouses located on the windward side of the clusters consume about 5% more heating fuel than those located on the leeward side. Windward walls should be highly insulated therefore, and air tight to prevent excessive infiltration that can apparently account for up to 30% of a house’s heating bill.[2] On the other hand, the pressure differences on the windward and leeward sides of the building can contribute to air flow inside the building. Placement of openings is most effective when they capitalize upon air pressure differences. Those openings facing high-pressure areas should be inlets, while those openings facing low pressure areas should be outlets. Thus, the rate of air exchange is governed by pressure differences and the placement of the exposed openings as a consequence.

WIND EFFECT ON A BUILDING

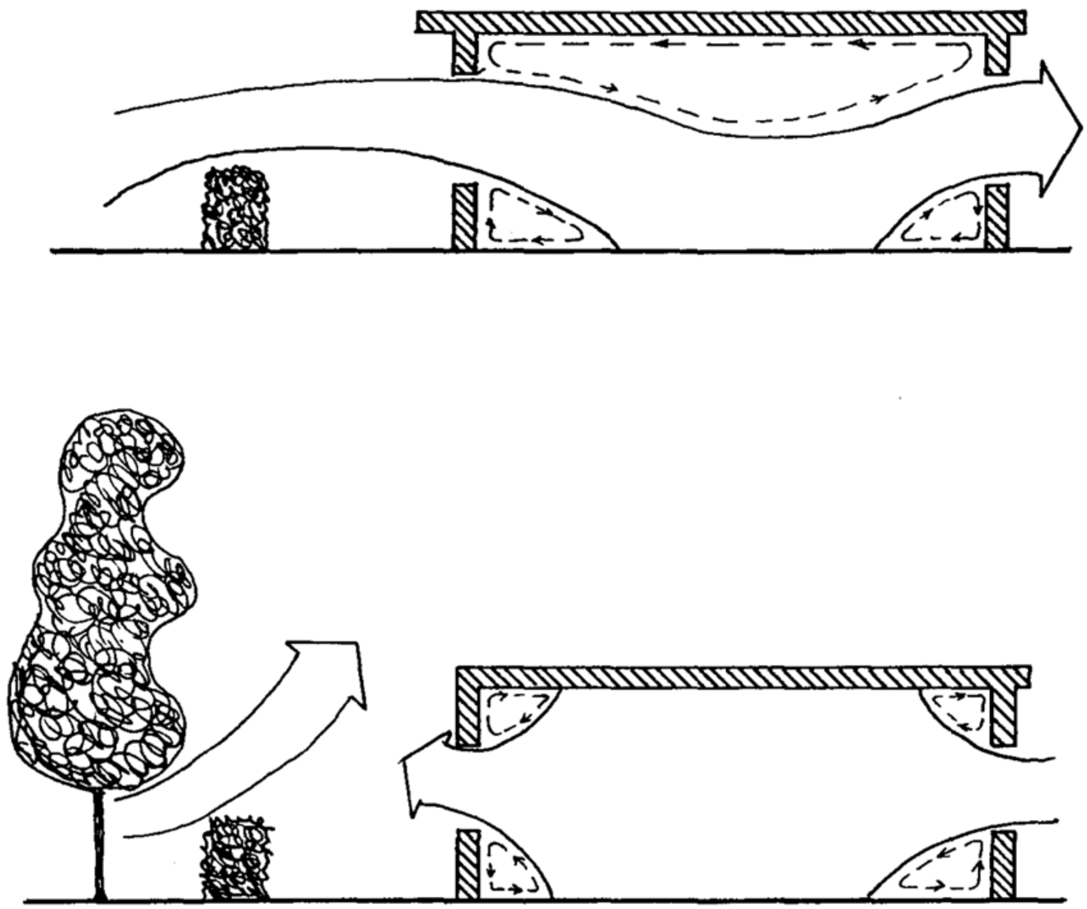


(Source: <u>Energy Conservation Design Guidelines for Office Buildings</u>, GSA/PBS, 1974)

FINS WILL PREVENT THE WIND FROM BLOWING AWAY THE WARM BLANKET OF AIR WHICH COATS THE WINDOW.

Figure 4

WIND VENTILATION



THE AIR STREAM DIVERTED UPWARD BY THE TREE CAUSES REVERSED FLOW IN THE BUILDING.

Figure 5

When the direction of the wind is normal to the building side and the areas of inlets and outlets are equal, the approximate rate of air exchange can be expressed as:[3]

$$Q = 3150\ AV$$

where Q = rate of air flow, cu. ft./hr.

A = area of inlets, sq. ft.

V = wind velocity, mph.

Area of Outlets / Area of Inlets	Value to be substituted for 3150
1:1	3150
2:1	4000
3:1	4250
4:1	4350
5:1	4400
3:4	2700
1:2	2000
1:4	1100

Furthermore, it is essential that the designer plot the average wind direction (Figure 6a-c) for the four seasons in order to obtain natural ventilation when the ambient temperature is near the comfort zone so as to decrease reliance upon mechanical systems. Such a design procedure however, does require the specification of adequate insulation and leak-proof windows to guard against cold winds in the winter.

Another vital factor to consider for energy conservation in building design is the sun. Generally speaking, building envelopes should be constructed to take maximum advantage of the winter sun through fenestration for heating, and provide for solar control in the summer. One method of achieving these desired results is to calculate the monthly solar loads in order to obtain the data on heat and light intensities for a given site.

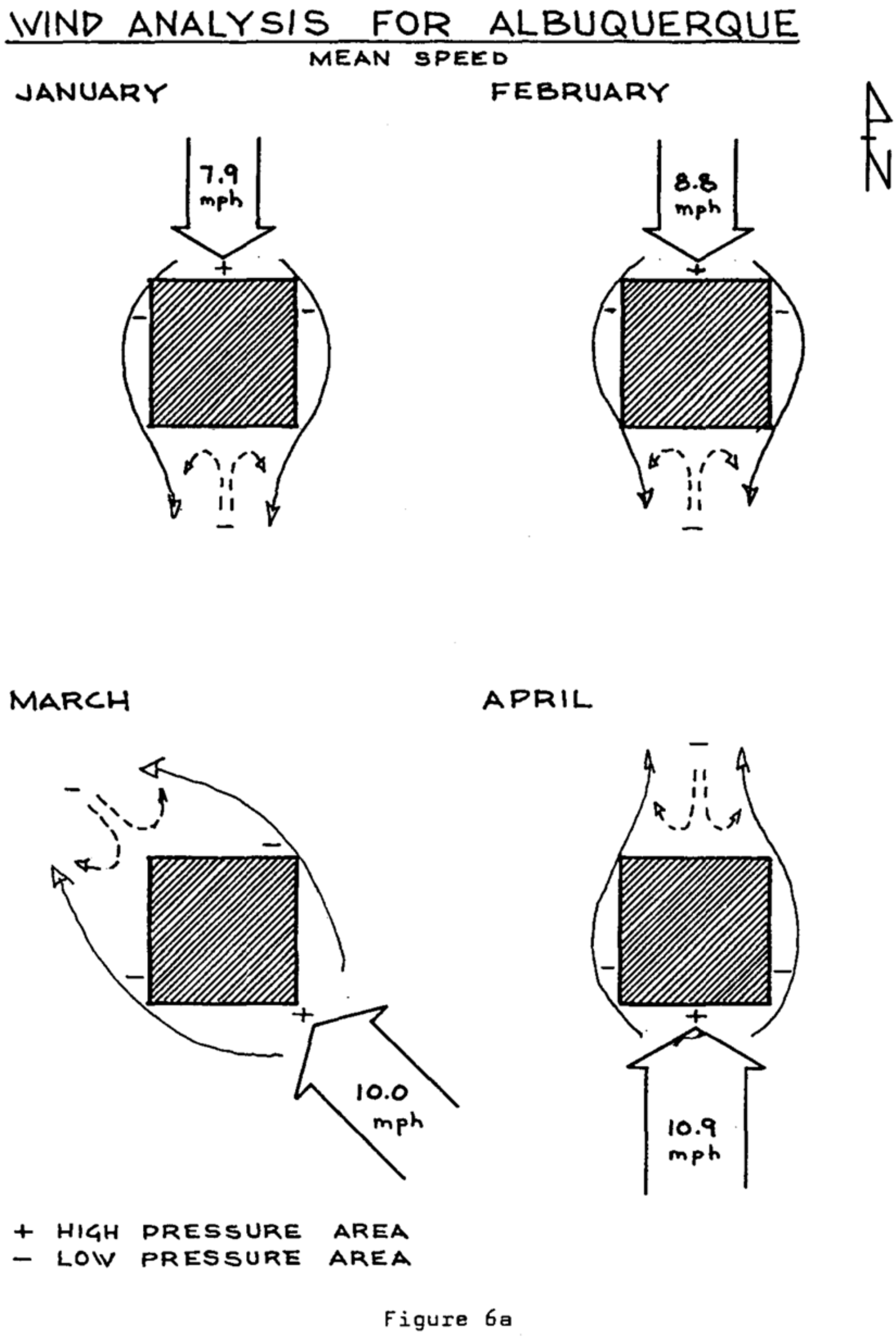

WIND ANALYSIS FOR ALBUQUERQUE
MEAN SPEED
JANUARY
7.9 mph
FEBRUARY
8.8 mph
N
MARCH
10.0 mph
APRIL
10.9 mph
+ HIGH PRESSURE AREA
– LOW PRESSURE AREA

Figure 6a

WIND ANALYSIS CONTINUED

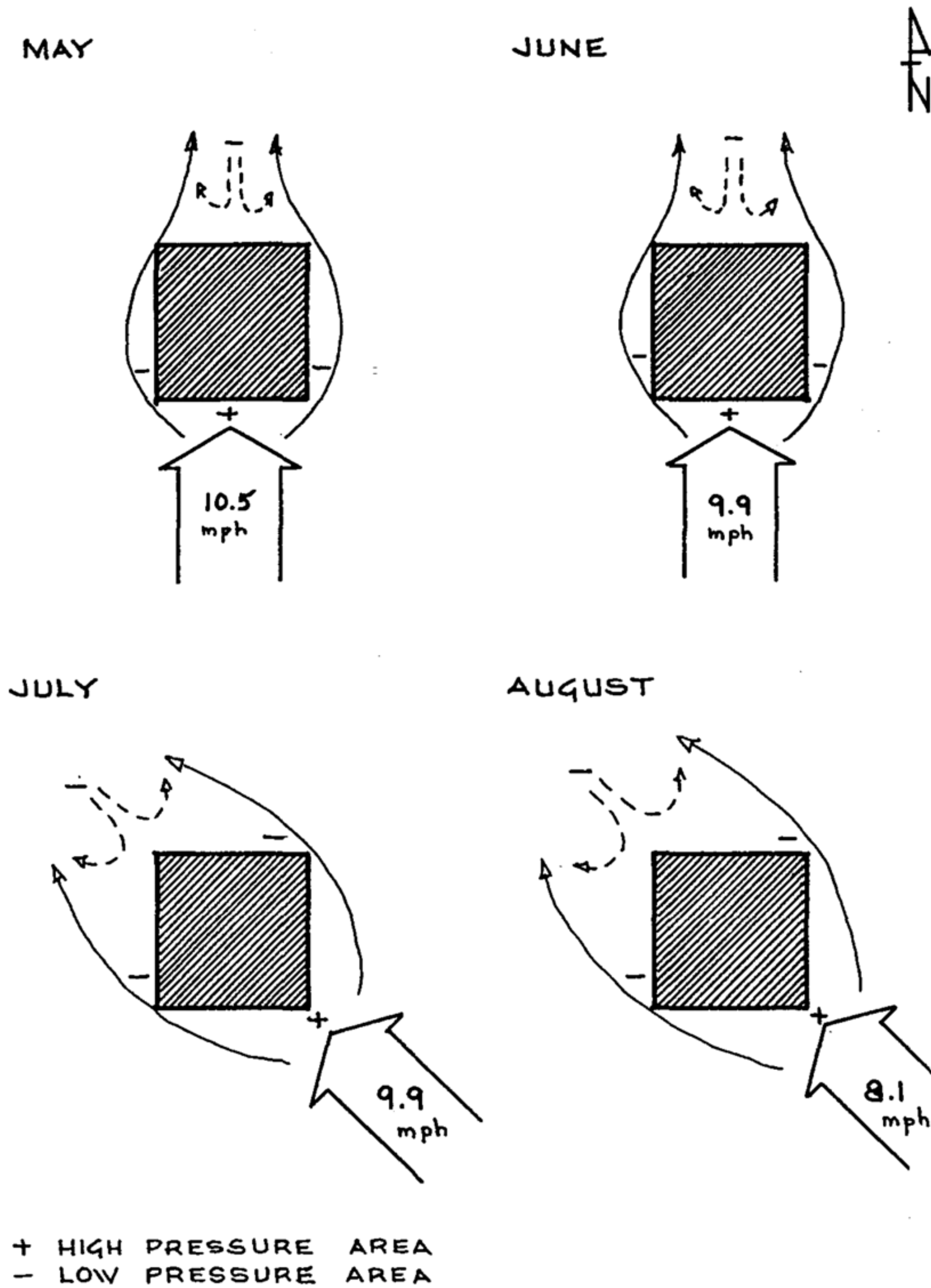


Figure 6b

WIND ANALYSIS CONTINUED

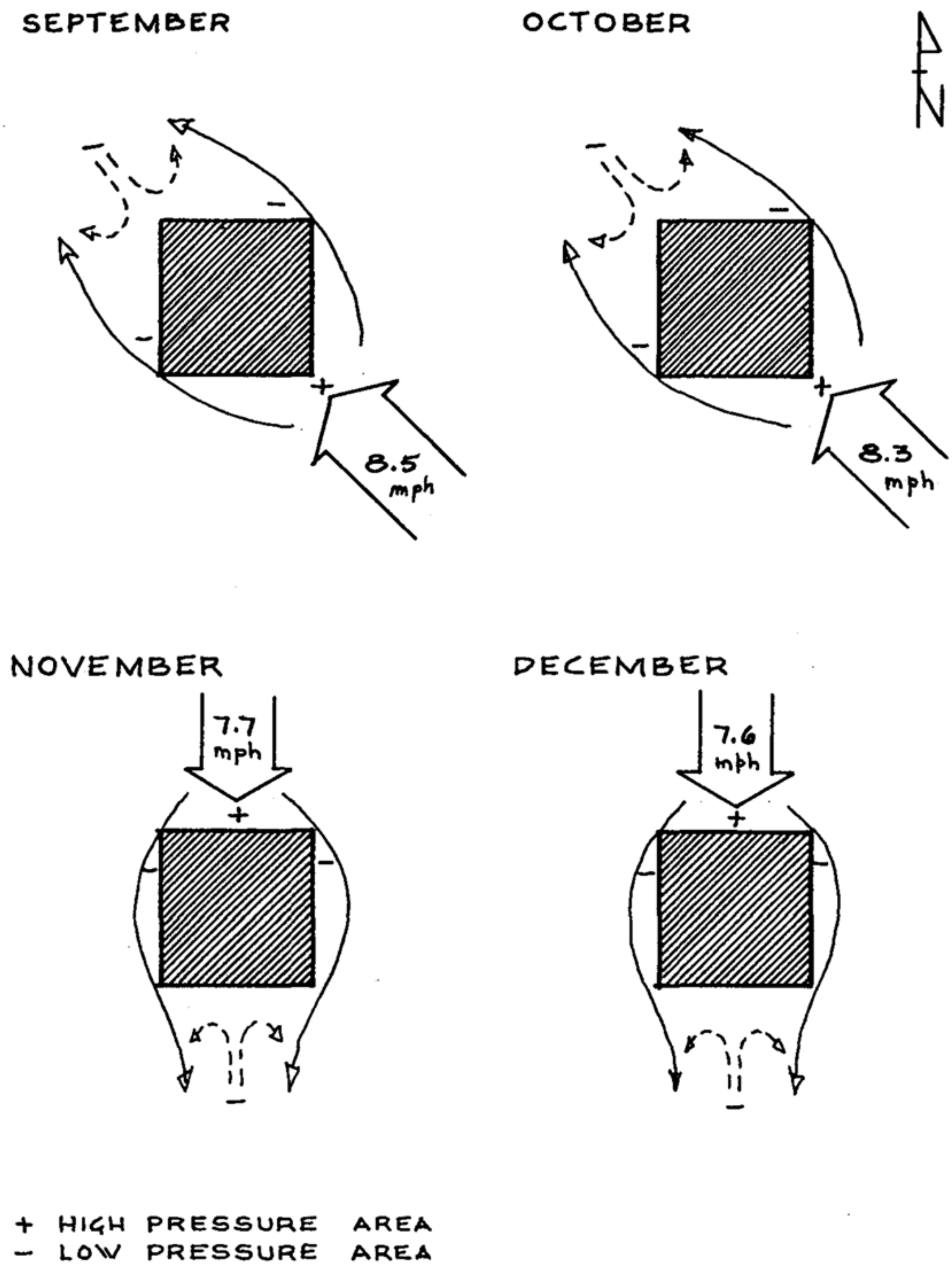
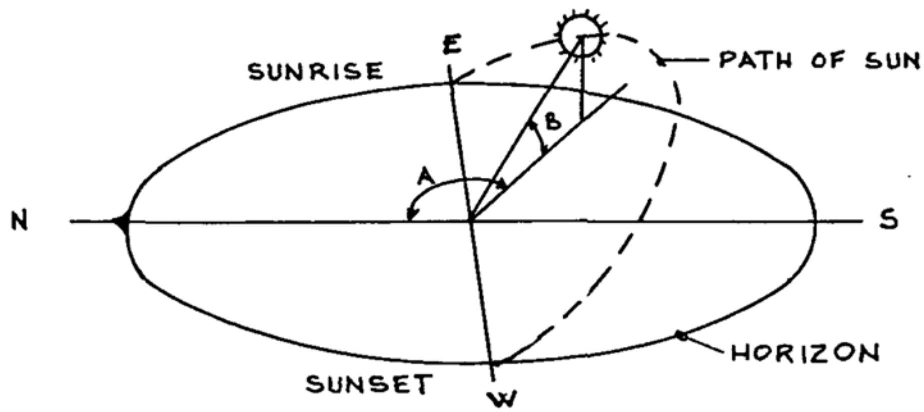


Figure 6c

Information pertaining to the total impact of solar radiation for each hour of the day will provide valuable criteria needed to determine building shape, configuration, and orientation for maximum energy savings. Similarly the azimuth and altitude of the sun should be included to allow for indirect lighting without excess heat or glare. Such information can be obtained from Time Saver Standards, from which Figure 7 provides the required data for Albuquerque. Shading devices for glazed areas may thus be manipulated to control unwanted sunlight most advantageously and secure further energy reductions in lighting and cooling systems (Figure 8). Finally, the sun's energy may replace or assist conventional power systems for heating, cooling, and hot water through the use of solar collectors.

In planning a structure architects have the choice of designing for winter heat loss or summer heat gain. Nonetheless the critical engineering factor to consider here is that more energy is required to heat a building for a given time period per Btu of heat loss than is needed to cool a building for the same time period per Btu of heat gain.[4] Therefore, it is important to determine for a particular site whether the greatest energy economy can be achieved by reducing heat loss or heat gain, and subsequently what materials will assist the resultant mechanical system most efficiently. Admittedly, securing information on climatology and meteorological conditions for a proposed site requires a certain amount of effort and time. Nevertheless, the research is worthwhile if the energy saved in operation and maintenance would allow new construction in areas where utility companies anticipate shortages. Therefore, the following section is intended as a time-saver analysis of southwestern, and especially Albuquerque climate for design considerations.

SOLAR ANGLES



ANGLE A - AZIMUTH
ANGLE B - ALTITUDE

SUN LOCATION for 35° NORTH LATITUDE

THE AZIMUTH IS THE ANGLE MEASURED HORIZONTALLY FROM THE NORTH MERIDIAN.
THE ALTITUDE IS THE ANGLE MEASURED VERTICALLY, BETWEEN THE SUN AND THE HORIZONTAL PLANE.

WINTER DEC. 22

AM	PM	AZIMUTH	ALTITUDE
NOON		180°-0'	31°-30'
10:00	2:00	149°-30'	25°-0'
8:00	4:00	126°-30'	8°-30'
7:10	4:50	119°-0'	0°-0'

FALL & SPRING SEPT. 23 MARCH 21

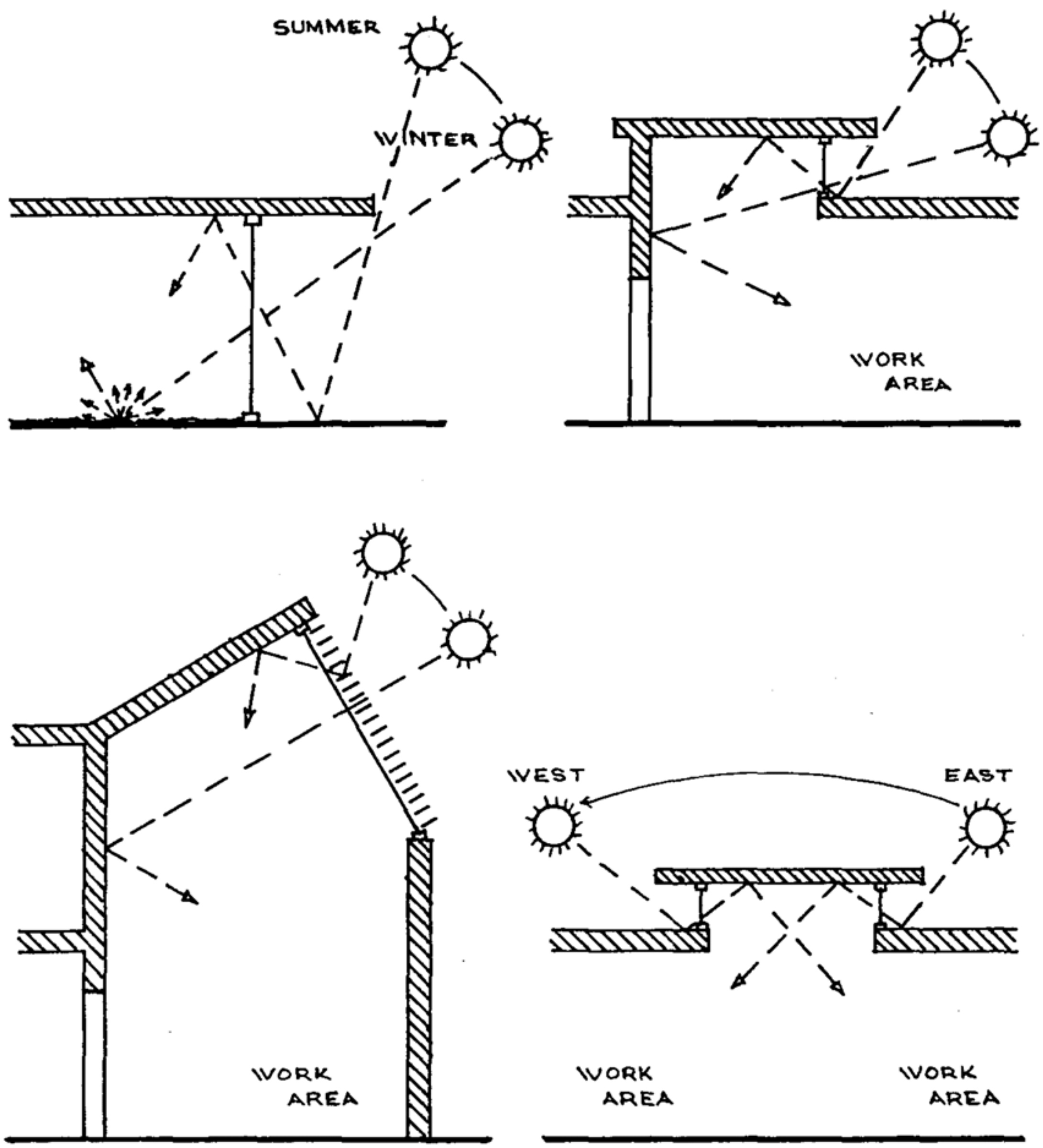
AM	PM	AZIMUTH	ALTITUDE
NOON		180°-0'	55°-0'
10:00	2:00	135°-0'	45°-0'
8:00	4:00	108°-30'	24°-0'
6:00	6:00	90°-0'	0°-0'

SUMMER JUNE 22

AM	PM	AZIMUTH	ALTITUDE
NOON		180°-0'	78°-30'
11:00	1:00	127°-30'	62°-30'
10:00	2:00	105°-30'	61°-30'
8:00	4:00	85°-30'	37°-0'
4:50	7:10	61°-0'	0°-0'

Figure 7

SUN ANALYSIS



ARCHITECTS CAN DESIGN THE BUILDING SHAPE TO UTILIZE NATURAL LIGHT IN SUMMER AND WINTER, WITHOUT DIRECT GLARE OF THE SUN.

Figure 8

Albuquerque Climate Characteristic

Many widely different climatic conditions prevail throughout the United States, and each micro-climate exerts a set of influences which must be addressed in the selection, design, and construction of all building subsystems and components. The intensity and duration of seasons, the wet and dry bulb temperatures, the frequency and amount of precipitation, storm patterns, and wind and sun characteristics of a site are vital in the determination of the energy needs of a building project. Computerized weather tapes, containing hour-by-hour data for Albuquerque, New Mexico, are available at the U.S. Department of Commerce: National Oceanic and Atmospheric Administration, Environmental Data Service (Figure 9).

Temperatures in Albuquerque – latitude 35°03' N; longitude 106°37' W; elevation 5,311 feet – are those characteristic of high altitude, dry continental climates. There is less than one day a year when the temperature reaches 100 or drops to zero. In fact, the ASHREA winter design temperature for Albuquerque is 10°F, while the summer design temperature is 96°F. Daytime temperatures during the winter average near 50°f with only a few days on which the temperature does not rise above the freezing mark. In the summer daytime maxima average less than 90°F, except in July, and with the large daily range the nights are usually cool. Normally dry air contains an average annual relative humidity of approximately 43%. The warmer part of the day is about 30% humid, dropping to less than 20% in June, the least humid month of the year, which renders the mechanical humidifier or "desert cooler" desirable equipment in all structures.[5]

NORMALS, MEANS, AND EXTREMES

Station: ALBUQUERQUE, NEW MEXICO INTL AIRPORT-KIRTLAND AFB Standard time used: MOUNTAIN Latitude: 35° 03' N Longitude: 106° 37' W Elevation (ground): 5311 feet Year: 1973

Month	Temperature – Normal – Daily maximum	Normal – Daily minimum	Normal – Monthly	Extremes – Record highest	Year	Record lowest	Year	Normal heating degree days (Base 65°)
(a)	(b)	(b)	(b)	14		14		(b)
J	46.9	23.5	35.2	69	1971	-17	1971	924
F	52.6	27.4	40.0	75	1972	1	1964	700
M	59.2	32.3	45.8	85	1971	9	1966	595
A	70.1	41.6	55.8	89	1965	22	1973	282
M	79.9	50.7	65.3	94	1969+	28	1967	58
J	89.5	59.7	74.6	102	1972+	42	1971	0
J	92.2	65.2	78.7	104	1971	54	1964	0
A	89.7	63.4	76.6	99	1972+	52	1968	0
S	83.4	56.7	70.1	94	1971	37	1971+	7
O	71.7	44.7	58.2	87	1972+	25	1971+	218
N	57.1	31.8	44.5	73	1973	12	1973	615
D	47.5	24.9	36.2	68	1966	4	1968	893
YR	70.0	43.3	56.8	104	JUL. 1971	-17	JAN. 1971	4292

Month	Precipitation – Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Ice pellets – Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)	(b)	34		34		34		34	34		34	
J	0.30	1.17	1941	T	1970+	0.87	1962	2.1	9.9	1973	9.1	1973
F	0.39	1.42	1948	0.04	1959	0.48	1957	1.8	8.2	1964	4.2	1946
M	0.47	2.18	1973	T	1966+	1.11	1973	2.1	13.9	1973	10.7	1973
A	0.48	1.97	1942	T	1972+	1.46	1969	0.5	8.1	1973	6.6	1973
M	0.53	3.07	1941	T	1945+	1.14	1969	T	T	1951	T	1951
J	0.50	1.71	1967	T	1964+	1.64	1952	0.0	0.0		0.0	
J	1.39	3.33	1968	0.14	1958	1.77	1961	0.0	0.0		0.0	
A	1.34	3.30	1967	T	1962	1.22	1967	0.0	0.0		0.0	
S	0.77	1.99	1940	T	1957	1.92	1955	T	T	1971+	T	1971+
O	0.79	3.08	1972	0.00	1952	1.80	1969	T	0.5	1970	0.5	1970
N	0.29	1.45	1940	0.00	1949	0.76	1940	1.2	9.3	1940	5.3	1946
D	0.52	1.85	1959	0.00	1956+	1.35	1958	2.7	14.7	1959	14.2	1958
YR	7.77	3.33	JUL. 1968	0.00	DEC. 1956+	1.92	SEP. 1955	10.4	14.7	DEC. 1959	14.2	DEC. 1958

Month	Relative humidity – Hour 05 (Local time)	Hour 11	Hour 17	Hour 23	Wind & – Mean speed	Prevailing direction #	Fastest mile – Speed	Direction #	Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset
(a)	13	13	13	13	34	13	34	34		34	34
J	66	48	36	57	9.9	N	61	E	1949	73	4.8
F	62	43	32	51	8.8	N	68	NW	1944	73	4.9
M	54	32	24	41	10.0	SE	80	NW	1943	74	4.9
A	45	25	18	33	10.9	S	72	S	1946	77	4.5
M	44	23	16	31	10.3	S	72	W	1950	80	4.1
J	45	24	18	32	9.9	S	82	SE	1946	83	3.2
J	61	36	28	49	9.1	SE	68	E	1945	76	4.5
A	65	39	30	52	8.1	SE	61	SE	1951	76	4.2
S	58	40	30	52	8.5	SE	62	SE	1945+	81	3.3
O	58	37	29	47	8.3	SE	66	N	1959	79	3.4
N	64	43	35	54	7.7	N	57	NW	1948+	77	3.9
D	69	51	43	60	7.6	N	90	SE	1943	72	4.6
YR	58	37	28	47	8.9	SE	90	SE	DEC. 1943	77	4.2

Month	Mean number of days – Sunrise to sunset – Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures – Max. – 90° and above ‡	Max. – 32° and below	Min. – 32° and below	Min. – 0° and below
(a)	34	34	34	34	34	34	34	13	13	13	13
J	13	8	10	3	1	*	1	0	3	29	1
F	11	8	9	4	1	*	1	0	1	23	0
M	12	10	9	4	1	1	1	0	*	18	0
A	13	9	8	3	*	2	*	0	0	5	0
M	15	10	6	4	0	4	0	3	0	*	0
J	18	9	3	4	0	5	*	16	0	0	0
J	12	14	5	9	0	11	*	23	0	0	0
A	14	13	4	10	0	12	*	16	0	0	0
S	18	7	5	5	0	9	*	3	0	0	0
O	18	7	6	5	0	3	*	0	0	2	0
N	16	7	7	3	1	1	1	0	*	15	0
D	14	8	9	4	1	*	1	0	2	29	0
YR	174	110	81	59	4	43	3	61	6	121	1

· Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows:
Maximum monthly precipitation 8.15 in June 1852 (measured by Medical Officers of Army at Army Post near plaza).

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological normals (1941-1970).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
\- Below zero temperatures are preceded by a minus sign.
‡ ≥ 70° at Alaskan stations.

The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

\# To 8 compass points only.

** The National Weather Service considers the accuracy of solar radiation data questionable; therefore, publication is suspended pending determination of corrected values.

Figure 9

Another feature of the climate, which directly influences design criteria, is the large number of clear days accompanied by a corresponding high percentage of sunshine. This particular region receives one of the greatest intensities of direct solar radiation in the country, which makes New Mexico an ideal state for the development of solar energy as an alternate energy resource. Sunshine is recorded during more than three-fourths of the hours from sunrise to sunset, and this high percentage carries through the winter months when clear sunny weather predominates.

Finally we must also consider airflow as a design factor. Wind movement throughout the year averages around nine miles per hour, but during the late winter and spring months this average is somewhat higher and frequently windy and dusty days do occur. These occasional dust storms are the most discomforting part of Albuquerque's climate. However, on the average, 28 there are only 46 days during the year when the maximum wind velocity reaches thirty-two miles per hour.[6]

Site Considerations

A particular site can affect the climatic conditions with respect to energy conservation. For example, existing buildings adjacent to the proposed structure will increase or decrease wind velocities and modify the intensity of sunlight. The location of a building on the selected site will also influence the tradeoffs between heat loss and heat gain on each exposure with regard to sun and wind. Furthermore, thought must be given to the surrounding natural structures, such as trees, shrubs, or hills, and how they may be utilized to enhance the entire scheme.

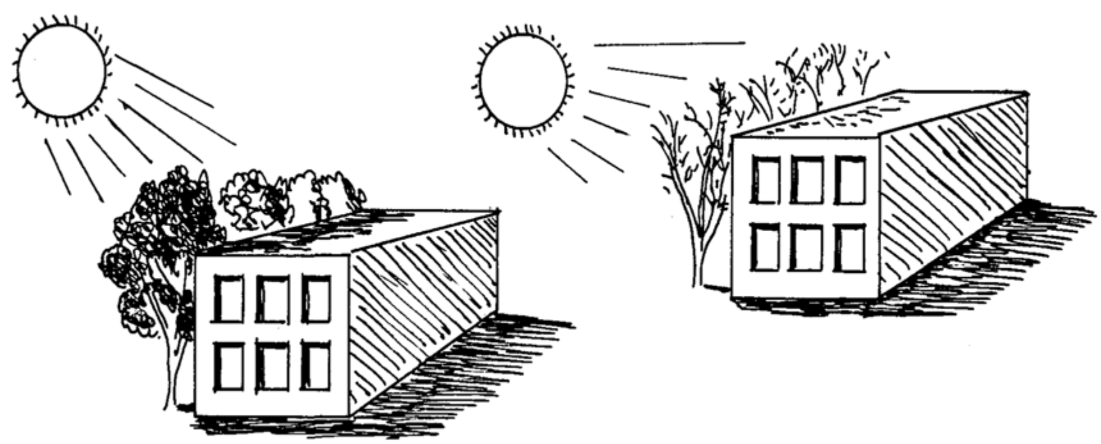
The following guidelines, intended for architects and planners, illustrate the possible energy saving techniques that relate directly to the southwestern arid climate. Any number of these considerations may be employed by the architect according to the dictates of the local conditions and specific design criteria (Appendix A).

1. Use conifer trees for summer and winter sun shading and wind breaks. (Figure 10 displays alternate scheme)
2. Shade walls and paved areas adjacent to buildings to reduce indoor/outdoor temperature differential.
3. Reduce paved areas and use grass or other vegetation to reduce outdoor temperature

build-up.

4. Use ponds, water fountains to reduce ambient air temperature around building.
5. Locate building on site to induce airflow for natural ventilation and cooling. (North winds – winter; S, SE winds – summer)
6. Select site with low pollution to enhance natural ventilation.
7. Utilize sloping site to partially bury building or use earth berms to reduce heat transmission and solar radiation.
8. Select site that has topographical features and adjacent structures that provide desirable shading.
9. Select site that allows optimum orientation and configuration to minimize energy consumption.[7]

USE OF TREES TO CONSERVE ENERGY



DECIDUOUS TREES SHADE LOW BUILDING IN SUMMER BUT ALLOW SUN'S HEAT TO BE USED IN WINTER WHEN THE LEAVES ARE GONE.

Figure 10

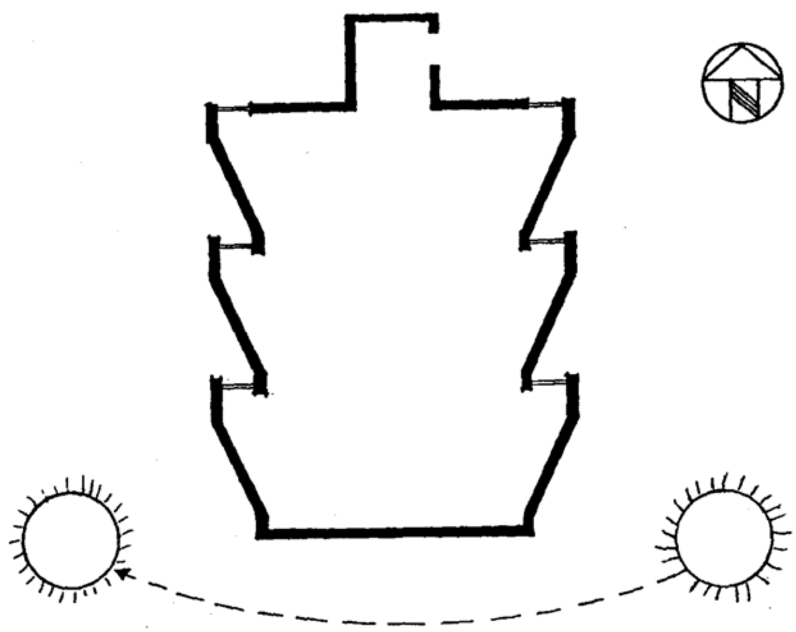
Building Orientation

How a building is situated and even its color can be energy saving determinants. For example, the temperature of a dark gray roof on a sunny day will heat up to 175°F since dark colors absorb rather than reflect heat. The same phenomenon has appeared in the long flat building style of the southwest, indicating that a single-story building tends to encourage heat build-up more so than a multi-story building of equal floor area, but having a smaller roof area. One implication here is that such low flat roofed-buildings with air-conditioning in hot-arid climates may prove to be a disadvantage and an inefficient energy consumer. Finally, a sloping roof that faces south is subjected to far greater solar radiation than a roof sloping to the north.

Building orientation that utilizes the sun's rays most efficiently and is complemented by controlled heat convection will maintain temperature levels near the comfort zone. Under cold conditions additional solar radiation will be desirable and a building should be positioned to receive as much sun as possible. Conversely, under conditions of excessive heat, the orientation of the same building should decrease unwanted solar impacts. Figure 7 provides the necessary data for positioning buildings properly with respect to the sun in Albuquerque.

In addition to the above building orientation, which must be modified in reference to its envelope and configuration, the careful positioning of a structure may capitalize upon the available natural light; thereby reducing needed power for lighting systems. For example, double glazing on side walls can be directed northward with the sawtooth plan to catch the natural light without the glare (Figure 11).

SAWTOOTH PLAN



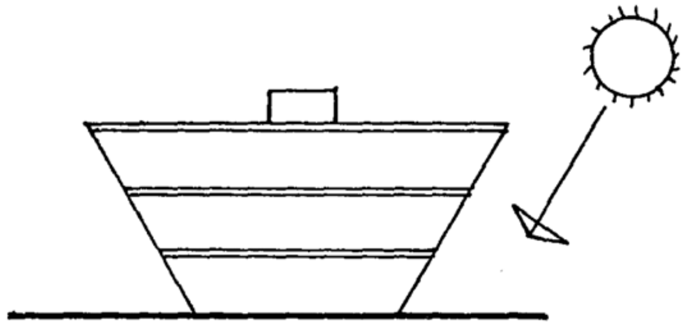
(Source: Energy Conservation in Building Design, AIA, 1974)

Figure 11

Building Configuration

The configuration of a building greatly influences the amount of energy it will consume. When using a round building, which has less surface area than any other shape of equal volume, for instance, heat gains or losses will be limited considerably. Likewise a square building has less surface area than a rectangular one of equal floor space and will consume a substantially smaller quantity of energy. Yet another configuration, also appropriate for the Southwest, is the upside-down pyramid with glass facades which serve the dual purpose of protecting the interior against glare and reducing the heat gain and discomforting reflections from the exterior (Figure 12).

UPSIDE-DOWN PYRAMID



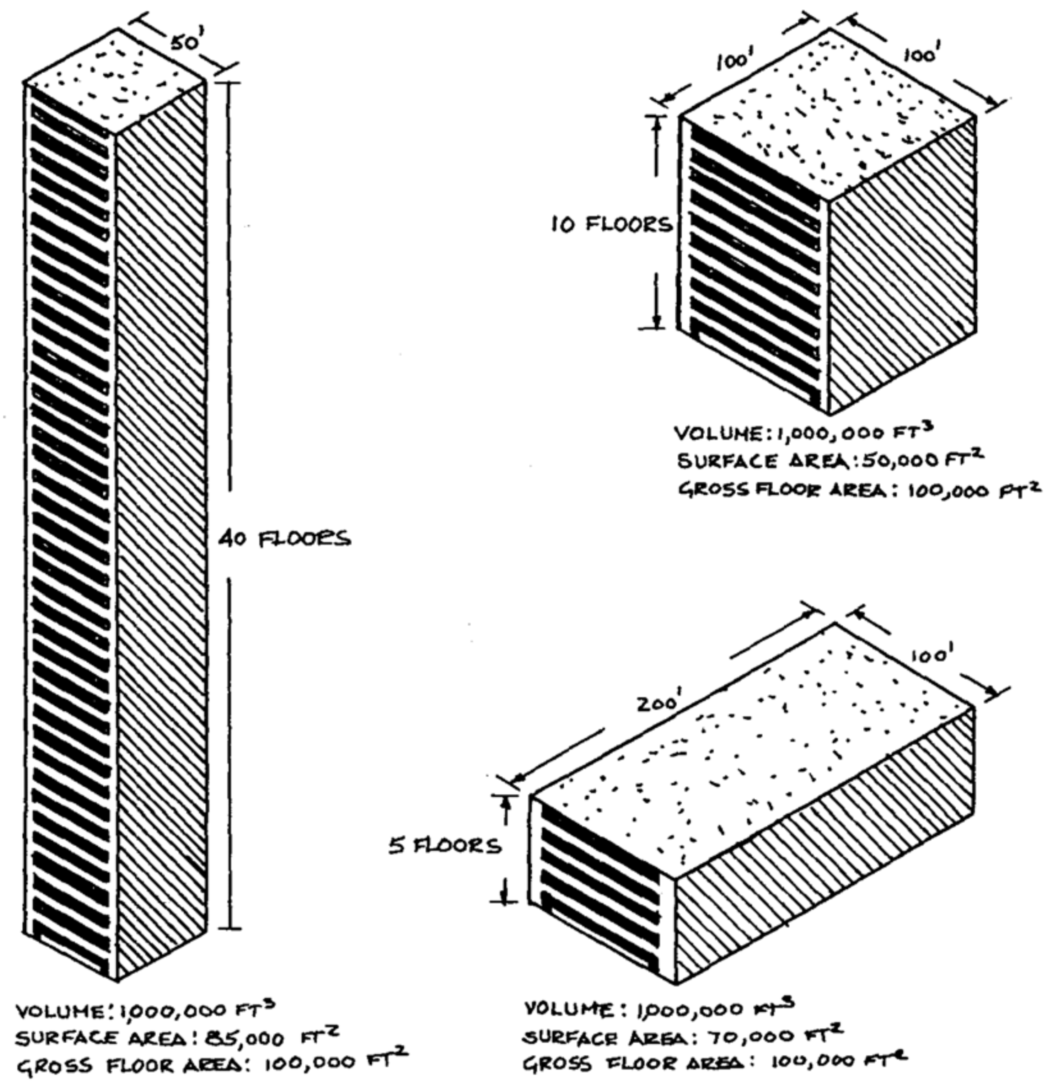
(Source: Energy Conservation in Building Design, AIA, 1974)

Figure 12

In selecting high-rise over low-rise buildings, the architect has many energy conservation variables to consider. For example, a 40-story tower with 100,000 sq. ft. has an exterior surface area of 85,000 sq. ft. susceptible to heat gain or loss, compared with a 5-story building of equal floor area, which has 70,000 sq. ft. of exposed facade. However, the cube shape with 100,000 sq. ft. has only 50,000 sq. ft. of surface area and appears to be the most efficient shape.[8] Finally, there is the tower which does have less roof exposed to solar heat gain, but must nevertheless endure greater wind velocities and requires larger mechanical support and power distribution systems. Figure 13 presents the shape-surface area comparisons graphically.

Regardless of which configuration the architect chooses, each shape has the capacity for diminishing energy requirements by supplementing artificial lighting with natural illumination through the judicious use of glazed areas, courtyards, atriums, and skylights. (See Figure 8 for examples of indirect lighting with the use of clerestory windows) Of course, these design options would serve best in warm climates where the ambient temperature remains close to indoor design temperatures most of the year. Ultimately the energy saved by reducing artificial illumination must be weighed against the energy lost from other factors such as heat *gain* during the day, or heat loss during the night.

RELATION OF SHAPE TO SURFACE AREA



(Source: Energy Conservation Guidelines for Office Buildings, GSA/PBS, 1974)

Figure 13

Several other building considerations with respect to shape are:

1. Select a building configuration to give maximum south wall to reduce heating loads.
2. Reduce heat transmissions through the roof by reflective surfaces, roof pond, location of equipment rooms on the roof, and the use of ventilated space at the roof.
3. Utilize the stack effect in vertical shafts, stairways, etc., to promote natural air flow

through the building.[9]

Building Envelope

Generally speaking, the building envelope consists of those materials that are subjected to climatic conditions. Included here should be the combination of wall mass, insulation, exterior surface color and texture, and the type of glazing, all of which increase energy consumption when not adapted to the environment. Moreover, the envelope substantially influences the infiltration rate and is a major determinant in the type and size of heating and cooling distribution systems selected.

Larger wall masses generally promote favorable thermal protection by delaying heat losses from within or heat gains from without. The quantity and quality of materials composing the wall in turn will affect the U-value on heat transmissions over a period of time. Old adobe buildings with 18 inch walls, or Medieval castles built with heavy stone masonry successfully withheld solar impacts for many hours and kept the interior areas cool without the benefits of air-conditioning or costly insulation materials. Contrast these building techniques with today's modern light construction methods that have produced walls, which absorb heat quite rapidly. In the case of light construction, the placement and amount of insulation within a wall is a crucial factor in realizing true energy savings (Discussed in Chapter III). It is also important that insulation be protected from the weather since its effectiveness is decreased when wet or damp.

Needless to say windows have a major role in the building's energy consumption due to solar gain and heat loss. Large glass areas create discomfort for occupants with excess solar heat, cold down drafts, and glare. Furthermore, heat transmission is far greater through glass than most other building materials. Consequently the window size should not be in excess of its functional requirement. (Appendix D).

Shading devices are quite an effective means of lessening the unwanted solar radiation that penetrates glazed areas. Since solar radiation varies with altitude and azimuth, solar control should be designed specifically for every facade. On the south side of the building, for example, horizontal shading devices are the most efficient against excessive sunlight. In addition a combination of movable vertical and horizontal sun baffles is desirable in order to capture the sun's heat in the early spring and late fall.[10]

As previously mentioned definite power reductions could be achieved if the building were situated to maximize natural lighting. However, the envelope must complement the structure's orientation if any energy is to be saved (Appendix B).

Space Planning

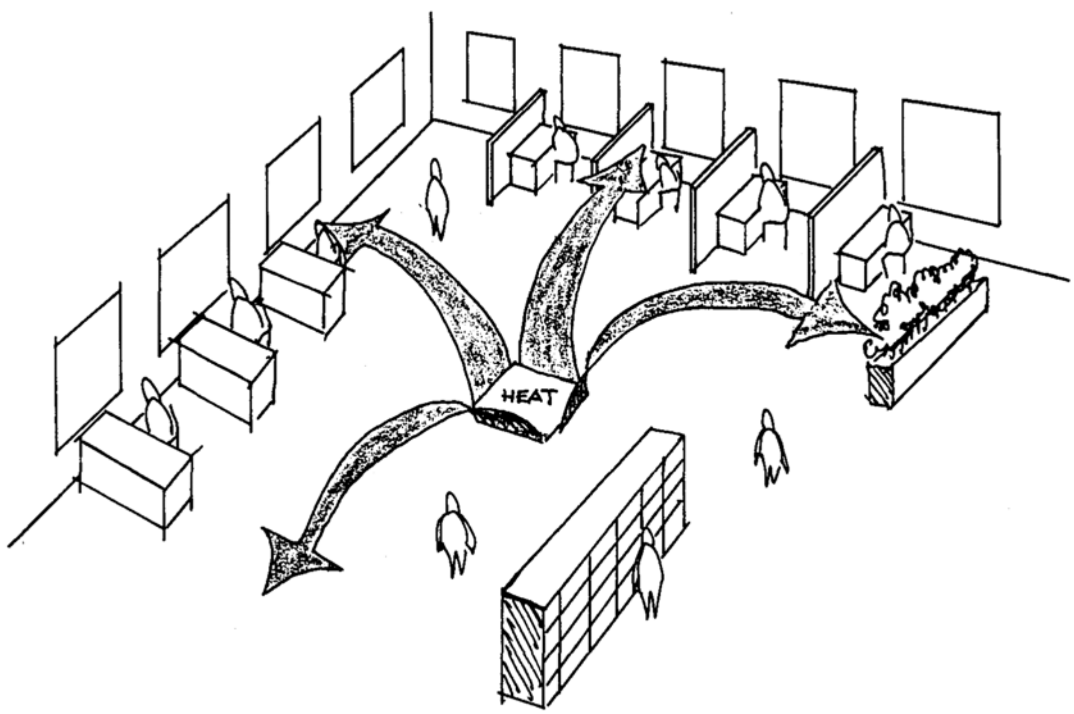
Of equal priority with a building's exterior is the entire matter of interior planning, which should be designed to allow the most efficient distribution of air circulation and lighting, whether these elements are supplied by mechanical subsystems or combined with the natural ventilation and lighting. There are many space planning techniques available to the designer, some of which follow:

1. Size a room to meet and not exceed its functional requirements.
2. Use as little interior partitioning as possible.
3. Use colors that reflect rather than absorb heat and light.
4. Use perimeter buffer zones such as hallways, storage areas, etc., to absorb excess heat gains or losses.
5. Utilize a more efficient ventilating system by grouping rooms together in such a manner that the same air can be used more than once, by operating in cascade through spaces in decreasing order of priority, i.e. office, corridor, washroom.[11]

Well-planned interior areas can offer many architectural and energy conservation advantages. Interior landscaping of an office space replaces conventional wall partitions with the use of furniture, plants, color, and bookcases, which provide a lively working atmosphere both psychologically and visually. The primary advantage for reducing energy is that landscaping consumes up to 25% less lighting energy than a partitioned floor - the results of a study by Dubin-Mindell-Bloome Associates.[12] In a similar manner power cuts for ventilation systems can be achieved by supplying fresh air to the interior portion of the floor, and then allowing this air to flow naturally to the perimeter areas, thereby reducing the mechanical control (Figure 14, and Appendix C).

A building that ignores the impact of the natural environment will almost assuredly require unnecessarily large expenditures of energy in the form of mechanical, structural, or material items to compensate for adverse natural conditions. Thus, a building project should start with a thorough analysis of the assigned or potential site. Designers, and especially architects, should understand and anticipate the effects of the immediate climate, geographic location, and the particular site on the energy flow of a building if the design is to utilize the environment to the highest degree of efficiency possible.

OPEN INTERIOR PLAN



AN OPEN PLAN ALLOWS EXCESS HEAT FROM LIGHTS, MACHINES AND PEOPLE TO TRANSFER TO THE PERIMETER AND OFFSET COOLING EFFECT OF EXPOSED SURFACES.

Figure 14

FOOTNOTES

[1]AIA, Energy and the Built Environment, (Washington, D.C., 1974), p 23.

[2]Griffin, p. 38.

[3]Victor Olygay, Design With Climate (Princeton, N.J., 1973), p. 104.

[4]Dubin-Mindell-Bloome Associates, Energy Conservation Guidelines for Office Buildings (Washington, D.C., 1974), p. (9-5).

[5]Local Climatological Data: Albuquerque, New Mexico, U. S. Department of Commerce: NOAA, (Washington, D.C., 1973), leaflet.

[6]Ibid.

[7]Dubin-Mindell-Bloome , pp. (10-4) - (10-5).

[8]Griffin, p. 40.

[9]Dubin-Mindell-Bloome , p. (10-12).

[10]Ibid., p. (9-17).

[11]Ibid., p. (10-13).

[12]AIA, p. 50.

Chapter III BUILDING DESIGN TECHNIQUE FOR ENERGY CONSERVATION

> "Economy denotes the proper management of materials and of site, as well as a thrifty balancing of Cost and common sense in construction of works. This will be observed if in the first place, the architect does not demand things which cannot be found or made ready without great expense." - Vitruvius.

Structural Design

When energy consumption is deemed the greater concern over initial dollar cost, materials will be managed differently than at present. For example, aluminum requires six times more energy per pound to process and assemble than does steel, with the energy expended mostly in the form of electricity.[1] In order to arrive at reasonable judgements based on energy economy, the selection process requires materials to be classified by energy use and not a pound-for-pound basis alone. A more meaningful comparison of interchangeable end products can be instituted. As an example of the magnitude of savings possible: a 100-story tower with an aluminum and glass exterior would require 4 million pounds of aluminum, while 5.75 million pounds of stainless steel would be needed. The aluminum would require 2.1 million Kw-hours of electricity to produce and assemble, whereas stainless steel would require only 0.77 million Kw-hours. Of course, over a 10-year period these savings, at present operating costs, would represent only 3% of the operation and maintenance costs of the building. However, if the buildings have a 20 to 30 year life, these substances could be recycled and increase the savings considerably.[2]

Steel, concrete, and other structural materials are generally used in greater quantities than is actually necessary to perform their respective tasks. Some excess is due to design, some to poor planning, and some to wasteful habits, but all have a detrimental effect. For instance, a steel beam is designed to resist failure at the critical point of its span. The cross section is generalized for reasons of manufacture and is carried through unchanged from end to end. Only in large structures or those for which weight is an important factor, such as trusses, ships, planes and bridges, is there an effort to place materials where the design approximates the efficient form for the structural job required. Changes in fabrication methods and greater repetition of structural components can reduce the amount of steel required to perform largely the same functions now specified.[3]

In mixing concrete, the plant will not infrequently provide a product that is 10 to 20% above the design value, in order to avoid rejection. Also, concrete will continue to gain strength for years after it has been assumed to have reached full strength. And as a final safety factor, no structural credit is taken either for applied cement finishes or the capacity of the structure to resist loads in a much more complicated and unified manner than indicated in the original calculation.[4]

But what if the building function changes? If we look to the past, during the Renaissance, for instance, buildings were designed and constructed to last a 1,000 years; during the 19th century, structures were made to last 250 to 300 years; today buildings are discussed as if they were designed to last for 50 years or less. Obviously then, short and long-term functional goals become major design criteria and influence greatly the quantity and quality of materials selected.

As the importance of energy savings in the use of building materials becomes more accepted, it will also have a profound effect on design. Building complicated shapes without regard to climatic conditions or changing functional requirements may well be a thing of the past. The ability of the architectural profession to satisfy performance needs without reducing standards and life style, could well mean a 10% savings on materials and thus the energy required to produce them.[5]

Basic to any in-depth study of energy conservation in various structures is the need for an experimental building with a means for accurately recording all cost data relative to its construction and subsequent operation. The amounts of materials, money, and labor that went into its construction would be compared with the output and maintenance of the building. Such a building was the Manchester government office building in New Hampshire, a project by the General Services Administration/Public Building Service (GSA/PBS). The work was done by Dubin-Mindell-Bloome Associates and the architectural firm of Isaacs & Isaacs. The resulting data from this experimental office building can be applied to any regional climate or design problem. See Appendices for some of the published results.

At the present time, approximately 14.4% of the annual total energy used in the United States is consumed in the operation of commercial buildings. This represents the equivalent of

5.47 million barrels of oil a day. If the energy were decreased by 20%, a resultant savings equal to 1.09 million barrels of oil a day could be realized.[6]

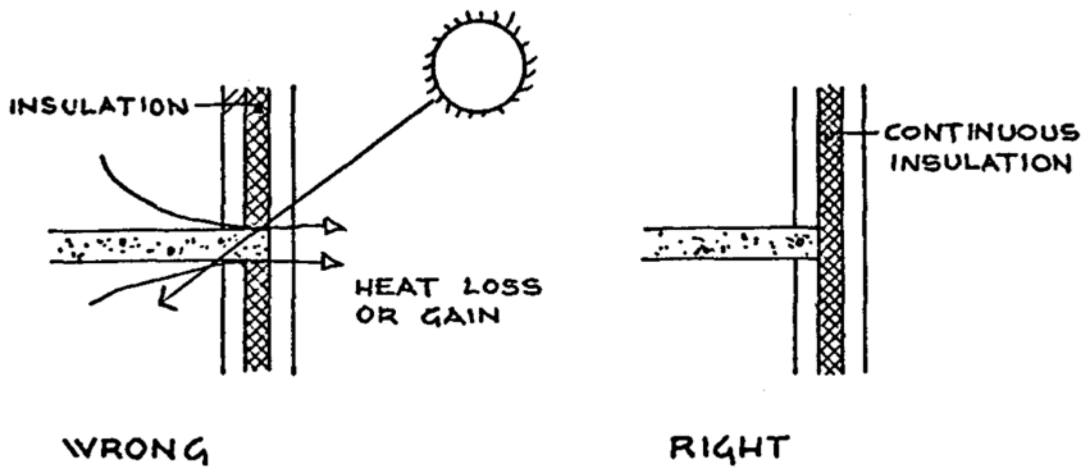
In order to reduce energy consumption in buildings now being designed, realistic energy goals should be established, setting upper limits on-the amount of consumption permitted. The Manchester project showed that it was possible to achieve as high as 60% savings in energy over conventional construction by careful attention to energy saving construction features and energy conserving environmental systems. Therefore the following suggestions are presented to reduce energy expenditures without sacrifice to comfort levels.

The design of multi-use buildings represents an important factor in energy savings, especially in large metropolitan areas. Chicago's 100-story John Hancock Center, considered to be an energy waster by some critics, may have conservation qualities as a multi-use structure. The energy used by the Hancock resident, commuting by elevator from his 8Oth floor apartment to his 30th floor office, is insignificant compared with that of a suburban commuting motorist. A commuter who drives just 10 miles each way in heavy traffic uses from 2 to 3 times as much energy as he does at work. Since the energy content of 500 gallons of gasoline is 75,000,000 Btu's, compared with 150,000 to 250,000 Btu's/gals./sq. ft. x 150 sq. ft. per worker, the amounts of energy consumed at work is only 25,500,000 to 37,500,000 Btu's.[7]

A critical design specification is the envelope of a building, which basically involves two factors: thermal insulation and the heat transmission of materials. Thermal insulation offers many benefits such as more evenly maintained comfort levels throughout the building, prevention of condensation on interior surfaces, and reduction in HVAC capacity requirements and thus operating costs. The primary advantage of thermal insulation is to resist heat transmission by conduction. Convection, however, requires an air current to convey heat energy from one place to another such as leakage through cracks and joints. The amount and proper placement of insulation and weather stripping in a building is an essential factor in the proper control of heat transmission (Figures 15 and 16).

Heat is also transmitted across air spaces by radiation. However, the installation of reflective foil insulation within the vertical air space in a wall will decrease the radiative heat transmission by about two-thirds.[8] This reduction in radiative heat transmission results from the polished metallic surface's low absorptivity and low emissivity of radiant energy.

PLACING INSULATION



(Source: Energy Conservation in Building Design, AIA, 1974)

Figure 15

Another physical property that will resist heat transmission through the building envelope is the heat absorbing capacity of various materials. Earth, adobe, concrete, and masonry are substances that possess good capacity insulation, a highly advantageous property for hot-arid climates in which there is a 40°F temperature differential daily. Earth may be utilized in still another manner. For example, underground structures will reduce the energy consumption of a building considerably due to the fact that temperatures a few feet below ground level are constant year round. Even partially underground structures built with earth berms piled against the walls and earth fill on the roof would provide extremely efficient insulation.

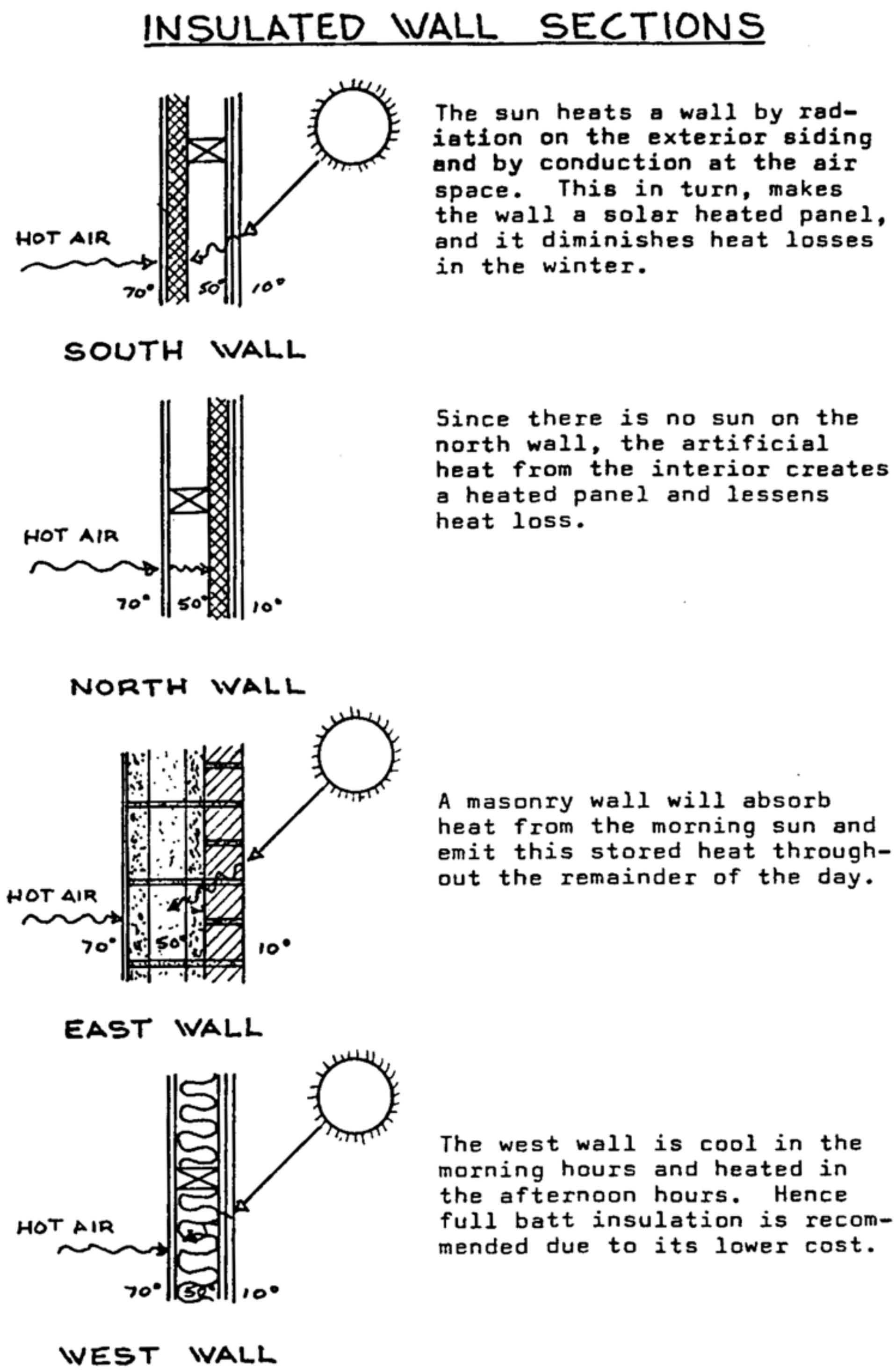


Figure 16

It is possible to take these different wall types and materials and combine them in one building to incorporate the natural environment with thermal comfort for the interior. For instance, wall shading is an effective technique in reducing energy consumption and supporting insulation. Deciduous trees protect walls from solar radiation in the summer, but allow the wall to be warmed by the sun in cooler seasons when the branches are free from leaves. Canopies, projecting mullions, louvers, grillwork, awnings, and solar glass screens can all drastically reduce summer heat gains.

Glass Wall Design

An architectural trend for the past 20 years is the glass wall that has dominated the design of modern office towers and many other commercial buildings. Clear glass, ¼ in. thick, admits ten times as much heat in hot weather as a conventional insulated wall, with the reverse true for winter. In addition glass lowers the winter interior wall surface temperature and impedes the maintenance of thermal comfort (Figure 17).[9]

Several design techniques for solving these problems are as follows: reduction of glass area; shading the glass; use of double plate with insulating air space; and use of heat absorbing and heat reflecting glass. The most inexpensive solution is simply to reduce glass areas, which entails a corresponding decrease in the natural light that enters a building. A comparative study would be necessary here to determine the areas in which energy savings are possible. The desired results may be accomplished by using either of two design alternatives:

1. Use natural light combined with increased building perimeter to reduce the amount of artificial light needed for the interior space.
2. Use artificial light systems with reduced perimeter and glass areas to obtain energy savings through the reduction of heat loss. Figure 18 is taken from GSA/PBS, Energy Conservation Design Guidelines for Office Buildings.

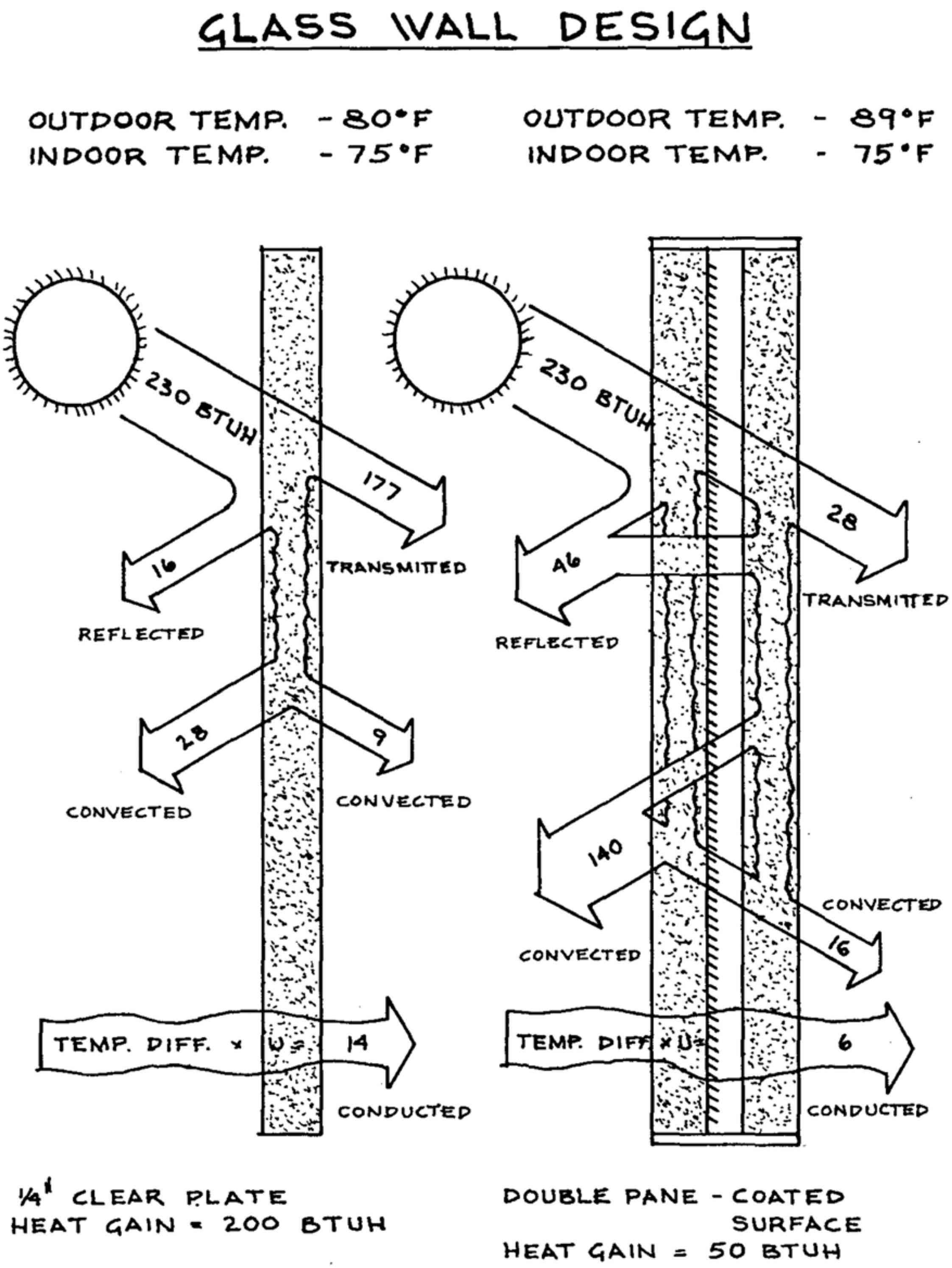
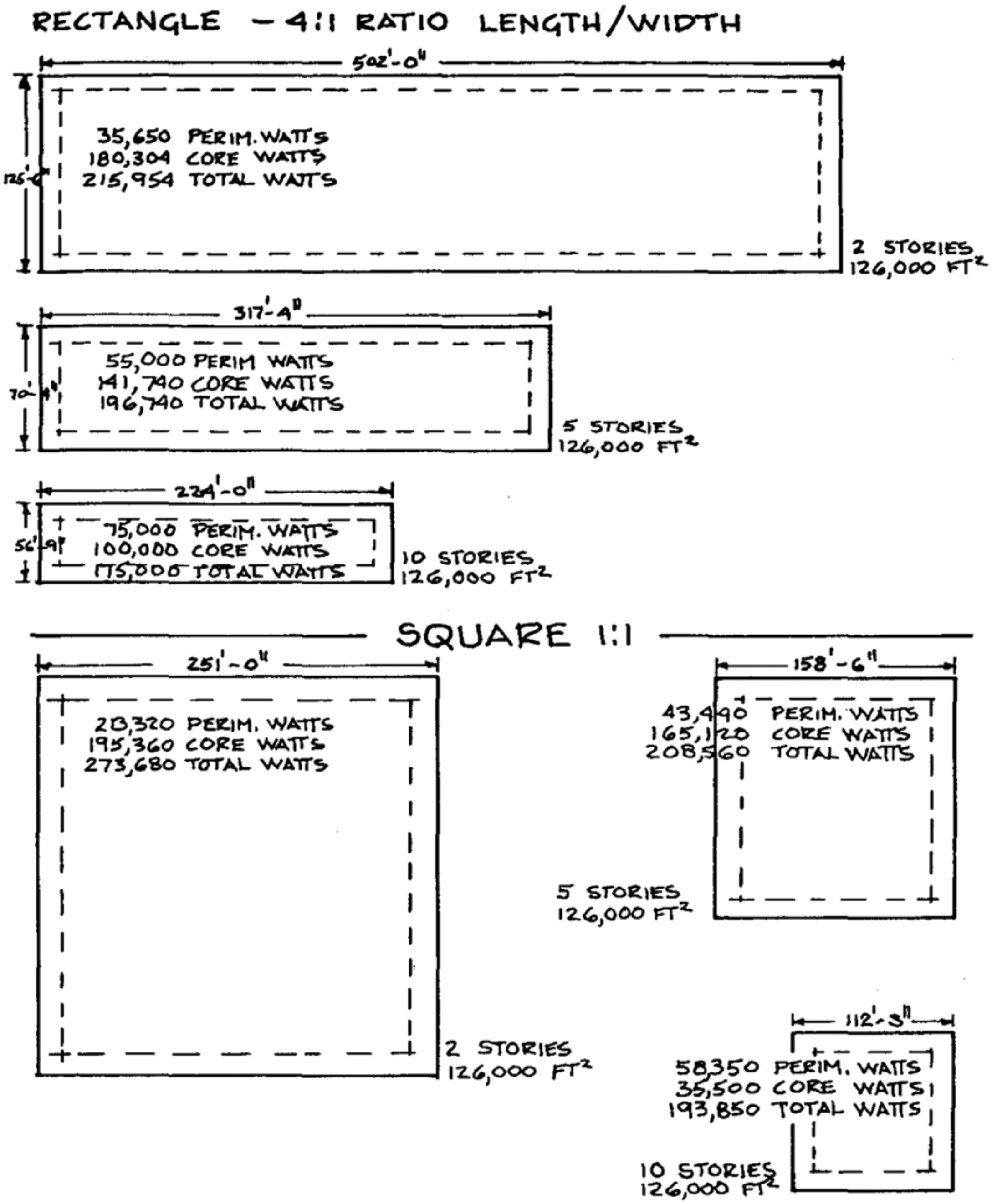

GLASS WALL DESIGN
OUTDOOR TEMP. - 80°F
INDOOR TEMP. - 75°F
OUTDOOR TEMP. - 89°F
INDOOR TEMP. - 75°F
230 BTUH
177
TRANSMITTED
16
REFLECTED
28
CONVECTED
9
CONVECTED
TEMP. DIFF. × U = 14
CONDUCTED
230 BTUH
28
TRANSMITTED
46
REFLECTED
140
CONVECTED
CONVECTED
16
TEMP. DIFF × U = 6
CONDUCTED
1/4" CLEAR PLATE
HEAT GAIN = 200 BTUH
DOUBLE PANE - COATED SURFACE
HEAT GAIN = 50 BTUH

Figure 17

RELATION OF BUILDING PERIMETER TO LIGHTING SYSTEM



ASSUMPTIONS:

126,000 SQ. FT. TOTAL FLOOR AREA
15 FT WIDE PERIMETER ZONE UTILIZING NATURAL LIGHT
LIGHTING – 1 WATT/SQ. FT PLUS DAYLIGHT IN PERIM.
LIGHTING – 2 WATTS/SQ. FT. IN CORE

Figure 18

HVAC Systems

There is no doubt that space heating, ventilating, and air-conditioning (HVAC) represent the greatest expenditure of energy in buildings today. Therefore it is essential that the designer eliminate as many avenues of waste in these cruciaI areas as possible. Of the various HVAC systems currently in use, the one selected will depend on many local factors, including the availability of energy Sources. For instance, there has been such a growing scarcity of natural gas that it is no longer available even for new buildings in some areas of the nation. Furthermore, there is a real possibility that utility companies may be forced to restrict the amounts of electricity supplied to new buildings. With these anticipated shortages in mind, the use of furnaces that convert from one fuel to another would be a worthwhile precaution for owners to insure continual operation of their buildings.

On a large scale, central district heating and air-conditioning for large building complexes offer substantial economies. Unlike individual heating and cooling plants, central district power plants not only supply heating and cooling, but they also service domestic hot water and generate a minor part of the project's electrical power. Additionally, operating and maintenance costs would be reduced considerably for such centralized units. For example, the labor force for 35 individual plants would have totaled 140 men, compared with 15 men for the central power plant.[10] Other benefits include a reduction in the total cooling capacity required to accommodate peak building loads, as well as reduction in initial costs, 52 since the cost per ton of capacity for large chillers is less than the cost of a large number of smaller machines. Finally, the architect can affect further savings by eliminating the rooftop cooling towers, basement rooms for boilers and chillers, and chimney stacks.

The general principles mentioned previously, including building shape, are equally important factors in operating economy. For instance, the proposed mechanical design of Carlton De Wolff, Fairport, Connecticut architect, will reduce the United Nations building's energy consumption by circulating cooler intake air on the north side of the building to the south-side for natural cooling in the summer, and the reverse to be true for the winter.

Heat Recovery Systems

Although heat reclamation is a highly economical energy conservation technique, it requires additional design work for which many clients have been unwilling to pay. Of all the mechanical techniques for conserving energy, perhaps the most productive is the recovery of wasted heat that is rejected into the atmosphere. According to the National Bureau of Standards, it would be possible to reduce heating consumption by 30 to 50% and decrease electrically powered air-conditioning by 15 to 20% through a combination of reduced ventilation and heat reclamation.[11]

Another energy-wise recovery system concerns itself with reclaiming wasted heat from lighting fixtures. Not only does the dissipated heat from interior lighting require a greatly increased cooling capacity, but the longevity of illuminating devices could be extended if they were cooled. The method used for this purpose is to circulate water through lighting fixtures, a highly efficient process of absorbing high temperatures (Figure 19). Hollow-cored louvers placed at the windows will reduce the heat loss during the winter. During the summer, the recirculated water flows from the luminaires and louvers to the evaporative cooler where the heat is rejected. This portion of the system entails a closed water circuit connected in parallel. However, during the winter operation, the recirculated water, heated by the lighting fixtures, flows through the thermal louvers where the heated water offsets perimeter heat losses through the glass windows. In this case the system involves a closed water circuit connected in series.

Such a heat recovery system will absorb close to 90% of the solar heat gain at the glass walls and 70% of the lighting heat. In the summer the excess heat is exhausted, providing effective assistance to diminish cooling loads. However, in the winter the reclaimed heat can provide sufficient warmth for an entire building to relieve heating loads. In addition, this system will cut initial costs by 10% and fuel costs by 60%. According to engineer, Gershon Meckler, of Washington, D.C., the first cost tradeoffs will realize a 45% reduction in central refrigeration capacity, plus extra savings in smaller ducts, fans, and pumps, even though there are additional costs for thermal louvers, water piping circuits, and evaporative coolers.

HEAT OF LIGHT RECOVERY

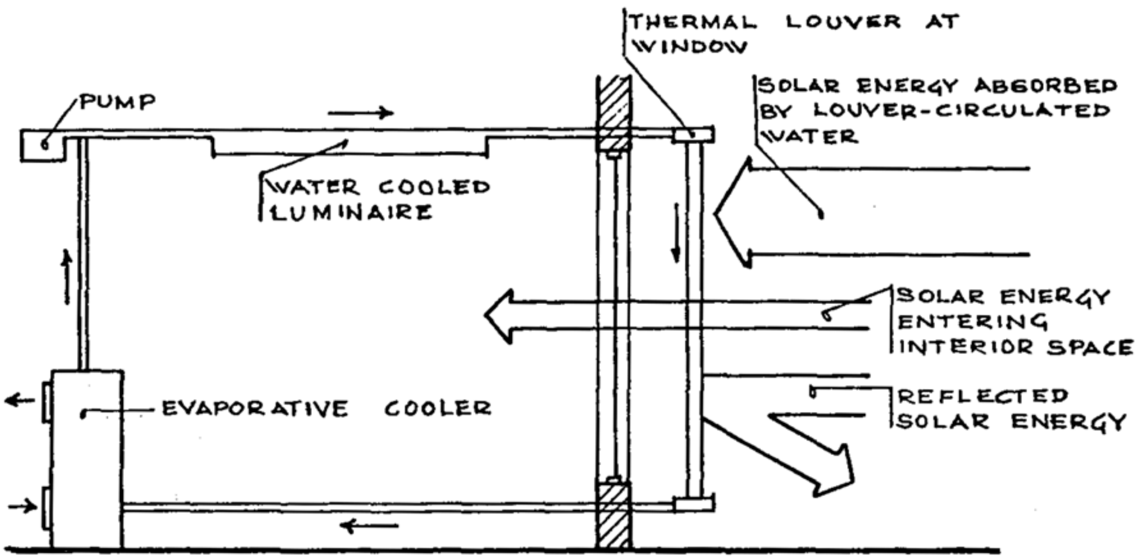


Figure 19

Exhaust Heat Recovery

Perhaps one of the greatest sources of wasted energy in commercial buildings lies in their heat exhaust systems. Nevertheless, savings can be managed here if the designers plan their mechanical systems properly. To illustrate the point let us examine the rotary wheel concept, which can recover up to 80% of the heat in an exhaust air stream (Figure 20). The principle demonstrated here is that a rotary heat recovery wheel extracts the heat from exhaust air and rotates it to the intake air where it is recycled. In addition there are other methods of heat exchange, such as the water cooled coil exchangers, heat pipe banks, and air-to-air exchangers.

Conventional HVAC systems are designed not only to provide heating and cooling, but to meet the capacity energy demands at peak periods that hold only 2½% of the time.[13] C. W. Griffin, P.E., author of Energy Conservation in Buildings, believes the conventional approach seldom fulfills this goal. Heating and cooling loads depend on a great number of architectural variables such as building orientation, local climate, cloud cover, local wind patterns, topography, shading from trees or other structures, interior occupancy, and door and window openings. Moreover, the heat absorbing capacity of materials may not be considered in HVAC calculations to the extent it should be. For example, light materials may absorb solar heat in minutes, but massive substances, such as concrete, may take hours.

EXHAUST HEAT RECOVERY SYSTEM

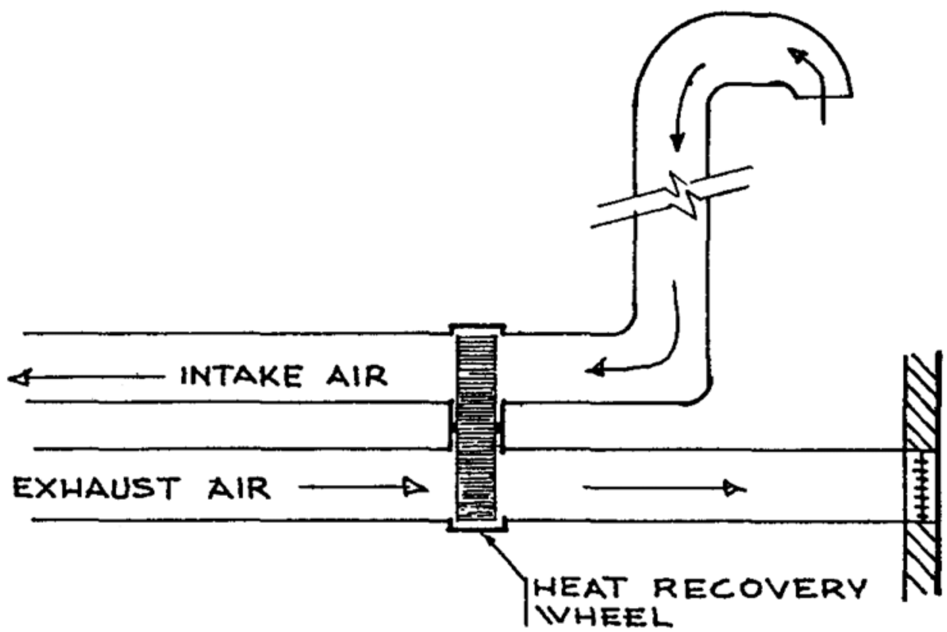


Figure 20

See Appendix E for further energy saving HVAC design guidelines.

Electrical Design

Of all the various energy forms currently in use, e1ectricity is perhaps the greatest in demand. It is therefore essential that architects and planners critically analyze the power needs in their total design schemes to determine the sources of possible waste, especially in large commercial buildings, the single largest group of electrical consumers. However, data is needed on generation capacities and the areas of consumption before any meaningful study can be attempted. Thus the following figures are presented to aid in planning.

The electrical energy consumed by a hypothetical million square foot building would be divided approximately as follows: lighting – 54%; advertising display – 7%; elevators – 11%;

fans and air-handling equipment – 10%; pumps and motors – 5%; miscellaneous office machines – 13% (if electricity is not used for heating and air-conditioning). Here the application of proper conservation techniques could lead to savings of approximately 25% on the air-conditioning load. In total there could be up to a 50% reduction in this item of electrical use.[14]

The existing central generating and distribution systems generally operate at 30% efficiency, which means less than one-third of the raw source energy ever reaches consumers as electrical power.[15]

In the larger commercial buildings, GSA has adopted the medium voltage service and distribution systems. Electricity is purchased at 13,800 volts and distributed at this relatively high voltage to local substation transformers in the buildings. These transformers in turn reduce the voltage even more to 277/480 volts for fluorescent lighting, heavy equipment, general power needs, and distribution. A second set of transformers reduces the voltage to 120/208 volts for the remainder of the building's electrical equipment.[16]

One possible solution to wasted incoming electricity that must be stepped down for local consumption is the utilization of total energy systems, which consist of on-site electrical generating plants and are designed to reuse their own waste heat to increase efficiency. A total energy plant requires about one-half the fossil fuel to deliver the same quantity of energy as a central utility, while simultaneously emitting less pollutants. Because such a system does recover its waste heat, efficiencies as high as 75% can ultimately be achieved.[17]

Electric Lighting

The most apparent example of the use of electrical energy is lighting which consumes about 25% of all electrical energy sold.[18] According to Richard C. Stein, FAIA, the Illuminating Engineering Society (IES), standards in most cases have doubled in the past 15 years. A cited example was the New York City Board of Education Manual of School Planning, which called for 20 footcandles in classrooms in 1952. This was raised to 30 in 1957, and to 60 footcandles in 1971. Libraries increased from 20 footcandles in 1952 to 40 in 1957, to 50 in 1959, and to 70 footcandles in 1971. Shops now require 75 footcandles, 511 while drafting rooms call for 100 footcandles. The value of such high lighting levels has been questioned.[19]

Tests conducted by M. A. Tinker at the University of Minnesota in 1938, and studies by P. C. Butler and J. T. Rusumore at San Jose College in 1968 demonstrated that a light level between 6 and 10 footcandles is adequate for efficient reading, and that higher light levels do not increase efficiency, and may even promote fatigue under normal conditions. Only fine discriminations require 20 to 25 footcandles for satisfactory vision.[20]

As an architectural material, lighting is used to create an efficient and pleasant environment. Adequate illumination can be provided for sufficient vision without the wasteful uniformity of lighting so prevalent in buildings today. Moderate variations of lighting are desirable to avoid monotony and to create perspective effects. Fixtures can be selected and arranged to complement or accentuate the architectural features. Recessed lighting, directional lighting, hues and intensities of lighting may vary the utilization as well as the quality of space.

In order to design an economical and efficient lighting system, the planners must approach each problem with a specific lighting program. Initially one must analyze the problem, considering occupancy and tasks, checking for brightness, reflectance, lighting level, and the quality of light. Secondly, it will be necessary to calculate the lighting requirements and establish the fixture pattern, determining architectural effects simultaneously. At this stage the designer may select other lighting systems with respect to economics, electrical loads, and day-lighting. In the process of reviewing the lighting design for quality, quantity, and aesthetic appeal, one should consult the ASHREA Standard 90-75 for the latest energy conservation recommendations and calculation procedures.

Further energy savings can result from re-examining the light fixture itself. For example, the fluorescent lamp delivers three times the lumens per watt of a standard filament bulb. However, for even distribution, the fluorescent lamp is placed in a second diffusing container which reduces the efficiency of the bare tube by as much as 25%.[21] For additional power and lighting energy conservation, see Appendix F.

Electric Heating

Although electric heating is innately inefficient, there were 23% non-residential buildings heated by electricity in 1969.[22] A fossil fuel such as natural gas or oil is and will continue to be the prime fuel source for producing electricity. The conversion of fossil fuels into electricity and back to the original heat is less than half the efficiency with which the fuel can be used were it directly converted into heat in the end result. Architects should therefore consider these facts carefully in accordance with energy conservation before selecting heating and cooling systems.

Electric heating is also popular with speculative homebuilders, because it reduces the initial cost of the house. More than half of the new homes to be built in the United States this year alone will be heated electrically. The number of homes heated by electricity in the nation increased from 4.8 million in 1910, to 7.3 million in 1913.[23] According to Don Hidel, the Boneville Power Administration (BPA Washington) administrator, the BPA cannot keep up with the energy demands and will be 7% short of producing power by 1979.

Has our fourfold increase in electrical energy use in the past two decades produced a comparable increase in the quality of life? Dr. Lawrence, in his study of 80 post-World War II buildings, noted that energy use per square foot has been increasing with time, although the performance of the buildings – the services rendered for tenants – has been largely unchanged. There is a greater monotony, less individualization, and greater disconnection between the environment in which people work and the factors creating that environment.[24]

Operation and Maintenance

In order to obtain higher levels of efficiency in the operation and maintenance of mechanical, electrical, and plumbing subsystems, additional investments will be required in the primary stages of construction. However, such expenditures would be recovered through the savings in life-cycle costs. Unfortunately inadequate operations and maintenance procedures can and do waste tremendous quantities of energy and may well offset any long-term economy. Frequently the losses sustained may be attributed to unqualified personnel who are responsible for maintaining the control system. Still another factor that may cancel the projected savings results from overlooking the common and most obvious energy wasting sources such as air leakage through loosely fitted windows and doors.

Nevertheless, with no further energy conserving measures other than an efficient, well scheduled operation and maintenance program, requiring no additional capital for new controls or equipment, a competent consultant could reduce a building's energy consumption by as much as 10%. According to Walter A. Meisen, Assistant Commissioner for Construction Management of the Public Buildings Service, this 10% could be achieved through the following: closing outside dampers; shutting off reheat; adjusting humidity controls.[25]

Any effective maintenance program will include regular inspections and scheduled parts replacement. This strategy will not only relieve costly and time-consuming repairs, but it will also promote the energy savings that malfunctioning equipment would otherwise negate. Other strategies that might be incorporated into a building program are those related to scheduling of large power consuming operations at off-peak hours. An example of this type of planning would be the operation of pumps at night to refill water tanks.[26]

The operation and maintenance guidelines presented in Appendix G were included to assist designers in obtaining maximum efficiency from their mechanical and electrical systems, while still providing air circulation and lighting levels within the comfort zone.

When one is dealing with energy conservation in buildings, the custodial and maintenance personnel, whether government or privately employed, cannot be ignored. In fact, the success or failure of any energy conserving program introduced by the architect/engineer in his design will depend heavily upon how diligently the maintenance people observe the prescribed guidelines. Here it is necessary to conduct periodic inspections of the building to insure that its operation is not exceeding the design criteria.

Today it is becoming more evident that an increasing number of architect/engineers produce spatial relationships and enclosed environments that are economically feasible but present many complications in their operation and maintenance. Therefore the institution of ‘crash courses,’ sponsored by the owner and architect/engineer societies for maintenance crews, may promote the proper execution of complex energy systems and serve to relieve the problem of the misused building.

Another facet in the matter of proper building management is the increasingly difficult problem of obtaining responsible skilled labor needed for the operation of sophisticated mechanical and electrical equipment. While crash courses do have benefits, there is another alternative gaining in popularity. Automatic control systems are being implemented with greater frequency to replace maintenance personnel, and they are proving to be more effective in conserving energy. Furthermore, the automation of a building’s mechanical and electrical systems can reduce the labor force by at least one-half and perform the required tasks more efficiently.[27]

At present the cost of mechanical and electrical equipment may represent up to 50% of a building's total construction expenses. In addition, with the prospects of increasing energy costs, efficient operation of sophisticated buildings will become a greater concern to the owner. Hence, there are great opportunities for architect/engineers to pursue economical operation and maintenance techniques with respect to lifecycle costs (Appendix I).

Other Energy Sources

Our consumption of energy has been predicted on an inexhaustable supply. That *is* the attitude we are accustomed to. Furthermore, it has been predicted on a relatively inexpensive supply. Projections call for approximately three times the present fossil fuel consumption in 25 years, and at a time of increasing international competition for petroleum.

The nuclear sources have not produced the low cost energy, which was initially projected. In fact light-water reactors and liquid metal fast breeders not only pollute, but are extremely expensive.[28] Therefore, architect/engineers must question these demand projections in depth before the future course of the building industry can be meaningfully charted.

Solar energy may be one solution to meeting the future energy demands. Every day the radiation from the sun that reaches the earth equals several thousand times as much energy as we consume. A solar collector 5,000 square miles in area placed in New Mexico could supply the entire energy needs projected for the United States in the year 2,000. Additionally, solar energy is quite safe to use and pollution free with a virtually limitless supply.

Will there be an incentive for the use of solar energy in commercial buildings, as well as in residences? The Rocky Mountain region, and Colorado in particular, has suffered from a critical shortage of natural gas in the past few years. Despite the potential supply of gas from Canada, and liquified natural gas from the Far East, there is forecast a substantial deficit in the supply of natural gas compared to the demand anticipated by the year 1990. It has already been estimated that the cost for gas will escalate 300% by the year 1990. There is also indicated a 125% increase in the cost of electrical energy, and these figures are conservative.[29]

To illustrate the potential and savings that are possible with alternate energy sources an engineering feasibility study for Denver Community College, using a solar heating system, was done by Frank Bridgers, of Bridgers & Paxton, Consulting Engineers. The 15-year weather records of the Denver area were studied to determine the coldest period and the cloudiest period. With this information calculations were made to determine the required collector surface and storage tank volume.

The results were a total net premium. Cost, including insulation, double glass, approximately 50,000 square feet of solar collectors, and a 400,000 gallon storage tank, amounted to $667,000. The energy savings were figured on 1973 prices and came to $29,502 a year. Based on the escalation of energy costs, the energy savings in 1990 are estimated to be $95,000 a year. If we average these figures out, the total energy savings per year is $62,300, with the payoff period in 10.7 years. For an institutional building which has a life expectancy of from 40 to 50 years, this is considered to be an economically feasible project, particularly in view of the fuel shortage in the Colorado area.[30]

Numerous projects are being conducted around the country on an experimental basis to analyze and evaluate various energy conserving techniques in building design. For instance, there are some architects and engineers in New York City, who are meeting the challenge of energy restraint within towers. Two such buildings are the 40-story Econ Building, with a proposed solar energy system that could save one million dollars annually in energy costs, and the 46-story, 914 foot Citicorp Tower (Figure 21), with solar power set up by MIT with a grant from the National Science Foundation.[31] The Citicorp Tower, now under construction, is being built at a cost of $128 million and has more than one million square feet of office space. Its main tower, which rests on top of four 10-story “super columns,” has a sloping roof with a large-scale experimental solar energy system facing south. This system will provide enough-h power for at least 5% of the building’s heating and cooling loads. Another energy saving system is the double deck elevators that will transport twice as many passengers without increasing elevator shaft space. Also considered is the reduction of window area which could represent a fenestration factor of about 35%, compared with the normal glass tower’s 50%.[32]

Perhaps one of the finest in depth studies conducted for energy conservation was the GSA's experimental Manchester Building. Experts combined the latest technology with creative design methods to produce a building that realized a 33% reduction in energy consumption. Some of the more outstanding features contained in the structure include improvements in the building envelope through the increase in thermal resistance of walls, floors and roofing to a U-factor of 0.06 instead of the conventional 0.20 to 0.30, which resulted in an 18% reduction in energy consumption. Substantial energy savings were further achieved through the additional use of 10% glass wall (double-panel) surface coverage on exterior walls. Furthermore, the common problem of energy-robbing air infiltration was kept at a minimum by utilizing gasketed windows and sealants in doors.[33]

Dubin-Mindell-Bloome analyzed fifteen different HVAC systems and six lighting schemes, of which the most efficient provided power consumption at the rate of two watts per square foot.[34] Methodical studies were also conducted on waste heat from lights, exhaust air, space heating, domestic hot water, heating, and absorptive cooling. With the combined skills of mechanical, electrical, and architectural consultants, the experimenters were able to devise techniques that reduced the computed yearly energy consumption from 116,000 Btu's/sq.ft./yr. to 56,000 Btu's/sq.ft./yr., or a total reduction of more than 50%. Peak cooling loads were cut from 300 to 157 tons of refrigeration – 50% less; peak heating loads were cut from 4 million Btu's to 2.4 million Btu's – 40% less. 35 Subsequently the team provided conclusive evidence that conservation oriented design schemes coupled with expert planning will not only reduce initial HVAC costs, but long term operational expenses as well.

CITICORP TOWER

Figure 21

Codes and Standards

Although the body of knowledge dealing with energy conservation in buildings is expanding daily, there still remain many obstacles in the path of continuing future progress, with building codes emerging as the more restrictive. Traditionally, legislation has lagged well behind technology, but our deepening energy crisis has intensified the need to remove any hindrances to economic growth and survival. This is particularly critical *in* the building industry where the savings in energy and materials could be quite substantial were it not for outmoded codes which also discourage experimentation.

For example, structural design standards may warrant closer scrutiny. In considering the loading for a particular building type, live loads are assumed to be simultaneously applied over all rooms, not including corridors, lobbies, stairs, etc. Another analogy drawn by Richard Stein, using the uniform live load without the allowed reductions, shows as follows: a 750 square foot classroom for 30 pupils is computed to withstand a load of 40 pounds on every square foot, or a total of 30,000 pounds in addition to the weight of the structure. Thirty children and a teacher might weigh 5,000 pounds. Thirty-one desks and chairs might add another 3,000 pounds. Adding another 1,500 pounds for friends, books, paraphernalia and miscellaneous items would bring the total to 9,500 pounds – less than one-third of the figure used in the original computation. Furthermore, the values given for the concrete have a 300% safety factor; for steel 50%.[36] Lastly, the structural designer will select steel for reinforcement and overall dimensions for his beam cross section at the first size above that required by the computation, adding another 5%.[37]

It seems quite obvious that these codes and standards will not change overnight, as a good number of architects and engineers feel that such codes possess beneficial safety factors and should not be tampered with unless otherwise proven over time. In some cases, however, codes are made by special interest groups and are based on antiquated ideas. For instance, only thirty years ago steel had half the allowable strength compared with today, while ventilation, according to some codes, is based on three air changes per hour, and there is no physiological reason for this.[38] Similarly, it was disclosed on page 47 that requirements for adequate lighting levels have been spiraling upwards for the past 20 years, again with no physiological basis.

When a careful analysis of the amount of space required to house the functional programs in a building is conducted, the results may lead to the elimination of excessive materials and the corresponding outlay in energy required for heating, cooling, ventilation, and illumination. Such a project was successfully completed in the Manchester office design which avoided the over-simplified formulas on which many codes are based, such as “X square feet per occupant” that automatically results in the excessive space and consequent materials' requirements found in many buildings today.[39]

There are committees here in New Mexico on the state, regional, and local levels trying to put an end to the special interest groups. The Albuquerque Code Review Committee headed by Garlan Bryan, of Flatow, Moore, Bryan & Fairburn, Inc., is now actively involved in trying to revise and develop the building codes into a more substantive guideline for the building industry.

Nonetheless, it still remains the architect's responsibility to keep abreast of the latest available energy conservation policies and programs and to implement them. Wasteheat recovery and various other mechanical techniques demonstrate great energy saving potential, but it is the appropriate architectural innovations in thermal insulation placement, glass and lighting design, building orientation and shape, etc., that ultimately contribute the major part of the total energy reductions possible in buildings.

FOOTNOTES

[1]This comparison deals with raw materials only and not fabrication.

[2]Richard Stein, "Spotlight on the Energy Crisis," AIA Journal, (June, 1972), p. 18.

[3]Ibid.

[4]Ibid.

[5]Ibid., p. 19.

[6]Dubin-Mindell-Bloome, p. (4-1).

[7]Griffin, p. 41.

[8]Ibid., p. 52.

[9]Ibid., p. 62.

[10]Ibid., p. 79.

[11]Ibid., p. 87.

[12]Ibid., p. 89.

[13]Ibid., p. 103.

[14]Stein, "Architecture and Energy," p. 46.

[15]AIA, Energy Conservation in Building Design," p. 19.

[16]Ibid., p. 82.

[17]Ibid., p. 83.

[18]Stein, "Spotlight on the Energy Crisis," p. 19.

[19]Ibid., pp. 19-20.

[20]Ibid., p. 20.

[21]Ibid.

[22]Ibid., p. 21. (quoting F. Thompson, Electric Comfort Conditioning Journal, April 1970, pp. 13-16).

[23]Bob Lane, "Electricity Bandwagon Soon May Be Overloaded," Seattle Times, March 31, 1974, microfiche.

[24]Stein, "Architecture and Energy," p. 39.

[25]Griffin, p. 111.

[26]Ibid., p. 115.

[27]Ibid., p. 116.

[28]Stein, op. cit., p. 39.

[29]Frank H. Bridgers, "Applying Solar Energy for Cooling and Heating Institutional Buildings," ASHRAE Journal, (September, 1974), p. 30.

[30]Ibid.

[31] ___"Designers Relying on Solar Energy," New York Times, September 15, 1974, p. 12. (Unsigned)

[32]Leo Standora, "Construction Starts Here on a Giant Sun-Tower," New York Post, April 8, 1975, p. 73.

[33]Griffin, p. 153.

[34]Ibid., p. 154.

[35]Ibid., p. 155.

[36]Concrete with a rated strength of 3,000 psi. has an ultimate strength of 3,750 psi. In structural computations, however, the design strength used for this concrete is 1,350 psi., only 36% of its ultimate strength. Steel is designed at 60% of its yield point. Steel, at 36,000 psi., is designed for a maximum stress of 21,600 psi.

[37]Stein, "Spotlight on the Energy Crisis," p. 18.

[38]Stein, "Architecture and Energy," p. 47.

[39]Dubin-Mindell-Bloome, p. (6-1).

Chapter IV CONCLUSION

The impending shortages of materials and fuels have created new and greater problems for our already besieged building industry. Previously architects had little need to concern themselves with energy conservation. However, with the limits of natural resources in sight, a comprehensive reevaluation of building technology will be necessary.

Consequently, architects and engineers must examine their own values and design procedures, for these professionals have a vital role in the energy crisis. Moreover, as the Earth's population increases, there will be a corresponding increase in construction and related energy demands necessary to produce the required building materials.

The growing number of high salaried workers has created further demands for more leisure time and comfort, which in turn necessitates the installation of more sophisticated heating, ventilating, and air-conditioning systems in buildings with the accompanying greater energy consumption.

At present there seems to be some question as to when our natural resources will be depleted. The exponential quantities are illustrated in Figure 3. However, the basic issue is not the accuracy of the data, but that shortages and the total depletion will occur eventually, and we will have to deal with the problem accordingly. To avoid the ensuing chaos therefore, serious thought must be directed toward alternate design criteria now.

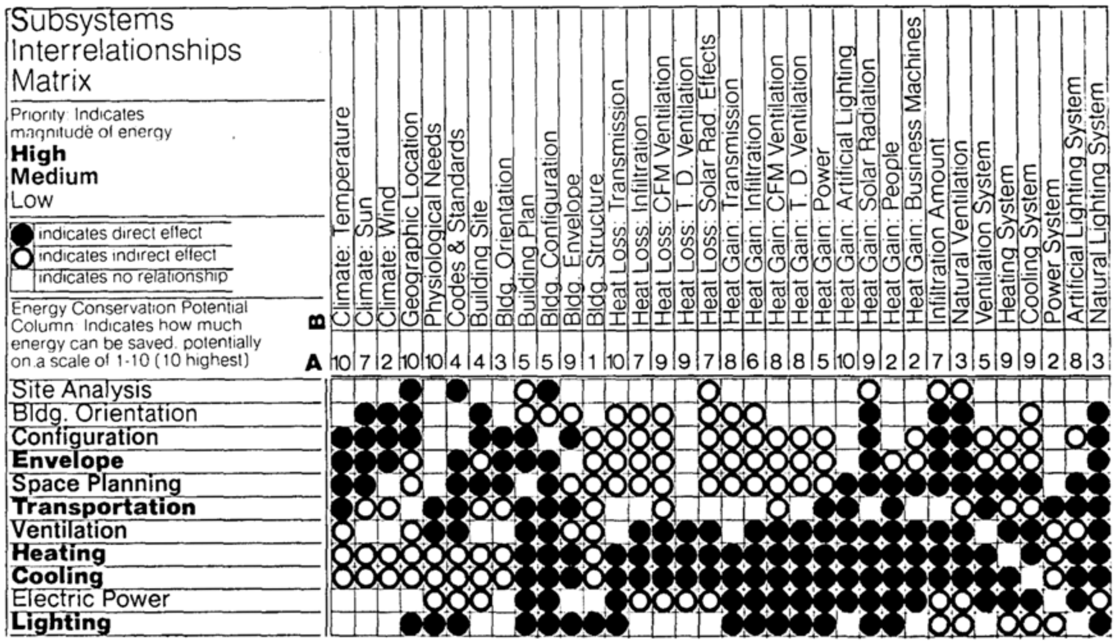
One portion of the crisis can be attributed to the vast population growth. But let us consider for a moment that popu1stion expansion is directly related to economic conditions. During prosperous times, the population of industrial countries escalates, but when the economy drops, so does the rate of increase in population. The resultant vicious cycle simply cannot be resolved with a few governmental policies. Conversely, underdeveloped countries, such as many in South America, are doubling their populations every 20 years compared to the United States' doubling every 65 years. Finally, as increasing numbers of countries in Africa and Asia become industrialized, greater portions of the already limited natural resources are consumed, and competition with the Western World escalates.

Previously unmentioned, there exists still another factor that is a far more subtle but devastating threat to economics and conservation – namely – pollution. As industrialization expands so does pollution, the most dangerous but apparently inevitable by-product of our modern technology. Owing to the prevalent American philosophy of 'waste as natural,' and to the fact that some of the worst forms of pollution cannot be perceived, nor its impact fully understood, the gravity of the problem will continue to be ignored in the light of other world crises such as the imminent energy shortage.

Another unrealized factor is that the exponential growth of pollution is progressing at an even greater rate than our other problems because of the uncontrolled wastes and poisons which are destroying our surrounding ecological system, the only true curb on pollution. According to, Limits to Growth, the levels of pollution will meet or exceed our supplies of natural resources by the year 2050 AD, at which time industrial output, food, and population will take a disastrous decline. Of course, this is an assumption, but it can become a reality unless mankind's social flexibility and technology provides the needed changes.

This paper has outlined the relationships of building materials and subsystems with respect to the natural environment. An attempt has been made to select tradeoffs that must be considered in choosing one measure over another, particularly in the hot-arid climate. However, humanistic, aesthetic, and other traditional values in the architectural field may alter the energy conservation techniques presented herein. It is precisely the combination of energy conserving techniques along with conventional design methods that will ultimately serve as a compromise for the designer and prove to be the most successful.

The order of priorities in which energy and materials may be conserved are listed and assigned to various design elements in Figure 22. This chart summarizes appropriate building subsystems in relation to the natural environment, and evaluates each component individually with repect to the entire system. However, it must be kept in mind here that the priorities established in Energy Conservation in Building Design, by the AIA, cannot be assessed without regard to the other subsystems and their correlated effects.



(Source: Energy Conservation in Building Design, AIA, 1974)

Figure 22

Yet, the architect's concern with building design and selection of materials is not the only architectural decision that has to be determined. He is also responsible to the client, finance company, public opinion, current styles, available materials, and economic conditions. As mentioned earlier, energy expenditures can be reduced anywhere from 25 to 50% in new or existing structures without sacrificing comfort. And because of the existing and future resource shortages, it will be essential for architects to design building components with far more discrimination than previously.

Such precision will manifest itself in the preference for low energy as opposed to high energy produced materials, although the availability of natural resources, many of which are close to depletion, may serve as the ultimate criterion in the selection of building materials and remove the luxury of choice. Further, the design of building configurations, which provide higher levels of efficiency for mechanical and electrical equipment as well as for users, will be necessary. Complicated building configurations created merely for visual interest or for a feature story in Architectural Record will have to be discouraged if energy is to be saved, for we can no longer afford to build simply for the highest profits or personal glory. Hence, architecture must be regarded as a source of energy and material consumption, which reduces the irreplaceable natural resources.

Similarly, mechanical and electrical engineers also have an obligation to the environment. Through the utilization of the suggestions in Chapter III HVAC systems can be designed with greater efficiency.

Economically, the time is right to initiate a new thinking process and apply our advanced technology in practical ways. The labor and materials required to produce coal and petroleum, for instance, are increasing far more rapidly than any other commodity. Oil prices alone tripled last year because of limited resources and political forces. These unavoidable factors are the catalysts for change in the methodology of architectural design.

The American Institute of Architects is currently deliberating with the Bureau of Standards to assume a leadership role in calling a conference of all the disciplines involved in the building industry – the architect, the client, the contractor, the money lender, and the people concerned with the manufacture of building materials – to establish the ground rules and a decisive plan for approaching the energy consumption problem.[1] Such conferences among various professionals in the past were convened in 1972, “A Round Table on Energy Conservation,” and in 1973, “Energy's Impact on Architecture.”[2]

In the future architects may have to consider changing the established planning practices in order to impose energy conserving principles. Formerly the architect was expected to provide a basic design before the mechanical, electrical or structural engineers submitted their individual schemes. Each specialist added his own subsystem, usually one that was easy and economical to install, with little regard for energy saving techniques. Consequently, this traditional linear design approach has resulted in much wasted energy and resources in contemporary buildings.

Furthermore, even if the architect's original plan included many energy conserving features, the design could easily be foiled by conventional mechanical and electrical subsystems. Therefore, the use of consultants with expertise in the various segments of energy conservation in building design should be encouraged. In this manner, it may also be possible to stimulate those engineers and contractors, who have ignored conservation practices up to now, into reappraising their own techniques through a form of economic boycott.

Our conservation technology has not only challenged the merits of a linear design approach, but it has raised new questions about the traditional role of the architect himself.

Although the general practitioner is best suited to meeting community needs in most cases, an architect must specialize in other professions as well. Conceptually architecture is a “know all” profession due to the nature of the services rendered, but the vocation's primary objective is to design buildings that will serve the users. However, architects today find themselves as mediators for the client, builder, and other professional services, and have little time for any new demands that may arise.

Subsequently the trend has been for the architect to become more specialized. People from all walks of life are entering the profession and becoming architects of socio1ogy, law, business, and of the building industry. Sociology experts serve to inform the public as well as their clients of the changing trends in world thinking. Our priorities and modes of living are changing constantly because of technology, economics, and world politics. As a result we also need architect-lawyers, not only for protection, but to become involved in major decision making, especially since the matter of solar and air rights is becoming an increasingly critical issue as the technology develops.

Up to now architects have had very little say in government policies and related fields. Yet the architect occupies a unique leadership role in the building industry, as coordinator of all persons and elements involved in the design and construction of buildings, and thus is capable of influencing many sectors of society. Were he to use this position more vigorously through the AIA, the architect could make his voice heard in the government and provide active assistance in formulating a national energy policy.

However, there are many obstacles to overcome before the architect can achieve such a goal. For instance, the entire nature of the building industry revolves around the fragmentation in design, construction, and operation of the building process.

If we examine the automobile industry for a moment, we find that the basic design, implementation, and manufacture of the automobile occurs under one source. In contrast, each building industry specialist emanates from a different sector and has only indirect contact with related professionals through the architect. For example, a heat of light recovery project, involving the efforts of the mechanical engineer, the electrical engineer, the architect, and poesib1y some manufacturers, all working in their own spheres and each taking separate profits, may become somewhat cumbersome.

Because of this serious lack of feedback and communication within the building industry, the greatest force for change has originated from financial sources. Most structures are designed and built-to-be-sold within a three-year period from completion, with little or no regard for operation and maintenance costs. Furthermore, as long as there are buyers for energy consuming buildings, there will be financial support for them. This is the primary reason why architects cannot wait for change in the financial institutions.

Rather, the building professionals themselves must close the communication gap within their realm, if for no other reason than financial survival. In this respect it is essential that an architect maintain a close rapport with the construction industry. Both institutions have a common goal, and that is the completion of an architectural structure for a specified amount of money, and at a specified time limit for the owner. Yet there remains certain prejudices and ambivalent feelings toward each other's profession.

In many cases there is poor communication between architectural firms and construction companies through contract documents. The construction industry, especially smaller companies, are caught in an economic squeeze by the very nature of the bid system. If a contractor were to allocate sufficient funding for every specification of the architect, he would never be the lowest bidder. However, if the contractor reduces estimate costs to the limit, in all likelihood he will suffer losses in the construction process, particularly with steadily escalating labor and material costs. Fortunately, the communication barriers are slowly disappearing today, and are being replaced with a growing sense of cooperation among the related professions.

Perhaps the most important economic factor considered in the design and construction of a building is the labor expenditure. Previously labor was considered a very expensive item with the high rate of increase in wages, while materials remained fairly stable and relatively inexpensive. Today however, when we find ourselves with shortages of energy and some materials, and with the increasing costs in the labor market, the reversal of the traditional balance is developing.

Numerous examples of resource shortages can be cited. For instance, such materials as copper, lead, and zinc have reached the crisis state of supply with the end already in sight. Not only are the natural resources running short, but the life expectancy of the products made from these substances is in doubt. In the petroleum industry paints, plastics, insulation, waterproofing membranes, and other building materials composed of petroleum products, already are reflecting the shortage and subsequent escalating cost of this valuable mineral. In addition, these shortages of materials have led to political and economic warfare, creating uneven distribution and unnaturally high costs of materials. Man's greed and avarice are major factors that have contributed to the crisis today.

Formerly the philosophy of the architect and other related professional was to decrease the cost of labor through the excess use of materials. It was thought that over-designing the structure would compensate for any poor workmanship due to negligence, for there are times when poor construction is the result of the contractor's attempt to minimize expensive building procedures, often not considered by the architect. Similarly, technology was aimed at eliminating as much labor as possible with quick erection methods through mechanization without regard to the waste in materials and energy that such methods generate.

However, with the growing shortages in materials and energy today, this philosophy cannot continue because of the changing trends mentioned above. The rethinking may well be to expend more effort and capital in labor to conserve the building materials and still realize savings for the owner. Here one could consider a better-trained labor force along the lines of energy conservation techniques.

To illustrate the advantage of a greater labor investment let us examine the savings possible in vital phases of construction. Concrete and concrete form work have displayed tremendous cost increases recently, but even with this expense the budget should be adequate if the labor force is deployed properly to build form work, place steel, and mix concrete carefully. The energy savings alone in the production of that concrete, which would be lost through careless construction methods, has been estimated to represent 2 billion Kw. hours a year.[3] Compare these savings with 5,000 Kw. hours of energy that must be generated to meet the power needs of the average family for a year.[4] Therefore, with the abundance of labor and the depleting supplies of raw materials, it seems apparent that the architect will have to rely more upon labor to cooperate and assume the responsibility for their role in the conservation of materials end energy.

Regardless of the nature of any evolving energy policy, it will have to be an integral part of the national growth policy. Such a plan will affect and directly influence the American lifestyle by the way we use land, where and how homes are built, and the distance between homes and places of employment. It will force the redesign of transportation systems and the reappraisal of consumer and industrial products that are short-lived and wasteful. Once people realize the degree to which energy is wasted and what the resulting economic reverberations mean to them personally, the incentive to conserve will grow.

The science of energy conservation is in its infant stages, and although the research has been progressing, it has not as yet been able to solve the major difficulties. Potential use of alternate energy sources such as solar, wind, and fuel cells, requires that buildings be designed so they will be adaptable for such systems when technology permits commercial use. While every indication suggests that these alternate sources will develop in the next few years, there is less reason to be optimistic about nuclear power or geothermal energy. Even if the promised breakthroughs do occur in these two latter areas, they would have relatively little impact on the present 85 design decisions.

Therefore, it is essential to continue research and development in conservation, the funding for which will have to be provided to a great extent through private enterprise. Big business has the tax shelters and sufficient capital so necessary for experimentation. Oil companies are especially interested in alternate energy possibilities, as in the case of Shell Oil, whose donation of three million dollars to the University of Delaware sponsored valuable research in solar energy.[5] Some local governments are providing tax incentives for alternate energy devices, such as the solar tax credit bill in New Mexico, which can save a home owner up to one thousand dollars. Universities throughout the country are also conducting research on building materials and alternate energy uses with government funding.

One remaining great challenge for the architect is that he must educate the clients as to the need for considering and promoting the concept of life-cycle costing to replace the still prevalent first-cost system. However, in order to establish life-cycle costing as a more valid procedure, we must have precise data on the performance of mechanical and electrical systems, as well as guarantees on the quality and longevity of the equipment to promote their use. It will be necessary therefore for architect/engineers to collect data on systems' performance and review past projects. Hopefully the data will reveal the benefits and superiority of the new systems and serve to successfully influence owners and money-lenders into accepting energy saving techniques in the light of high energy costs (Appendix 1).

In this respect engineers have a distinct advantage over the architect in that they can sell their energy saving ideas to clients whose buildings are becoming too expensive to operate. Such is the case with Rice University in Texas, whose mechanical system costs one million dollars a year to run. Bridgers and Paxton, consulting engineers in Albuquerque, have devised an alternate system that will reduce operating costs by a quarter of a million dollars for an initial outlay of about $100,000.[7] Even with the disadvantages it is possible for engineers and allied professionals to come up with new ideas or revisions of old concepts that are marketable as well as profitable.

Mr. Walter A. Meisen, assistant commissioner for Construction Management of Public Service and Government Service Administration, is convinced that the owner has to playa major role in energy conservation.

> "Ninety percent of the design decisions made in the office building today are not given to the owner as an option. How much you pay for lighting and how much air-conditioning you get is not left up to the client."[8]

The owner should insist on options from the designer, but a majority of clients do not know what to ask for and have little or no knowledge of the building industry. Therefore, the owner relies upon the architect, and the architect in turn relies upon the consulting engineers and builders who have a favorable record of efficiency and dependability, even though they may lack any knowledge of conservation techniques.

A possible solution to the ignorance, misconceptions, and fragmentation in design techniques that prevails throughout the building industry might be the production of an equivalent text to the <u>Time Saver Standards</u> or <u>Graphic Standards</u>, that would deal primarily with energy conservation techniques in buildings. Such a handbook would include the following items:

1. A list of the meteorological elements for specific regions of the country. For example, the thermal, wind, solar, and precipitation figures might be provided to do a climatic analysis for a site.
2. In relation to the above data, criteria for designing the structure, operation and maintenance of a building would be furnished to maximize efficiency and minimize costs. This in turn would allow planners to make a meaningful feasibility cost analysis for alternate energy sources and the incorporation of new design features. Hopefully this would encourage further experimentation to meet future energy needs.

Herein there is also an urgent need for a more centralized communication system for the AIA and related agencies to provide the latest information available to the architects, engineers, contractors, and manufacturers, nationwide, on the research and innovations *in* building design. Such a computer-based program would be able to deal with the entire system, not simply the parts. However, this concept requires total industry concurrence and leadership to secure a program which will be available and viable for all concerned.

Many large general contracting firms already use computers for their payroll records, which are kept as cost analysis referral sheets for the estimator's convenience. Computers have simplified the task of predicting the cost of a new building far more accurately than ever, and have provided figures on cost comparisons of mechanical and electrical systems, as well as the use of materials with operation and maintenance costs, so that tradeoffs can be analyzed in conjunction with the natural environment for maximum efficiency. Because future costs of labor, materials and fuels are a major consideration in the present design of a building, much of the waste and subsequent expenses could be reduced in the entire industry if computers were used in the planning process.

The turbulence of the sixties has ushered in a new wave of thinking predominated by one all-inclusive theme: the challenging of traditional values and modes of behavior. Reforms initiated at that time in social, political, and economic spheres are continuing today with even greater momentum. Adding to these eruptions is the threat of dwindling natural resources and energy. Yet, so compelling are the forces for change, that one recognition has gained in urgency – we must conserve and cooperate if we are to survive.

All of the above factors may be discerned in the building industry, a remarkably sensitive indicator of our society's development. The confrontation with steadily diminishing supplies of energy and materials has inaugurated the quest for more efficient techniques in the design and construction of buildings and the corresponding need for greater communication among allied professionals.

In order to provide an adequate comfort zone for its occupants, all the features of a building must be interrelated and coordinated to function in harmony. Consequently the primary objective of the architect evolves as his ability to design a structure within energy conservation guidelines, while fostering and maintaining the cooperation and combined skills of all related professionals. This challenge requires the deferral of today's initial profits for the savings of tomorrow.

FOOTNOTES

[1] ___"A Round Table on Energy Conservation Through Higher Quality Building," Architectural Record, (January, 1972), pp. 97-106. (Conference).

[2] ___"Energy's Impact on Architecture," Forum, (July/August, 1973), p. 59-76. (Conference).

[3] Stein, "Architecture and Energy," p. 47.

[4] Ibid.

[5] George S. Wolbert, Energy and the Architect: The Challenge of Change, Report to the Texas Society of Architects, (Houston, Texas, March 29, 1974), pp. 1-32.

[6] Interview with Michael G. Supple, Bridgers & Paxton Consulting Engineers, Albuquerque, New Mexico, January 29, 1975.

[7] ___"Energy's Impact on Architecture," p. 62.

APPENDIX A

SITE[1]

1. Use deciduous trees for their summer sun shading effects and wind break for buildings up to three stories.
2. Use conifer trees for summer and winter sun shading and wind breaks.
3. Cover exterior walls and/or roof with earth and planting to reduce heat transmission and solar gain.
4. Shade walls and paved areas adjacent to building to reduce indoor/outdoor temperature differential.
5. Reduce paved areas and use grass or other vegetation to reduce outdoor temperature build-up.
6. Use ponds, water fountains, to reduce ambient outdoor air temperature around building.
7. Collect rain water for use in building.
8. Locate building on site to induce air-flow effects for natural ventilation and cooling.
9. Locate buildings to minimize wind effects on exterior surfaces.
10. Select site with high air quality (least contaminated) to enhance natural ventilation.
11. Select a site, which has year-round ambient wet and dry bulb temperatures close to and somewhat lower than those desired within the occupied spaces.
12. Select a site that has topographical features and adjacent structures that provide desirable shading.
13. Select site that allows optimum orientation and configuration to minimize yearly energy consumption.
14. Select site to reduce specular heat reflections from water.
15. Utilize sloping site to partially bury building or use earth berms to reduce heat transmission and solar radiation.
16. Select site that allows occupants to use public transport systems.

APPENDIX B

BUILDING SHAPE AND ENVELOPE[2]

1. Select building configuration to give -maximum south wall to reduce heating load.
2. Utilize building configuration and wall arrangement (horizontal and vertical sloping walls) to provide self-shading and wind breaks.
3. Locate insulation for walls and roofs and floors over garages, at the exterior surface.
4. Construct exterior walls, roof, and floors with high thermal mass with a goal of 100 lbs. per cubic foot.
5. Select insulation to give a composite “U” factor from 0.06 when outdoor winter design temperatures are less than 10 degrees F., to 0.15 when outdoor design conditions are above 40 degrees F.
6. Select “U” factors from 0.06 where sol-air temperatures are above 144 degrees F., up to a “U” volume of 0.3 with sol-air temperatures below 85 degrees F.
7. Provide vapor barrier on the interior surface of exterior walls and roof of sufficient impermeability to provide condensation.
8. Use concrete “slab-on-grade” for ground floors.
9. Provide textured finish to external surfaces to increase external film co-efficiency.
10. Provide solar control for the walls and roof in the same areas where similar solar control is desirable for glazing.
11. Consider length and width aspects for rectangular buildings as well as other geometric forms in relationship to building height and interior and exterior floor areas to optimize energy conservation.
12. To minimize heat gain in summer due to solar radiation, finish walls and roofs with a light colored surface having a high emissivity.
13. Reduce heat transmissions through roof by one or more of the following items:
    - a. Insulation.
    - b. Reflective surfaces.
    - c. Roof spray.
    - d. Roof pond.

e. Sod and planting.

f. Equipment and equipment rooms located on the roof.

g. Provide double roof and ventilate space between.

14. Insulate slab on grade with both vertical and horizontal perimeter insulation under slab.

15. Use insulation with low water absorption and one, which dries out quickly and regains its original thermal performance after being wet.

16. To reduce heat loss from windows, consider one or more of the following:

a. Use minimum ratio of window area to wall area.

b. Use double glazing.

c. Use triple glazing.

d. Use double reflective glazing.

e. Use minimum percentage of the double-glazing on the north wall.

f. Allow direct sun on windows November through March.

g. Avoid window frames that form a thermal bridge.

h. Use operable thermal shutters, which decrease the composite "U" value to 0.1.

17. To reduce heat gains through windows, consider the following:

a. Use minimum ratio of window area to wall area.

b. USB double-glazing.

c. Use triple glazing.

d. Use double reflective glazing.

e. Use minimum percentage of double-glazing on the south wall.

f. Shade windows from direct sun April through October.

18. To take advantage of natural daylight within the building and reduce electrical energy consumption, consider the following:

a. Increase window size but do not exceed the point where yearly energy consumption, due to heat gains and losses, exceeds the saving made by using natural light.

b. Locate windows high in wall to increase reflection from ceiling, but reduce glare effect on occupants.

c. Control glare with translucent drapes operated by photo cells.

d. Provide exterior shades that eliminate direct sunlight, but reflect light into occupied spaces.

e. Slope vertical wall surfaces so that windows are self-shading and walls below act as light reflectors.

f. Use clear glazing. Reflective or heat absorbing films reduce the quantity of natural light transmitted through the window.

19. In climatic zones where outdoor air conditions are suitable for natural ventilation for a major part of the year, provide operable windows.

20. In climate zones where outdoor air conditions are close to desired indoor conditions for a major portion of the year, consider the following:

a. Adjust building orientation and configuration to take advantage of prevailing winds.

b. Use operable windows to control ingress and egress of air through the building.

c. Adjust the configuration of the building to allow natural cross ventilation through occupied spaces.

d. Utilize stack effect in vertical shafts, stairwells, etc., to promote natural air- flow through the building.

APPENDIX C

PLANNING[3]

1. Group services rooms as a buffer and locate at the north wall to reduce heat loss or the south wall to reduce heat gain, whichever is the greatest yearly energy user.
2. Use corridors as heat transfer buffers and locate against external walls.
3. Landscaped open planning allows excess heat from interior spaces to transfer to perimeter spaces, which have a heat loss.
4. Rooms can be grouped in such a manner that the same ventilating air can be used more than once, by operating in cascade through spaces in decreasing order of priority, i.e., office-corridor-toilet.
5. Reduced ceiling heights reduce the exposed surface area and the enclosed volume: They also increase illumination effectiveness.
6. Increased density of occupants (less gross floor area per person) reduces the overall size of the building and yearly energy consumption per capita.
7. Spaces of similar function located adjacent to each other on the same floor reduce the use of elevators.
8. Offices frequented by the general public located on the ground floor reduce elevator use.
9. Equipment rooms located on the roof reduce unwanted heat gain and heat loss through the surface. They can also allow more direct duct and pipe runs reducing power requirements.
10. Windows planned to make beneficial use of winter sunshine should be positioned to allow occupants the opportunity of moving out of the direct sun radiation.
11. Deep ceiling voids allow the use of larger duct sizes with low pressure drop and reduces HVAC requirements.
12. Processes that have temperature and humidity requirements different from normal physiological needs should be grouped together and served by one common system.
13. Open planning allows more effective use of lighting fixtures. The reduced area of partitioned walls decreases the light absorption.
14. Judicious use of reflective surfaces such as sloping white ceilings can enhance the effect of natural lighting and increase the yearly energy saved.

APPENDIX D

VENTILATION AND INFILTRATION[4]

1. To minimize infiltration, balance mechanical ventilation so that supply air quantity equals or exceeds exhaust air quantity.
2. Take credit for infiltration as part of the outdoor air requirements for the building occupants and reduce mechanical ventilation accordingly.
3. Reduce C.F.M./occupant outdoor air requirements to the minimum considering the task they are performing, room volume and periods of occupancy.
4. If odor removal requires more than 2000 C.F.M. exhaust and a corresponding introduction of outdoor air, consider re-circulating through activated carbon filter.
5. Where outdoor conditions are close to but less than indoor conditions for major periods of the year, and the air is clean and free from offensive odors, consider the use of natural ventilation when yearly energy trade-offs with other systems are favorable.
6. Exchange heat between outdoor air, intake and exhaust air by using heat pipes, thermal wheels, run-around systems, etc.
7. Provide selective ventilation as needed; i.e., 5 C.F.M./occupant for general areas and increased volumes for areas of heavy smoking or odor control.
8. Transfer air from “clean” areas to more contaminated areas (toilet rooms, heavy smoking areas) rather then supply fresh air to all areas regardless of function.
9. Provide controls to shut down all air systems at night and weekends except when used for economizer cycle cooling.
11. Reduce the energy required to heat or cool ventilation air from outdoor conditions to interior design conditions by considering the following:

    a. Reduce indoor air temperature setting in winter and increase in summer.

    b. Provide outdoor air direct to perimeter of exhaust hoods in kitchens, laboratories, etc. Do not cool this air in summer or heat over 50-F. in winter.

APPENDIX E

HEATING, VENTILATION, AND AIR-CONDITIONING[5]

1. Use outdoor air for sensible cooling whenever conditions permit and when re-captured heat cannot be stored.
2. Use adiabatic saturation to reduce temperature of hot, dry air to extend the period of time when “free cooling” can be used.
3. In the summer when the outdoor air temperature at night is lower than indoor temperature, use full outdoor air ventilation to remove excess heat and pre-cool structure.
4. In principle, select the air handling system, which operates at the lowest possible air velocity and static pressure. Consider high-pressure systems only when other tradeoffs such as reduced building size and duct size are an overriding factor.
5. To enhance the possibility of using waste heat from other systems, design air handling systems to circulate sufficient air to enable cooling loads to be met by a 60°F. air supply
temperature and heating loads to be met by a 90°f. air temperature.
6. Design HVAC systems so that the maximum possible proportion of heat gain to a space can be treated as an equipment load, not as a room load.
7. Schedule air delivery so that exhaust from primary spaces (offices) can be used to heat or cool secondary spaces (halls).
8. Exhaust air from center zone through the lighting fixtures and use this warmed exhaust air to heat perimeter zones.
9. Design HVAC systems so that they do not heat and cool air simultaneously.
10. To reduce fan horsepower, consider the following:

    a. Design duct systems for low-pressure loss.

    b. Use high efficiency fans.

    c. Use low-pressure loss filters concommitant with contaminant removeable.

    d. Use one common air coil for both heating and cooling.

11. Reduce or eliminate air leakage from duct work.
12. Limit the use of re-heat to a maximum of 10% of floor area and then only consider its use for areas that have atypical fluctuating internal loads such as conference rooms.

13. Design chilled water systems to operate with as high a supply temperature as possible – suggested goal – 50° (this allows higher suction temperatures at the chiller with increased operating efficiency).

14. Use modular pumps to give varying flows that can match varying loads.

15. Select high efficiency pumps that match load. Do not oversize.

16. Design piping systems for low pressure loss and select routes and locate equipment to give shortest pipe runs.

17. Adopt as large a temperature differential as possible for chilled water systems and hot water heating systems.

18. Consider operating chillers in series to increase efficiency.

19. Select chillers that can operate over a wide range of condensing temperatures and then consider the following:

   a. Use double bundle condensers to capture waste heat at high condensing temperatures and either use directly for heating or store for later use.

   b. When waste heat cannot be either used directly or stored, then operate chiller at lowest condensing temperature compatible with ambient outdoor conditions.

20. Consider chilled water storage systems to allow chillers to operate at night when condensing temperatures are lowest.

21. Consider the use of double bundle evaporators so that chillers can be used as heat pumps to upgrade stored heat for use in unoccupied periods.

22. Consider the use of gas or diesel engine drive for chillers and large items of ancilliary equipment and collect and use waste heat for absorption cooling, heating, and/or domestic hot water.

23. Locate cooling towers or evaporative coolers so that induced air movement can be used to provide or supplement garage exhaust ventilation.

24. Use modular boilers for heating and select units so that each module operates at optimum efficiency.

25. Extract waste heat from boiler flue gas by extending surface
cells or heat pipes.

26. Select boilers that operate at the lowest practicable supply temperature while avoiding condensation within the furnaces.

27. Use unitary water/air heat pumps that transport heat energy from zone to zone via a common hydronic loop.

28. Consider the use of thermal storage in combination with unit heat pumps and a hydronic loop so that excess heat during the day can be captured and stored for use at night.

29. Consider the use of heat pumps both water/air and air/air if a continuing source of low-grade heat exists near the building, such as lake, river, etc.

30. Consider the direct use of solar energy via a system of collectors for heating in winter and absorption cooling in summer.

31. Minimize requirements for snow melting to those that are absolutely necessary and, where possible, utilize waste heat for this service.

32. Provide all outside air dampers with accurate position indicators and insure dampers are airtight when closed.

33. If electric heating is contemplated, consider the use of heat pumps in place of direct resistance heating as by comparison they consume one-third of the energy per unit output.

34. Consider the use of spot heating and/or cooling in spaces having large volume and low occupancy.

35. Use electric ignition in place of gas pilots for gas burners.

36. Consider the use of a total energy system if the life cycle costs are favorable.

APPENDIX F

LIGHTING AND POWER[6]

1. Use natural illumination in areas where effective when a net energy conservation gain is possible vis-a-vis heating and cooling loads. Provide exterior reflectors at windows for more effective internal illumination.

2. Consider a selective lighting system in regard to the following:

   a. Reduce the wattage required for each specific task by review of user needs and method of providing illumination.

   b. Consider only the amount of illumination required for the specific task considering the duration and character and user preference required as per design criteria.

   c. Group similar tasks together for optimum conservation of energy per floor.

   d. Design switch circuits to permit turning off unused and unnecessary light.

   e. Illuminate tasks with fixtures built into furniture and maintain low intensity lighting elsewhere.

   f. Consider the use of polarized lenses to improve quality of lighting at tasks.

   g. Provide timers to automatically turn off lights in remote or little-used areas.

   h. Use multi-level ballasts to permit varying the lumen output for fixtures by adding or removing lamps when tasks are changed in location or requirements.

   i. Arrange electrical systems to accommodate luminaries, which can be removed to suit changing furniture layouts.

   j. Consider the use of ballasts, which can accommodate sodium metal-halide bulbs interchangeably with other lamps.

3. Consider the use of high frequency lighting to reduce wattage per lumen output. Additional benefits are reduced ballast heat loss into the room and longer lamp life.

4. Consider the use of landscape office planning to improve lighting efficiency. Approximately 25% less wattage per footcandles on task for open planning versus partitions.

5. Consider the use of light colors for walls, floors, and ceilings to increase reflectance, but avoid spectacular reflections.

6. Lower the ceilings or mounting height of luminaires to increase level of illumination with less wattage.

7. Consider dry heat-of-light systems to improve lamp performance and reduce heat gain to space.

8. Consider wet heat-of-light system to improve lamp performance and reduce heat gain to space and refrigeration load.

9. Use fixtures that give high contrast rendition factor at task.

10. Provide suggestions to GSA for analysis of tasks to increase use of high contrast material which requires less illumination.

11. Select furniture and interior appointments that do not have glossy surfaces to give specular reflections.

12. Use light spills from characteristic areas to illuminate non-characteristic areas.

13. Consider use of greeter contrast between tasks and background lighting, such as 8 to 1 and 10 to 1.

14. Consider washers and special illumination for features such as plants, murals, etc., in place of overhead space lighting to maintain proper contrast ratios.

15. For horizontal tasks or duties, etc., consider fixtures whose main light component is oblique and then locate for maximum ES1 foot-candles on task.

16. Consider using 250 watt vapor lamps and metal-halide lamps in place of 500 watt incandescent lamps for special applications.

17. Use lamps with higher lumens per watt input such as:

    a. One 8-foot flourescent lamp versus two 4-foot lamps.

    b. One 4-foot flourescent lamp versus two 2-foot lamps.

    c. U-tube lamps versus two individual lamps.

    d. Flourescent lamps in place of all incandescent lamps except for very close task lighting, such as at a typewriter paper holder.

18. Use high utilization and maintenance factors in design calculations and instruct users to keep fixtures clean and change lamps earlier.

19. Avoid decorative flood-lighting and display lighting.

20. Direct exterior security lighting at entrances and avoid illuminating large areas adjacent to building.

21. Consider switches activated by intruder devices rather than permanently lit security lighting.

22. If already available, use street lighting for security purposes.

23. Reduce lighting requirements for hazzards by:

    a. Use light fixtures close to and focused on hazzard.

    b. Increase contrast of hazzard; that is, paint stair and riser white with black nosing.

24. Consider the following methods of coping with code requirement:

    a. Obtaining variance from existing codes.

    b. Change codes to just fulfill health and safety functions of lighting by varying the qualitative and quantitative requirements to specific application.

25. Consider the use of a total energy system integrated with all other systems.

26. Where steam is available, use turbine drive for large items of equipment.

27. Use heat pumps in place of electric resistance heating and take advantage of the favorable coefficient of performance.

28. Match motor sizes to equipment shaft power requirements and select to operate at the most efficient point.

29. Maintain power as close to unity as possible.

30. Minimize power losses in distribution system by:

    a. Reducing length of cable runs.

    b. Increasing conductor size within limits indicated by cycle costing.

    c. Use high voltage distribution within the building.

31. Match characteristics of electric motors to the characteristics of the driven machine.

32. Design and select machinery to start in an unloaded condition to reduce starting torque requirements. (For example, start pumps against closed valves.)

33. Use direct drive whenever possible to eliminate drive train losses.

34. Use high efficiency transformers (these are good candidates for life cycle costing).

35. Use liquid-cooled transformers and captive waste heat for beneficial use in other systems.

36. In canteen kitchens, use gas for cooking rather than electricity.

APPENDIX G
OPERATION AND MAINTENANCE[7]

1 Heat building to no more than 68°F. in winter when occupied.

2. Heat building to no more than 60°F. when occupied.

3. Cool building to no less than 78°F. when occupied.

4. Do not cool building when it is unoccupied.

5. Schedule morning start-up in winter so that the building is at 63°F. when occupants arrive and warms up to 68°F. over the first hour.

6. Limit pre-cooling start-up in morning to give building temperature of 5°F. less than outdoor temperature or 80°F., whichever is highest.

7. Close outdoor air dampers for the first hour of occupancy whenever outdoor air has to be either heated or cooled.

8. Close outdoor air dampers for the last hour of occupation whenever air has to be either heated or cooled.

9. Turn off heating or cooling 30 minutes before the end of the occupied period.

10. Close outdoor air dampers for 10 minutes in every hour (adjust time period according to experience).

11. Allow humidity to vary naturally in the building between 20% RH and 65% RH. Only add or remove moisture when building conditions exceed those limits.

12. Use cool night air to flush building and remove heat from structure providing energy to run fans is less than that required to run chillers.

13. Select controls that will allow variable differential (suggest 3°F.).

14. Light building for occupied periods only.

15. Turn off lights that are not needed.

16. Schedule cleaning and maintenance for normal working hour or when daylight is available and sufficient for task.

17. Draw drapes over windows or close thermal shutters when daylight is not available and when building is unoccupied.

18. Use economizer cycle whenever waste heat cannot be used or stored and outdoor enthalpy conditions do not impose a load that exceeds the value of cooling saved.

19. Maintain equipment to retain “as new” efficiency.

20. Clean air filters on a regular maintenance schedule.

21. Clean lighting fixtures and change lamps on a regular maintenance schedule to maintain desired lighting levels.

APPENDIX H

DESIGNING AND BUILDING ENERGY CONSERVING HOMES[8]

The significance of the following energy conservation will be shown by stating the actual savings in Btu's per hour. All examples are for a typical one-story, single-family detached home, having 1,600 square feet. The assumed design temperature difference is 70 degrees.

1. Building Type:

Building multifamily buildings reduces heat loss and heat gain. Individual dwellings in condominium buildings, town houses, semi-detached dwellings and apartments in apartment buildings all have less heat loss per square foot of floor area than single-family detached dwellings, other things being equal.

2. Building Shape:

   a. Reducing the ratio of exterior wall area to floor area will reduce energy demand. Theoretically, a two-story, square house has the least heat loss but with R-11 and R-19 insulation used in the walls and ceilings respectively, a one-story home, relatively deep front to back, has essentially the same heat loss as a two-story home.

   b. A one-story home, 32 feet deep by 50 feet long, has 675 Btuh less heat loss than a home having the same area whose dimensions are 24 x 66½ feet. (assuming R-11 wall insulation)

   c. Reducing the wall height in this one-story home from 8 feet to 7 feet 6 inches even with full thick wall insulation will conserve another 400 Btuh.

   d. Avoiding the use of L, T and H shaped dwellings conserves energy. A 24 ft. x 50 ft. house with a 20 ft. x 20 ft. L, has the same area as the 32 ft. x 50 ft. house but has about 1000 Btuh greater heat loss.

3. Reducing Window Area:

   a. The window area of the typical dwelling is probably equal to about 15% of the floor area. This can be reduced under most codes to 10%. In the 1600 square foot example home, this would mean a reduction of 6,300 Btuh if single-glass is used or 3,300 Btuh with double glass or storm sash.

b. When reducing window area, it is preferable to do so by raising the sill height. This has two advantages. First, it keeps the upper portion of the window, which provides better natural illumination. Second, it helps to reduce heat gain in the summer because the upper portion of the window is more easily shaded by overhang. Also, use light color finish for walls, ceilings and floors to enhance the level of natural light.

4. Increasing Window Glazing:

a. If only the minimum glass area of 10% is used, switching from single glass to either double-glazing or storm sash will save 6,200 Btuh and using double
glass and storm sash or triple glazing will save another 2,500 Btuh.

b. Thermal break type metal windows reduce heat loss. Authorities disagree on the amount of heat conducted through the metal sash compared to wood sash, but in any event the thermal break type does reduce heat loss and condensation.

5. Reducing Window Air Infiltration:

a. The quality of windows greatly influences the amount of air infiltration, which, overall, is a major heat loss factor. A poor-fitting window not weather stripped will allow 5½ times as much air infiltration as an average fit window that is weather stripped. In terms of energy the difference is very large, 20,400 Btuh for the example home, even with the minimum 10% glass area. On the other hand, the thermal effect of air infiltration between a poorly-fitted but weather stripped window and an average fit, weather stripped window is much less but still quite significant – a savings in the example of 4,500 Btuh.

b. Storm sash not only reduce heat loss but they also reduce air infiltration – a savings in the example of 3,700 Btuh.

c. In the example home the addition of storm sash would save 9,900 Btuh, about two-thirds due to reducing heat loss directly and the other one-third due to reducing wind infiltration.

d. In the example home, even one-quarter of an air change per hour for infiltration would be equal to 15 times as much air for four people as is necessary to maintain a satisfactory oxygen level. Further, if the house is extremely tight, and no wind persists for a long period of time, odors would build up to the point where people would voluntarily open the windows or doors for a short period of time long before oxygen depletion would be a problem.

6. Reducing Heat Gain Through Windows:

a. The area, location and shading of windows and the use of double-glazing or storm sash are important energy conservation factors for air conditioning.

b. Window glazing – If we assume the example house has 200 square feet of window area (12½ %) and that it is equally distributed on all four sides of the dwelling, the heat gain, (95 M) in the mid-section of the country, is reduced 2,000 Btuh with double glazing or storm windows instead of single glazing.

c. Window area – If the amount of east and west glass is reduced to 10% of the total for each exposure and 40% is used in the north wall and 40% in the south wall, another 2,100 Btuh can be saved, compared to the preceding example, even when double glazing or storm sash is used.

d. Window shading – Shading southern exposure glass with an overhang is an important method of reducing heat gain in the summer without impairing heat gain in the winter. At the 35-degree latitude (North Carolina, Oklahoma, Las Vegas) a 32-inch overhang will completely shade in the summer, floor to ceiling glass having a southern exposure and reduce heat gain 50% on that glass. In the above example, this would save 1,200 Btuh.

e. In high-priced homes where large east or west glass area is essential to the design and shading is not feasible, reflective coating paned glass can cut heat gain as much as 75% on east or west glass.

7. Storm Doors:

Assuming the example house has two regular-size exterior doors the addition of storm doors saves 600 Btuh due just to the increased insulating value of the storm doors.

8. Doors – Infiltration:

A well-fitted door allows as much air infiltration as a poorly fitted double-hung wood window and for wood doors this is doubled due to warpage. Storm doors cut this in half. Thus, storm doors will save 1,400 Btuh due to infiltration reduction and will save a total of about 2,000 Btuh.

9. Reducing Heat Loss Through the Framing:

The use of 24-inch on center wall framing and the adoption of some of the lumber framing techniques set forth in the Manual of Lumber and Plywood Saving Technigues[9] can

reduce heat loss by about 700 Btuh. This is because heat loss through the wood section is greater than through the wood section is greater than through the fully insulated
cavity. This calculation assumes that ½-inch insulation board is used for sheathing.

10. Insulation:

a. Garages and carports can help reduce the energy load. In hot climates, put the attached garages or carports on the east or west walls of the dwelling to shade east or west glass thereby reducing heat gain.

b. If there is a choice, it is thermally advantageous to have the ridge of the house parallel to the east/west axis.

c. If appropriate, use proportionately more glass on the south wall and shade it with the right amount of overhang to reduce heat gain.

d. Occasionally, it is possible to locate the dwelling or windows to take advantage of the shadow cast by existing trees to reduce solar heat gain in the summer.

e. Locating the air conditioning compressor where it will be shaded, particularly in the afternoon, by the house, trees, garage or carport will increase compressor efficiency and reduce energy use.

11. Crawl Space:

a. Using closeable vents (close in winter) and a vapor barrier ground cover if the crawl space is unheated will reduce heat loss even if the floors are insulated.

b. A preferable and more economic design is a heated crawl-space (plenum) with a vapor barrier on the ground and insulation on the perimeter walls rather than in the floor. In the example home, this reduces the area and cost of required insulation by two-thirds, the cost of duct work can be reduced and the people will feel much more comfortable because the mean radiant temperature will be higher. Furthermore, the heat loss will be reduced at least 2,800 Btuh, using R-11 insulation in both cases and taking into account the different design temperatures.

12. Basement Walls:

a. If we assume the example house has a full basement and that the average basement wall exposure above grade is two-feet, the heat loss through the typical 8-inch block wall would be 11,600 Btuh.

b. Adding furring strips and R-3 or masonry wall insulation covered with either gypsum board or 3/8-inch plywood, reduces the heat loss 6,400 Btuh.

c. If 2x2 furring strips are used and R-7 insulation is compressed to 1 ½inches in thickness, another 1,300 Btuh can be saved.

13. Slab-On-Grade:

a. If the example house has a slab-on-grade, the use of one-inch by 12-inch wide edge insulation will save 4,000 Btuh compared to using no insulation.

b. The use of two-inch by 24-inch wide edge insulation will save an additional 2,900 Btuh. If a perimeter hest duct system under the slab is used, the savings using edge insulation are greater.

14. Wall Insulation:

a. Insulation in the walls makes a large difference in heat loss and heat gain. Specifically, in the example, R-7 insulation in the walls, rather than none, save 8,800 Btuh. R-11 insulation instead of R-7 will save another 1,800 Btuh.

b. In usual calculations, these numbers would be 17% higher because the above savings takes into account the difference in heat loss through the wood studs and through the insulation.

c. If 3/4-inch foam polystyrene board is substituted for the t-inch insulation board, the heat loss would be reduced an additional 1,200 Btuh.

15. Ceiling Insulation:

Heat loss through the ceiling using R-11 instead of R-7 insulation in the ceiling reduces heat loss 4,400 Btuh. Using R-19 saves an additional 3,600 Btuh. Using R-22 saves an additional 700 Btuh.

16. Attic Ventilation:

a. Even with insulation having a vapor barrier in the ceiling, good practice requires one square foot of attic insulation area for each 300 square feet of ceiling. Forced mechanical ventilation of the attic space can significantly reduce air temperatures during the summer and thereby decrease air conditioning loads. Sufficient data are not available to pinpoint the required amount of ventilation or the contribution that would make to reducing the heating load. In general, however, 10 to 60 air changes per hour, depending on the humidity, will have a significant temperature reducing effect.

b. In the example home using a 4 in 12 pitch roof, 10 air changes per hour would require a fan having a capacity of 350 cfm and 60 air changes per hour would require a 2,100 cfm fan. The higher number of air changes per hour are necessary in climates having high humidity.

c. It has been estimated that with R-19 insulation in the ceiling and an exhaust fan system thermostatically controlled to maintain a temperature no higher than 100 degrees, the saving in heat gain load would be about 1,500 Btuh where the design temperature is 95 M.

17. Roof Shingle Color:

Even with a well-insulated ceiling the color of the roof does make a difference insofar as heat gain is concerned. In the example home, a light colored roof surface compared to a dark colored roof surface lowers the design energy requirement for cooling by 600 Btuh.

18. Duct Insulation:

a. Try to avoid running ducts through non-thermally conditioned space. If this is not possible, insulate the ducts.

b. In our example home, 2-inch flexible or 1-inch rigid insulation on the duct in non-conditioned spaces will reduce heat loss by about 3,400 Btuh or about 30% compared to the use of 1-inch flexible insulation.

c. For cooling, the 2-inch flexible or 1-inch rigid insulation will save 1,500 Btuh compared to the 1-inch flexible insulation assuming the ducts are in the attic space.

Equipment and Appliances

19. Equipment Size and Efficiency:

Avoid over-sizing equipment. One of the most important energy conservation measures that can be taken is to carefully determine the heat loss and heat gain requirements of the dwelling and install equipment no larger than that required. Oversized equipment results in short periods of operation, poor comfort conditions, lower seasonal efficiency and more energy consumption. Specify air conditioners having high ratios of Btuh/watt.

20. Heat Pumps:

If electricity is the source of energy for heating and the dwelling is to be air conditioned, consider using heat pumps since they use about one-third to two-thirds less energy than electric resistance heating. While the electric resistance heater is 100% efficient in the dwelling, electricity generation and line losses result in overall fuel efficiencies of only about 30 to 35%.

21. Furnace Location:

Require the HVAC subcontractor to install the furnace so that it will be relatively simple for the homeowner to change the filters on warm air furnaces. Clogged filters substantially reduce fuel efficiency both for heating and for cooling.

22. Clock Thermostat:

Consider installing a clock thermostat so that the homeowner can cut back the thermostat at night and have it start automatically in the morning. Reducing the temperature for 8 hours at night by 5 degrees in Chicago will save 7% of the annual heating bill; setting the thermostat back 7½ degrees will save 9%; and setting it back 10 degrees will save 11%. In warm climates like Los Angeles, the percentage savings is more, that is, 12, 14 and 16%, respectively. However, the total savings is higher in the cold climates.

23. Modulating Gas Water Heater:

If gas is used for water heating, consider installing a gas-fired water heater with modulating capacities. They have two burners and overall efficiencies are higher than for the single-burner type.

24. Hot Water Heater Thermostat Setting:

Set the hot water heater temperature to 120 degrees and suggest to the homeowner that he leave it there. If the temperature settings are not marked on the thermostat, 120 degrees may be estimated by assuming that the middle setting is equal to a temperature of about 140 to 150 degrees. 120 degrees is plenty hot for bathing, washing, clothes washing and dishw8shing. The 150-degree setting is not high enough to disinfect dishes or clothes, since that requires 180 degrees for at least 2 minutes. This can save from 20 to 25% of the energy required for the hot water heater – a very important quantity since the hot water heater is the second largest energy user is the home – 13%.

25. Humidifier:

a. Consider using a humidifier, since with higher humidity people feel equally comfortable at a lower air temperature. For example, if the relative humidity is increased from 20% to 60%, equal winter time comfort will be achieved with the air temperature reduced 3 degrees Fahrenheit.

b. A 3-degree lower thermostat setting on the average means about an 8% saving in the energy required for heating.

c. Instruct the homeowners to not operate the humidifier during the summer since it would add to the cooling load.

26. Clothes Dryer:

In most communities, the code does not require venting either a gas or electric clothes dryer. On the average, a clothes dryer uses 1.7% of the total energy required for the dwelling. In the winter, the discharge can be by-passed into the dwelling to save energy except in mild, damp, winter climates. However, better lint filters for most clothes dryers are needed.

27. Range Hoods:

If you provide a range hood, use the recirculating type in cold climates and the exhaust-to-outside-air type in warm climates where the air conditioning load is more important than the heating load.

28. Refrigerators:

a. A side-by-side refrigerator-freezer uses up to 45% more energy than the conventional over-under refrigerator-freezer.

b. Frostless refrigerators use up to 50% more energy than the normal defrost type. This is about 200 Btuh extra energy use. But this is only wasted during summer air conditioning periods.

29. Ovens:

Self-cleaning ovens reportedly require less energy for cooking but have a high energy consumption for cleaning. Microwave ovens claim to use up to 50% less energy than conventional types and generate no unwanted heat.

30. Shower 'Head:

Install a low water-consumption shower head. Studies show that bathing requires 40% of the hot water used in the typical household.

31. Lighting:

a. In the typical dwelling, lighting is the fourth largest energy user, about 3.4% of the total. During the winter, heat loss from lighting is gained in the structure so it is not lost.

b. In the summer, however L it is estimated that lighting adds about 500 to 1,000 Btuh in a typical size dwelling. Not much can be done about this in a typical dwelling in terms of installed capacity, although the use of less general purpose lighting and more specific purpose lighting will tend to cut back the total energy use for lighting.

c. Use fluorescent lamps when possible since they produce nearly four times as much light per watt as does the typical general service light bulb.

d. Do not use recessed or “bullet” lamps that penetrate into non-conditioned space like an attic. All heat from such lamps is lost. They can be a large source of air infiltration and furthermore they are a substantial acoustical short circuit, particularly for airplane noise.

Construction

32. Air Infiltration:

a. When using even modest amount of insulation, the energy load for heating infiltration air can easily be the dominant thermal load factor. In the example home, reducing air infiltration from 2 to 1 air change per hour can save 16,000 Btuh and reducing it to one-half air change per hour can save another 6,000 Btuh.

b. Well fitted and weatherstripped doors, windows, storm sash and exhaust fans will reduce air infiltration.

c. Sill sealer between the top of the foundation wall and the band joist or sill plate in frame construction will reduce air infiltration.

d. Sill sealer or flexible caulking between the bottom exterior wall plate and the floor sheathing.

e. A 1x4 for the bottom wall plate (rather than a 2x4, see Manual of Lumber and Plywood Techniques) is flexible enough in most cases to conform to irregularities in the floor surfaces when nailed at typical intervals.

f. Caulk outside cracks such as at doors and windows.

g. Wrap metal duct joints in non-conditioned spaces with duct tape to minimize leakage, even when they are wrapped with insulation.

h. When sheathing is nailed tight to the framing, air infiltration into the stud space is minimized. Even if the stud space is filled with insulation, air leakage into the space will increase convection and conduction losses that will reduce the thermal efficiency of the wall.

i. For the same reason as above, replace wall sheathing damaged during construction.

j. Ask the Superintendent to pay special attention to avoiding, eliminating or sealing cracks that can allow air to enter the house or the structure.

k. Construction practice to minimize air infiltration will require the same kind of supervision and attention to details and eliminating cracks that is necessary to obtain good acoustical performance, at least until this becomes standard practice of workmen.

33. Grading:

Grade the ground surface around the house so there is an adequate slope for the surface water to drain away from the dwelling. This will help to keep the earth next to the foundation wall drier (and thus warmer) which will reduce heat loss through that wall.

34. Insulation Installation:

a. Good insulation installation will reduce heat loss and heat gain. It is suggested that the insulation installer and Superintendent refer to the Insulation Manual for Homes and Apartments.[10]

b. Extend the ceiling insulation over the top of the top plate.

c. Insulate behind the band joist.

d. Insulate soffits of cantilevered floor construction.

e. Stuff all cracks around doors and windows and small odd-shaped cavities with insulation and staple polyethylene (vapor barrier) over these areas.

f. Cut batts to fit narrow spaces between studs and leave enough surplus to staple the flanges.

g. Put insulation behind pipes, wires and electrical outlet boxes in outside walls.

h. Butt the ends of batts tight against each other.

APPENDIX I

LIFE-CYCLE COSTING[9]

The concept of life-cycle (or long-term) costing embraces the total cost of owning a building throughout its assumed useful life. It differs from the traditional concept, expressed in conventional lump-sum bidding, of focusing exclusively on first cost as the sole economic criterion for comparing construction alternatives. For accurate comparison of alternatives, you must reduce costs to a common basis. Normally, this is the total annual cost comprising (a) amortization for the capital investment, plus (b) operating and maintenance (O & M) cost, plus such potential annual variables as insurance premiums or real estate taxes, if they differ for the compared alternatives. Another, less frequently used basis, is total lifetime cost, reduced to a "present-worth" basis.

Using one or the other of the foregoing basis, you can compute life-cycle cost through one, or all, of the following basic techniques:

1. Benefit-cost analysis
2. Time-to-recoup investment
3. Direct comparison of long-term owning cost

Benefit-cost analysis formalizes the decision confronting an owner who must decide whether a capital improvement is economically justified. In more sophisticated applications, a benefit-cost analysis can also provide a rational basis for choosing among alternatives, after the go-ahead decision has been made.

Virtually every decision that one makes entails, at least subconsciously, some form of benefit-cost analysis. We are constantly balancing costs – in time, money, or effort – against benefits – in saved time, or simply in satisfaction. All costs and benefits must be reduced to a monetary value and the ratio computed. If benefits exceed costs – i.e., the benefit-cost ratio exceeds 1 – then the project is economically justified.

The second method, time-to-recoup-capital-investment, merely calculates the time required to recoup the original capital investment through annual O & M saving, which is used to pay the annual debt service required to amortize a loan for the capital investment. If this is less than the estimated useful life of the added building component, then obviously the investment is economically justified.

As the most direct method of life-cycle cost comparison, you can simply reduce all costs to a total annual cost for the useful life of compared alternatives or you can reduce these costs to a total useful life on a present-worth basis.

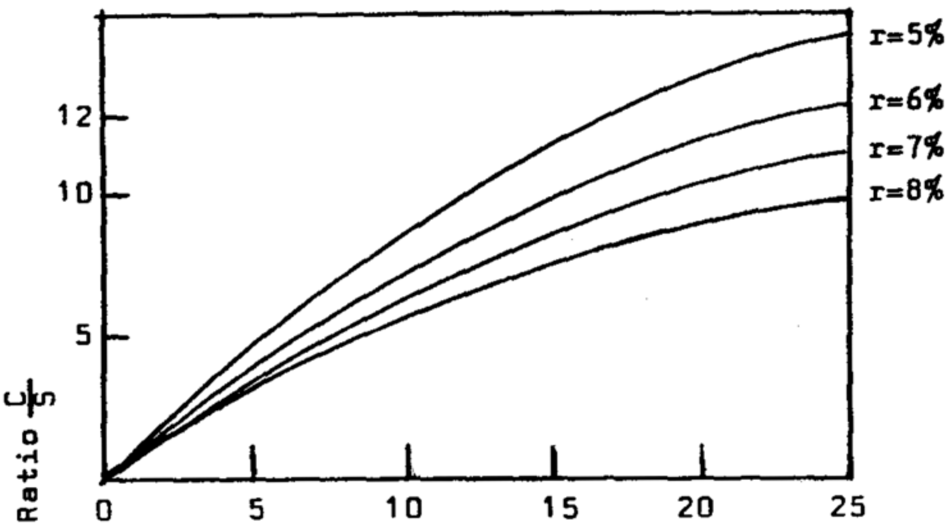
In the simplest case of comparing alternative systems with equal useful lives, the lowest total cost among Systems A, B, C. etc., is simply identified. But when the systems have different useful lives, the problem is obviously complicated. All costs must be reduced to the same useful life and amortization cost reduced to a uniform annual level. Suppose, for example, that a central HVAC system with 20-year useful life is compared with a packaged HVAC system with 10-year useful life. If the packaged HVAC system requires anticipated cost replacement of 70% of its originally installed value after 10 years, the annual cost of a capital-recovery fund necessary to finance that cost over a 20-year useful life can be added to the basic amortization cost to equate comparative costs of a 20-year central system vs. a 10-year packaged system.

The most common error in life-cycle costing involves attempts to compare initial cash investment with annually paid charges. Some prominent firms neglect the interest cost of money. You cannot, for example, claim that a $100,000 additional cash investment is paid off in 10 years if it cuts O & M costs by $10,000. At 6% interest, it takes more than 15 years to recoup the initial investment.

In keeping with this principle, convert future savings to a "present-worth" datum. The present-worth concept reduces future savings to a common datum with current savings. This reduction is necessary because a dollar saved today is worth considerably more than a dollar saved some years from now. (At 6% interest, a dollar saved today is worth more than twice as much as a dollar saved 12 years from now.) The present-worth formula accounts for these future interest losses. Whenever future costs or savings are involved in a lifecycle costing technique, convert these costs to current value by the present-worth formula (shown in a later example.)

Figure 1 Time to Recoup Capital Investment

Graphical Solution



n =Years to recoup capital investment

$$n = \frac{\log\left[\frac{S/rC}{S/rC - 1}\right]}{\log(1 + r)}$$

r =Interest rate

S =Annual O&M saving (=Debt service payment)

C =Additional capital cost

A. Sample benefit/cost analysis

Comparison of alternative HVAC systems

Data:	HVAC System A	HVAC System B
	Total first cost =$1,000,000	Total first cost =$1,100,000

HVAC System B exceeds System A first cost by $100,000

Maintenance	=$ 25,000	Maintenance	=$20,000
Energy	=$ 95,000	Energy	=$70,000
	$120,000		$90,000

HVAC System B's Annual O&M saving =$30,000

Interest rate =6%

Assume a 20-year useful life for both HVAC systems

d =Debt Service Constant Table

Yrs.	Interest rate, r					
n	4.0	5.0	6.0	7.0	8.0	10.0
5	0.2246	0.2310	0.2374	0.24389	0.25046	0.26380
10	0.1233	0.1295	0.1359	0.14238	0.14903	0.16275
15	0.0899	0.0963	0.1030	0,10979	0.11683	0.13147
20	0,0736	0,0802	0,0872	0,09439	0.10185	0.11746
25	0,0640	0.0709	0,0782	0,08581	0,09368	0,11017
30	0.0578	0,0651	0,0726	0.08059	0.08883	0.10608
40	0.0505	0.0583	0.0665	0.07501	0,08386	0,10226

d =Debt sevice constant, a factor that multiplied by the total loan amount, or total principal, yields the annual debt service payment, D, (principal + interest) required to amortize the loan.

$$d = \frac{R(1 + r)^n}{(1 + r)^n - 1}$$

in which r =interest rate

n =number of years to repay loan

From the Debt 5ervice Constant Table, d (for 6% interest and 20-year payment period) = .0872.

D =.0872 x \$100,000
=\$8,720 (additional amortization cost)

$$\text{Benefit-cost ratio} = \frac{\text{Annual O\&M Saving}}{\text{Additional Amortization Cost}}$$

$$\text{Benefit-cost ratio} = \frac{\$30,000}{8,720}$$

= 3.4 (a tremendous advantage for System B)

Now assume that the estimated O&M costs of the compared systems are considered so uncertain that a 0.7 correction factor must be applied.

$$\text{Benefit-cost ratio} = 0.7 \times \frac{\$30,000}{8,720}$$

= 2.4 (still a tremendous advantage for System B)

B. Time to Recoup Investment

To find out how long it would take to recoup the additional 1100,000 capital cost investment required for System B, assume that the entire 130,000 annual O&M cost saving is applied to paying off a loan for 1100,000 for n years at 6% interest.

$$n = \frac{\log\left[\frac{S/rC}{S/rC - 1}\right]}{\log(1 + r)}$$

in which C =additional capital cost ($100,000)

S =annual O&M saving ($30,000)

r =.06 (interest rate)

n =number of years off to pay capital debt with an annual debt service payment equal to S ($30,000)

$$n = \frac{\log\left[\frac{\$30{,}000/.06 \times \$100{,}000}{(\$30{,}000/.06 \times \$100{,}000) - 1}\right]}{\log(1 + .06)}$$

$$n = \frac{\log 1.25}{\log 1.06}$$

$$= \frac{.09691}{.02531}$$

$$= 3.84 \text{ years}$$

For a simple graphical solution to such problems, use the chart (Figure 1). 5imply compute the ratio, C/S, and find its intersection with the curve for the correct interest rate. The graph will present solutions of more-than-sufficient accuracy for most practical problems.

C. Total Longterm Saving

HVAC System A

Annual O&M Cost	=$120,000
Amortiz. =.0872 x $1,000,000	= 87,200
Total annual cost	=$207,200

HVAC System B

Annual O&M Cost	= $90,000
Amortiz. =.0872 x $1,100,000	= 95,000
Total annual cost	=$185,900

Difference =$207,200 - $185,900
=$ 21,300

$S\left[\frac{(1 + r)^n - 1}{\ }\right]$

Present worth of 20-year Difference $= \quad r(1 + r)^n$

$$= \$ \ 21{,}300 \left[\frac{(1 + .06)^{20} - 1}{.06(1 = .06)^{20}} \right]$$

$$= \$ \ 21{,}300 \times 11.47$$

$$= \$244{,}000$$

Note that the present worth saving totals just a little over half the $426,000 saving computed by simply multiplying the annual saving by the useful life. Because of the value of interest, present worth is the only valid way to compute anticipated future savings.

D. Cost Saving with Rising Energy Cost

Assume that energy costs continue rising at an annual rate of 8% (geometric progression). What would be the total 20-year saving?

If energy cost rises at a rate of f percent annually, the following formula holds:

$$\text{Present worth of total energy cost} = F \frac{a(a^n - 1)}{a - 1}$$

in which F =Original (year 0) annual energy cost

f =annual rate of fuel increase, starting with first year's cost F(1 + f)

n =number of years (20)

r =interest rate (.06)

$$a = \frac{1 + f}{1 + r} = \frac{1 + .08}{1 + .06} = 1.02$$

$$\frac{a(a^n - 1)}{a - 1} = \frac{1.02(1.02^{20} - 1)}{1.02 - 1}$$

$$= 24.73$$

System A

Energy cost	=$95,000 x 24.73	=$2,350,000
Maintenance	=$25,000 x 11.47	= 290,000
First cost	=	1,000,000
		3,640,000

System B

$70,000 x 24.73 =$1,730,000

20,000 x 11.47	=	230,000
		1,100.000
		$3,060,000

Present worth of 20-year cost saving for System B =$580,000

E. Life-cycle Costing with Partial Replacement Cost

Problem: Compare the life-cycle costs of two alternative HVAC systems with 20-year life. System X, however, requires replacement of 50% (by cost) of the equipment in 10 years.

Data:	HVAC System X	HVAC System Y
	First cost =$70,000	First cost =$100,000
	O&M cost =12,000 per annum	O&M cost =10,000 per annum

Problem analysis: The simplest way to approach this problem is via the present-worth formulas. For System X, we face an additional 0.50 x 70,000 =$35,000 investment at the end of year 10. What is the current value i.e., present worth of the sum that invested for 10 years would yield $35,000 at the end of 10 years?

Solve by the compound-interest formula:

$$PW\ (1 + r)n = \$35{,}000$$

$$PW = \frac{\$35{,}000}{(1 + .06)}10$$

$$= \frac{\$35{,}000}{1.7908}$$

$$= \$19{,}500$$

HVAC System X

Final cost	=$ 70,000
PW, O&M cost = 12,000 x 11.47	= 137,500
Added 10-year replacement	= 19,000
	$227,000

HVAC System Y

Final cost	=$100,000
PW, O&M cost = 10,000 x 11.47	= 114,700
	$214,700

System Y is roughly $12,000 less costly than System X on a 20-year present-worth basis.

The problem can also be handled with a total annual cost comparison. After computing the PW of the replacement cost, you can simply add this $19,500 sum to the $70,000 first cost to get a total equivalent first cost for System X.

HVAC System X

First cost = .0872 x 89,500	=$ 7,800
O&M	= 12,000
	$19,800

HVAC System Y

.0872 x 89,500	=$ 8,720
	= 10,000
	$18,720

On a total annual cost basis, System Y is nearly $1,100 less.

FOOTNOTES

[1]Dublin-Mindell-Bloome, pp (10-4) – (10-5)

[2]Ibid., pp. (10-6) – (10 – 12)

[3]Ibid., pp. (10-13) – (10 – 14)

[4]Ibid., pp. (10-15) – (10 – 16)

[5]Ibid., ., pp. (10-17) – (10 – 21)

[6]Ibid., ., pp. (10-22) – (10 – 27)

[7]Ibid., ., pp. (10-33) – (10 – 35)

[8]Ralph J. Johnson, Designing and Building Energy Conserving Homes, Report for NAHB Annual Convention, (Houston, Texas, January 21, 1974), pp. 2-20

[9]Available from NAHB Research Foundation, Inc., P.O. Box 1627, Rockville, Maryland 20850

[10]Ibid.

[11]Griffin, pp. 162-169

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