

ENERGY CONSERVATION IN RESIDENTIAL CONSTRUCTION: DAVIS, CALIFORNIA

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Recent events such as the New York City blackout, the oil embargo and the bitterly cold winter of 1977 have made society aware of the extent of its energy consumption and dependence.¹ The energy crisis can no longer be viewed as a temporary emergency situation, but rather, must be recognized as a fundamental condition of modern life. The critical shortage of energy stems, in part, from increasing energy demands and, in part, from a basic change in the character of energy use from abundant cheap energy to scarce expensive energy.² Thus, given this fact of modern society, energy scarcity has become an important component in all aspects of planning.³

The city of Davis, California, passed one of the first energy conservation ordinances for residential construction in the fall of 1975. This Note will examine the Davis ordinance in detail and some of the problems inherent in reforming building regulations to include energy conservation alternatives.

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1. Nordhouse, *The Allocation of Energy Resources*, in BROOKING PAPERS ON ECONOMIC ACTIVITY iii (1973). See also G. CRAWLEY, *ENERGY* (1975).

2. AMERICAN INSTITUTE OF ARCHITECTS, *ENERGY & THE BUILT ENVIRONMENT: A GAP IN CURRENT STRATEGIES 2* (1974) [hereinafter cited as *AIA CURRENT STRATEGIES*]. See also Lees, *Why the Energy Crunch Came in 1970's*, in *FOREIGN POLICY IMPLICATIONS OF THE ENERGY CRISIS* 51 (Sept.-Oct. 1972).

3. Present United States energy policy relies extensively upon nuclear power. JOINT COMM. ON ATOMIC ENERGY, *UNDERSTANDING THE NATIONAL ENERGY DILEMMA* (1973). See D. RAY, *ATOMIC ENERGY COMM'N, THE NATION'S ENERGY FUTURE: A REPORT TO RICHARD M. NIXON PRESIDENT OF THE UNITED STATES* (1973); M. SEIDEL, S. PLOTKIN, & R. RECK, *ENERGY CONSERVATION STRATEGIES*, ENVIRONMENTAL PROTECTION AGENCY R5-73-021 (July 1973).

I. ENERGY CONSERVATION AS AN ALTERNATIVE

Until recently, energy policy has failed to recognize the potential impact of conservation as an alternative energy strategy.⁴ The objective of energy conservation is the optimal efficiency of energy use, rather than an absolute reduction in energy demand and consumption.⁵ The inefficient use of energy in the man-made environment of today's buildings, highways and cities has a greater impact on energy consumption, and therefore the greatest potential for energy savings, than any other major component of the economy, except transportation and the military.⁶ A program of energy conservation in construction, both commercial and residential, could save the equivalent of more than twelve and a half million barrels of oil per day.⁷ Energy conservation becomes even more attractive because this potential reduction in energy consumption would yield significant annual savings.⁸ Furthermore, energy conservation requires no additional technology,⁹ produces little pollution and would not involve greater proportional energy use in

4. *E.g.*, ENERGY RESEARCH & DEVELOPMENT ADMINISTRATION, A NATIONAL PLAN FOR ENERGY RESEARCH, DEVELOPMENT & DEMONSTRATION: CREATING ENERGY CHOICES FOR THE FUTURE (1975).

5. AIA CURRENT STRATEGIES, *supra* note 2, at *a*. For example, thermal comfort depends more on cultural attitudes and comfort expectations than physical needs. Corr & Macheod, *Home Energy Consumption as a Function of Life-Style*, in 3 ENERGY AND HUMAN WELFARE 119, 119-21 (B. Commoner, H. Boksenbaum & M. Corr eds. 1975).

It is interesting to note that most energy is degraded in the energy production process into low-level heat which is not readily convertible and recoverable into more usable forms of energy. For example, electricity is produced so inefficiently that 70% of its energy input is lost as waste heat at the power plant. This inefficiency is even greater because electricity at the point of use is usually replaceable with another fuel or energy source. Electricity is a very specific energy form and its use should be confined to those applications which are uniquely dependent upon electricity, such as lighting and the operation of most appliances and machinery. Coal is burned to produce steam, which in turn produces electricity, which is used in residential buildings for space and hot water heating—uses which are not electricity specific and which could be accomplished with greater efficiency using direct combustion of the fossil fuel source. Socolow, *Energy Conservation in Housing: Concepts & Options*, in FUTURE LAND USE 311, 311-15 (R. Burchell & D. Listokin eds. 1975).

6. Stein, *Energy Use in Architecture and Building*, in 3 ENERGY AND HUMAN WELFARE 44 (B. Commoner, H. Boksenbaum & M. Corr eds. 1975) [hereinafter cited as Stein].

7. AMERICAN INSTITUTE OF ARCHITECTS, A NATION OF ENERGY EFFICIENT BUILDINGS BY 1990, at 3 (1974) [hereinafter cited as AIA ENERGY EFFICIENT BUILDINGS].

8. *E.g.*, Marcovich, *Autonomous Living in the Ouroboros House*, POPULAR SCIENCE 80 (Dec. 1975); Price, *Low-Technology Solar Homes That Work with Nature*, POPULAR SCIENCE 95 (Dec. 1976).

9. *E.g.*, Marcovich, *Autonomous Living in the Ouroboros House*, POPULAR SCIENCE 80 (Dec. 1975); Price, *Low-Technology Solar Homes That Work with Nature*, POPULAR SCIENCE 95 (Dec. 1976).

buildings.¹⁰ Energy conservation is, therefore, as significant an energy strategy as the development of conventional sources of energy.¹¹

High utility bills and shortages of energy resources such as natural gas, oil and electricity have sensitized both the consumer and the designer to the need for energy conservation.¹² A program of energy conservation in construction would produce energy¹³ and capital¹⁴ savings at all levels of the design and construction process, which would in turn generate savings throughout the economy.¹⁵ Energy conservation in design and its incorporation into commercial and residential construction would reduce maintenance or operational¹⁶ costs.¹⁷ Effective implementation of an energy conservation program, however, will require a significant change in the application of existing technology.¹⁸ Furthermore, the primary obstacles to these changes will be institutional and legal rather than technological.¹⁹

10. AIA CURRENT STRATEGIES, *supra* note 2, at 13.

11. AIA ENERGY EFFICIENT BUILDINGS, *supra* note 7, at 3.

12. Homeowners are receiving and paying monthly fuel and electricity bills sometimes twice as much as those of previous years. The cost of residential heating and cooling makes up an increasingly large percentage of the costs of homeownership since such dollars have no possibility of producing any return as an investment. The possibility of energy savings in existing residences is increased not only because most homes are inadequately insulated but also because a large percentage of existing homes were built before home air conditioning became widely used (which required that homes be better insulated). S. PETERSEN, CENTER FOR BUILDING TECHNOLOGY, INSTITUTE FOR APPLIED TECHNOLOGY, NATIONAL BUREAU OF STANDARDS, U.S. DEP'T OF COMMERCE, RETROFITTING EXISTING HOUSING FOR ENERGY CONSERVATION: AN ECONOMIC ANALYSIS 6 (Building Science Series 64, 1974).

13. Stein, *supra* note 6, at 46-50.

14. AIA ENERGY EFFICIENT BUILDINGS, *supra* note 7, at 3. For a provocative discussion of capital scarcity in relation to energy scarcity, see B. COMMONER, *THE POVERTY OF POWER* (1976).

15. Stein, *supra* note 6, at 46-50. For example, aluminum requires five times more energy per pound to produce than does steel. Aluminum is not replaceable pound for pound with steel in all uses but if steel were utilized whenever possible such substitution would result in tremendous energy savings in the manufacture of building materials. Aluminum would then be used only whenever its special properties were required, rather than in nonspecific applications. *Id.* at 50.

16. Operational costs are those service costs which are necessary to make the building envelope or physical structure habitable and include services such as heating, lighting, air-conditioning, and ventilation.

17. Stein, *supra* note 6, at 51-60; Wellesley-Miller, *Fuel Prices and Energy Technology: A Look at the Future*, in *FUTURE LAND USE* 247, 266-77 (R. Burchell & D. Listokin eds. 1975).

18. AIA CURRENT STRATEGIES, *supra* note 2, at 12-13.

19. Socolow, *supra* note 5.

An effective program of energy conservation in construction may involve several approaches of varying scope and complexity. One approach would focus on the building itself as a discreet unit. Building regulations or guidelines aimed at the prevention of energy loss or gain through the physical structure of the building would require additional insulation, weather-stripping, the restriction of window area, thermal windows and interior shading.²⁰ Additional building regulations would require more than minimal structural changes and include the use of more efficient building service systems, such as energy-efficient heating, ventilation, lighting, air-conditioning and internal transportation.²¹ Other regulations might specify the use of less energy-intensive building materials or certain architectural features such as foyers.²²

Another more radical approach to energy conservation in construction emphasizes the self-sufficiency of the individual structure and provides for the eventual substitution of on-site (*i.e.*, solar) for off-site or conventional energy sources.²³ This approach contemplates a fundamental change in energy production rather than energy performance.

Going beyond the single building, energy conservation in planning on the community or regional scale would require substantial changes in land use regulations.²⁴ For example, conventional subdivision regulations, zoning, siting restrictions and building codes will be affected by the need for energy conservation in the community.²⁵

The most practical approach to energy conservation programs combines energy conservation in the design and construction of new buildings with a program of retrofitting or rehabilitating existing structures to make them more energy efficient.²⁶ It is important to emphasize that

20. Such modifications are made to the "building envelope," which refers to those external surfaces or areas which allow the transfer of heat into or out of a building, and include the roof, exterior walls, windows and doors, and the foundation.

21. Moskow, *An Experiment in a Total Energy System*, HUD CHALLENGE 23-25 (June 1974); Wellesley-Miller, *supra* note 17, at 268-73.

22. Stein, *supra* note 6, at 45-60.

23. AIA CURRENT STRATEGIES, *supra* note 2, at 13-15. A self-sufficient building would import that minimum amount of energy required to fill its energy needs after it utilizes the energy available at the site and would emit minimum waste and pollution into the outside environment by first recycling such energy internally. *Id.*

24. See C. HARWOOD, *ENERGY CONSERVATION IN LAND USE* (1977).

25. *Id.* See also R. EISENHARD, OFFICE OF BUILDING STANDARDS AND CODES SERVICES, CENTER FOR BUILDING TECHNOLOGY, INSTITUTE FOR APPLIED TECHNOLOGY, NATIONAL BUREAU OF STANDARDS, U.S. DEP'T OF COMMERCE, BUILDING ENERGY AUTHORITY AND REGULATIONS SURVEY: STATE AUTHORITY (No. 76-986, 1976).

26. Most legislation has been directed to energy conservation in new building through building codes. *E.g.*, DEP'T OF GENERAL SERVICE, DIVISION OF BUILDING CONSTRUCTION

energy efficient *design* is critical, and that the mere incorporation of energy conservation features or construction techniques alone is insufficient to realize maximum savings in energy consumption.

II. BUILDING CODES: FRAMEWORK FOR IMPLEMENTATION OF ENERGY CONSERVATION IN BUILDINGS

Municipal building codes regulate the design, materials and methods of construction and, as such, define the range of permissible construction possibilities within their jurisdiction.²⁷ In discussing energy conservation, the question arises whether building codes will hinder or serve as a useful framework for the effective implementation of an energy conservation program of building. Building codes are usually the product of local legislation, and are enacted under the general police power of the state to protect the public health and safety.²⁸ In general, building codes specify minimum safeguards considered necessary for the reasonable protection of the public.²⁹

An initial consideration in drafting building codes involves the choice between specification or prescription codes and performance

& MAINTENANCE, FLORIDA ENERGY CONSERVATION MANUAL (March 1975); MINNESOTA DEP'T OF ADMINISTRATION, BUILDING CODE DIVISION, STATE BUILDING CODE §§ 6001-6013 (1975) (effective Jan. 30, 1976) (uses alternative calculation method); OHIO DEP'T OF INDUSTRIAL RELATIONS, BOARD OF BUILDING STANDARDS, OHIO BUILDING CODE § BB-48-05 (1970) (effective June 1, 1975) (modified energy budget approach).

See also GENERAL SERVICES ADMINISTRATION, PUBLIC BUILDING SERVICE, ENERGY CONSERVATION DESIGN GUIDELINES FOR OFFICE BUILDINGS (1974); GENERAL SERVICES ADMINISTRATION, PUBLIC BUILDING SERVICE, ENERGY CONSERVATION GUIDELINES FOR EXISTING OFFICE BUILDINGS (1975); GENERAL SERVICES ADMINISTRATION, PUBLIC BUILDING SERVICE, ENERGY CONSERVATION GUIDELINES FOR NEW OFFICE BUILDINGS (1975).

27. W. VALENTE, LOCAL GOVERNMENT LAW: CASES & MATERIALS, 479 (1975).

28. *Id.* *See* D. MANDELKER, MANAGING OUR URBAN ENVIRONMENT, 95-143 (2d ed. 1971).

29. Thompson, *The Principal Trend in Building Codes & Its Impact on the Training of Administrators*, 1 CODE ADMIN. REV. 34, 37 (1973). The specific provisions of building codes, however, are essentially political. S. REP. NO. 829, 66th Cong., 3d Sess. 21 (1921).

Most building codes are adaptations of a model code which has been developed by professional associations of building inspectors, industry advisors and code administrators, with the assistance of advisory committees of engineers, designers and materials manufacturers. There are four major model codes: Basic Building Code (Building Officials and Code Administrators/BOCA), Uniform Building Code, National Building Code and the American Institute of Architects Standard Building Code. Insurance companies and private technological associations also draft regulations within their particular areas of expertise. *E.g.*, AMERICAN INSURANCE ASS'N, NATIONAL BUILDING CODE (1967); BUILDING OFFICIALS & CODE ADMINISTRATORS, INTERNATIONAL, INC., BASIC BUILDING CODE (1970); INTERNATIONAL CONFERENCE OF BUILDING OFFICIALS, UNIFORM BUILDING CODE (1973). California has adopted the Uniform Building Code with some modification. CAL. ADM. CODE, tit. 24 (Building Regulations).

codes.³⁰ A specification or prescription code³¹ establishes minimum requirements for materials, building systems, design features, and construction techniques. In contrast, performance codes³² establish minimum levels of performance for individual building components or for the entire building without any restriction as to specific materials, design features and construction methods. Thus, these performance codes utilize a *procedure* of compliance, rather than specifying fixed lists of materials and methods to be used in construction. Therefore, performance codes are more flexible and less susceptible to administrative abuse than are specification codes.³³

Generally, performance codes are favored by architects and engineers because the flexibility in compliance allows greater freedom for the exercise of professional judgment and adaptation to the specific needs of a particular project. Effective use of performance codes depends upon the availability of evaluating techniques and the determination of performance values.³⁴ Admittedly, the identification of performance needs and their quantification remains theoretical³⁵ and further research is necessary to develop performance criteria for different types of buildings in the various climates and regions of the country. Thus, performance codes are frequently supplemented by specification provisions.

The approach of both performance codes and specification codes is used in drafting energy conservation programs in construction. Energy budgets,³⁶ which stem from performance codes, do not dictate any

30. UNITED STATES ADVISORY COMM'N ON INTERGOVERNMENTAL RELATIONS, BUILDING CODES: A PROGRAM FOR INTERGOVERNMENTAL REFORM 54 (1966) [hereinafter cited as ACIR REPORT].

31. *Id. E.g.*, FEDERAL HOUSING ADMINISTRATION, ARCHITECTURAL MINIMUM PROPERTY STANDARDS (1963) (Architectural Standards Division Guideline Criteria).

32. BUILDING RESEARCH ADVISORY BOARD, NATIONAL BUREAU OF STANDARDS, ECONOMIC & OTHER IMPLICATIONS OF PERFORMANCE BUILDING CODES (draft, 1965); CLAIBORNE, FUNDAMENTAL PRINCIPLES OF BUILDING CODE PERFORMANCE REQUIREMENTS, 2 CODE ADMIN. REV. 23, 24 (1974).

33. Wright, *Performance Criteria in Building*, 224 SCIENTIFIC AMERICAN 16 (March 1971).

34. *Id.*

35. ACIR REPORT, *supra* note 30, at 60.

36. Thompson, *Design Features, Shading, and Orientation for Energy Conservation*, ECP REPORT 1, 3 (Sept. 1976) (to be published as G. THOMPSON, ENERGY CONSERVATION AND BUILDINGS). *E.g.*, DEP'T OF GENERAL SERVICES, DIVISION OF BUILDING CONSTRUCTION AND MAINTENANCE, FLORIDA ENERGY CONSERVATION MANUAL (1975) (implementation guidelines for Florida Energy Conservation in Buildings Act, ch. 187, 1974 Fla. Laws); GENERAL SERVICES ADMINISTRATION, PUBLIC BUILDINGS SERVICE, ENERGY CONSERVATION GUIDELINES FOR NEW OFFICE BUILDINGS 1-2 (1975).

particular method of compliance. Rather, such energy budgets impose an upper limit of energy consumption per square foot which varies according to the type of building to be constructed. The success of an energy budget depends upon the selection of a maximum figure of energy consumption. The figure must be both realistic and, at the same time, low enough to initiate change and innovative design.³⁷ This technological limitation is the most significant drawback to the successful use of energy budgets.³⁸

An alternative method of forcing the consideration of energy conservation in construction, based on the approach of specification codes, is to require that certain design features be included in every building.³⁹ The required design specifications vary according to the type of building as well as the climate in which the structure is located. For example, exterior shading⁴⁰ increases energy efficiency in both residential and commercial buildings. Typically, building permits or zoning regulations⁴¹ will be conditioned upon proof of energy performance or incorporation of mandatory design specifications.

Although building codes are the most obvious way to encourage the construction of energy efficient buildings,⁴² they are frequently arbitrary,⁴³ and their jurisdiction is fragmented⁴⁴ and protective.⁴⁵ Furthermore, building code provisions necessarily reflect the existing technology and conventional application of that technology. Protective provisions discourage the development of new materials and methods as

37. Thompson, *supra* note 36, at 3-4.

38. *Id.* at 8.

39. *Id.*

40. *E.g.*, E. DANZ, SUN PROTECTION: AN INTERNATIONAL ARCHITECTURAL SURVEY 6 (1967).

41. *E.g.*, Davis, Calif., Ordinance No. 784 (Oct. 15, 1975); McGregor, *Davis, California Implements Energy Building Code*, 6 PRACTICING PLANNER 24 (No. 1, 1976).

42. Energy conservation in new and existing construction appears even more economically attractive when construction costs and operating expenses are analyzed in terms of life cycle costing (LCC). "Life cycle costing is a general name for procurement techniques that consider operating, maintenance and other costs of ownership, as well as the acquisition price. Because energy expenditures constitute an increasingly large portion of the operating costs of many items, LCC represents significant energy conservation potential." Tether, *Purchasing Strategies for Reducing the Direct Consumption of Energy*, 7 ECP REPORT 1, 24 (Sept. 1976).

43. ACIR REPORT, *supra* note 30, at 81.

44. REPORT OF THE NATIONAL COMM'N ON URBAN PROBLEMS, BUILDING THE AMERICAN CITY 7-8, 254 (1968).

45. NATIONAL COMM'N ON URBAN PROBLEMS, SURVEY OF THE ADMINISTRATION OF CONSTRUCTION CODES IN SELECTED METROPOLITAN AREAS 3 (Background Paper 28, 1961).

well as prohibit their use.⁴⁶ For example, such provisions may effectively prevent the rapid incorporation of solar energy technology into the residential construction industry.⁴⁷ Even where energy conservation techniques have been demonstrated to be economically feasible, the organization of the construction industry⁴⁸ makes it particularly resistant to technological change.⁴⁹ The time lag between the development of technology and its eventual inclusion in building codes⁵⁰ is prolonged by the fragmented state of the construction industry and the absence of consumer organization.⁵¹ Therefore, what is necessary is a comprehensive analysis of the relationship between architecture, energy use and actual construction.⁵²

III. DAVIS, CALIFORNIA: ENERGY GLUTTON

In the early 1970's, the city of Davis, California, commissioned a research study to look into the possibility of adopting an energy conservation building ordinance.⁵³ The study concluded that Davis was an "energy glutton" which consumed natural gas and electricity at a rate which was thirty percent greater than the national average, despite the favorable mild climate.⁵⁴ The study found that the poor design and

46. For example, California recently passed a state law regulating the manufacture and construction of factory-built housing units which specifically permit the use of approved units throughout the state and exempts such use from local building code compliance. CAL. HEALTH & SAFETY CODE §§ 19960-19985 (Deering 1975). See Note, *An Analysis of the Probable Impact of the California Factory-Built Housing Law*, 23 STAN. L. REV. 978 (1971). See also OHIO REV. CODE ANN. § 3781 (Page 1971); PA. STAT. ANN. tit. 35, §§ 1651.1-12 (Purdon 1977); WASH. REV. CODE ANN. § 43.22.485 (Supp. 1976).

47. G. McCUE & W. EWALD, *CREATING THE HUMAN ENVIRONMENT* 213 (Midwest Research Institute 1970); Hirschberg & Schoen, *Barriers to the Widespread Utilization of Residential Solar Energy: The Prospects for Solar Energy in the U.S. Housing Industry*, 5 POLICY SCIENCES 453 (1974).

48. ACIR REPORT, *supra* note 30, at 60; BUILDING THE AMERICAN CITY, *supra* note 44, at 254-55. The housing construction industry has been characterized as small-scale, fragmented and local. *Id.*

49. Hirschberg & Schoen, *supra* note 47.

50. BUILDING THE AMERICAN CITY, *supra* note 44, at 254-55.

51. Rivkin, *Courting Change: Using Litigation to Reform Local Building Codes*, 26 RUTGERS L. REV. 774, 781 (1973).

52. Stein, *supra* note 6, at 46. See also Stein, *Architecture & Energy*, 139 ARCHITECTURAL FORUM (No. 1, July-Aug. 1973).

53. The ordinance subsequently enacted was based on the recommendations of the report, J. HAMMOND, M. HUNT, R. CRAMER, & L. NEUBAUER, *A STRATEGY FOR ENERGY CONSERVATION 9-17* (Energy Conservation Ordinance Report 1974) [hereinafter cited as STRATEGY REPORT].

54. *Id.* at 19. In countries where energy has not been so cheap or as available for heating and cooling in buildings as in the United States, such as in underdeveloped

construction of the buildings and homes in Davis were among the contributing factors in the high level of energy consumption.⁵⁵

The ordinance was enacted in the fall of 1975.⁵⁶ The primary focus of the ordinance was new residential construction, based on the conclusion of the study that residential energy demand represented the fastest growing factor in the city's energy demand.⁵⁷ The city council had been concerned about the possibility of a major energy shortfall, rapidly rising energy costs⁵⁸ and the increasing burden imposed on lower and moderate income families by high utility bills.⁵⁹ Although California had recently adopted state standards for energy and noise insulation,⁶⁰ the ordinance concluded that the state standards were inadequate to meet the special needs of Davis.⁶¹

Since the need for supplemental energy for heating and air-conditioning would be substantially reduced if residential structures were designed to take advantage of Davis' summer seabreezes and winter

countries or where the climate is particularly severe, both architecturally and non-architecturally designed buildings (products of the particular culture rather than an architect) exhibit a much more sensitive approach to the demands of climate on buildings and its use. Modern architecture has increasingly moved away from any kind of conscious relationship with the surrounding climate or site conditions and instead toward the development and installation of a totally self-contained heating/ventilation/air-conditioning (HVAC) system. Absent air pollution or noise problems which would prevent opening the building to the outside air, sealed buildings represent very expensive operational costs. The building is totally dependent upon internal energy supplies and is divorced from the outside environment. Sealed structures (sealed windows) and inattention to solar radiation effects (no shading or windows) often produce imbalances in the otherwise carefully monitored HVAC system, forcing the system to over-operate. Sealed buildings also represent more massive structures to air currents and lose more hot or cool air.

See generally AMERICAN INSTITUTE OF ARCHITECTS, ENERGY CONSERVATION IN BUILDING DESIGN (1974); CAL. DEP'T OF HOUSING & COMMUNITY DEVELOPMENT, DIVISION OF CODES & STANDARDS, ENERGY DESIGN MANUAL FOR RESIDENTIAL BUILDINGS (1975); B. GIVONI, MAN, CLIMATE & ARCHITECTURE (1969); V. OLGAY, DESIGN WITH CLIMATE (1963); T. ROGERS, THERMAL DESIGN OF BUILDINGS (1964). The thesis of these studies is that energy efficient design must work with the climate, compensating for undesirable factors and utilizing the advantages of a particular climate or area. The climate of a region is unlikely to change due to the construction of a building but the climate will have a profound effect upon the operation and occupants of the buildings.

55. STRATEGY REPORT, *supra* note 53, at 19.

56. Davis, Calif., Ordinance No. 784 (Oct. 15, 1975); Davis, Calif., Ordinance No. 787 (Oct. 15, 1975); Davis, Calif., Resolution No. 1833 (Oct. 15, 1975).

57. Davis, Calif., Ordinance No. 784, § 1(A) (Oct. 15, 1975).

58. *Id.*

59. *Id.*

60. CAL. ADM. CODE, tit. 25, ch. 1, subch. 1, art. V, § 1094 (C) (1974).

61. Davis, Calif., Ordinance No. 784 (Oct. 15, 1975).

sunshine,⁶² the ordinance concentrates on four factors found to be critical to the thermal performance of a building: exterior color, window (glazing) area, window shading and thermal or heat storage capacity.⁶³ The ordinance specifically states that improved thermal performance and greater energy efficiency can be achieved without unduly restricting design freedom, increasing construction costs or developing new technology.⁶⁴

The Davis ordinance is enforced by the city building official in the same manner as is the conventional building code.⁶⁵ No building permit may be issued unless the proposed structure complies with the ordinance.⁶⁶ The ordinance stipulates that variances may be permitted in certain circumstances where the strict application of the ordinance would involve undue hardship or create practical difficulties.⁶⁷ For example, an exception to the maximum allowable area of unshaded glazing may be granted if there are "[o]verriding off-site view considerations which are determined to add appreciable incremental value to the subject property."⁶⁸ In no case, however, will a variance be granted if the structure exceeds present state residential energy conservation standards.⁶⁹

The heart of the city's energy conservation standard is Resolution No. 1833,⁷⁰ the compliance procedure. Thermal performance standards for winter and summer are defined in terms of Total Days Heat Loss and Total Days Heat Gain, respectively.⁷¹ The performance standard may be achieved by one of two alternative methods or "paths". Path I⁷² is a specification or prescription code, whereas Path II⁷³ is a true performance code. All structures are required to meet two additional mandatory standards: all windows and doors must be weather stripped and attic space and exposed pipes must be insulated.⁷⁴

62. *Id.* § 1(E)(1),(2).

63. *Id.* § 1(C).

64. *Id.* § 1(F)(1),(2),(3).

65. *Id.* § 5(A).

66. *Id.*

67. *Id.* § 8(A).

68. *Id.* § 8(E)(1).

69. *Id.* § 8(F).

70. Davis, Calif., Resolution No. 1833 (Oct. 15, 1975).

71. Davis, Calif., Ordinance No. 784, § 3(A),(B) (Oct. 15, 1975).

72. Davis, Calif., Resolution No. 1833, § 4 (Oct. 15, 1975).

73. *Id.* § 5.

74. *Id.* § 3(B)(1),(2),(3).

Path I requires a specific thickness or composite resistance value (R)⁷⁵ of insulating material in all exterior walls, attics, roof, ceilings and suspended floors. Natural or mechanical cross-ventilation is also required.⁷⁶ If all the specifications required by Path I are met, the proposed structure, by definition, complies with the thermal performance standard.⁷⁷ In practice, this means that architects or builders under Path I compliance do not need to preserve calculations of overall thermal performance. The study estimated that this simpler method of compliance would be flexible enough to approve ninety percent of all future construction.⁷⁸

Increasing the insulation of buildings is essential in any program attempting to improve energy efficiency because insulation improves thermal performance by reducing air infiltration and associated heat loss or heat gain.⁷⁹ Relatively simple design features which may significantly reduce heat loss or heat gain include replacing ordinary single-pane windows with thermal or storm windows, installing interior window shutters or draperies, providing exterior shading of windows and installing wood window and door frames.⁸⁰ Construction methods which will improve thermal performance include vapor barriers, thicker studs to accommodate thicker insulation in exterior walls and direct vertical alignment of studs and roof trusses.⁸¹

The most controversial aspect of Part I compliance is the restriction on the allowable window or glazing area.⁸² This restriction is critical to the achievement of improved thermal performance because the window (or door) is the part of the exterior wall which is vulnerable to heat loss and heat gain.⁸³ In fact, over half of the heat loss or gain in most homes occurs through the windows due to the low insulation value of

75. Davis, Calif., Resolution No. 1833, §§ 2(A), 4(A) (Oct. 15, 1975).

76. *Id.* § 4(F).

77. *Id.* § 4.

78. STRATEGY REPORT, *supra* note 53, at 19.

79. Davis, Calif., Resolution No. 1833, § 3(B) (Oct. 15, 1975).

80. *Id.* § 4.

81. U.S. DEP'T OF HOUSING AND URBAN DEVELOPMENT, ENERGY CONSERVATION HOUSES (Little Rock, Ark., HUD Office, outline paper, 1974-75).

82. Davis, Calif., Resolution No. 1833, § 4(D), (E) (Oct. 15, 1975). The maximum window area in the ordinance is approximately the minimum permitted under the FHA minimum property standards. JOINT VENTURE, INC., HERE COMES THE SUN 1981: SOLAR-HEATED MULTI-FAMILY HOUSING 30-31 (Background Report for the American Institute of Architects, U.S. Dep't of Housing and Urban Development, and the National Bureau of Standards, 1975).

83. STRATEGY REPORT, *supra* note 53, at 17.

the glass in windows and excessive air leakage around the window frame.⁸⁴

The ordinance specifically recognizes that the "present [California] state code allows the construction of buildings that will be unfit for human habitation in the event of the interruption in gas or electrical service during one of the frequently occurring hot or cold weather events [because of] its failure to adequately address the heat loss and heat gain considerations of glazing and glazing orientation."⁸⁵ Therefore, the ordinance restricts the area of unshaded glazing in single family residential construction to three percent of the dwelling unit's floor areas.⁸⁶ The *total* permissible glazing area is not fixed but may be increased by several design features: thermal or storm windows, interior and exterior shading and window orientation to the northern exposure.⁸⁷

The Davis ordinance requires special attention to site orientation and window placement. As discussed above, windows not oriented to the north must be shaded⁸⁸ from direct solar radiation on the Summer Design Day, August 21,⁸⁹ and glazing oriented to the southwest and southeast must also be protected from direct sun in the afternoon and morning, respectively.⁹⁰ The ordinance gives examples of acceptable methods of shading: interior and exterior shading that meets certain specific requirements,⁹¹ landscaping and natural plantings⁹² and on-site and off-site obstructions which attenuate eighty percent of the direct solar beam.⁹³

Although Path I will accommodate most residential construction, any building which does not or cannot comply with the specifications of Path I must comply with Path II. Path II is a minimum thermal

84. *Id.* at 17-18. The major problem in the summer is direct heat gain through the window.

85. Davis, Calif., Ordinance No. 784, § 1(F)(2) (Oct. 15, 1975).

86. Davis, Calif., Resolution No. 1833, § 4(E)(1) (Oct. 15, 1975).

87. *Id.* §§ 4(D)(1),(2),(3); 4(E)(2),(3),(4).

88. *Id.* § 4(E)(1).

89. *Id.*

90. *Id.* The shading or sun protection of glazing should not unduly restrict the architect. *E.g.*, DANZ, *supra* note 40.

91. Davis, Calif., Resolution No. 1833, § 4(E)(2),(3) (Oct. 15, 1975).

92. *Id.* § 4(E)(4)(ii).

93. *Id.* § 4(E)(4)(i).

performance standard for the entire structure as a unit and is calculated with reference to heat loss and heat gain on winter and summer design days.⁹⁴ The schedule,⁹⁵ which describes the range of acceptable compliance, is intended to serve only as an approximation of actual thermal performance and to promote the consideration of energy efficiency in the *design* of residential construction.⁹⁶

Path II represents a more sophisticated approach to thermal performance. It is not restricted to certain materials or the efficiency of individual components, but instead focuses upon total thermal performance. Compliance is determined by a series of calculations. The Total Day's Heat Loss cannot exceed the standards set out in Table 2 of the ordinance.⁹⁷ Winter heat loss is determined by the composite resistance (R_t) of the exterior building surface to heat transfer to the outside air from the heated interior surfaces.⁹⁸ Winter heat loss calculations are based upon this formula: $TDHL=(DHL - SHGC)/FA$.⁹⁹ TDHL is Total Day's Heat Loss in BTU's per square foot per day, DHL is Day's Heat Loss in BTU's per day; SHGC is Solar Heat Gain Credit in BTU's per day; FA is the floor area of the particular building.¹⁰⁰

DHL is determined by this formula: $DHL=HL + SHL$.¹⁰¹ The component HL represents the heat loss for all surfaces facing the outside air except the slab on grade; SHL represents the heat loss from the concrete slab floors on grade.¹⁰² SHGC represents the direct use of solar energy and is the lesser of two figures, the Day's Solar Heat Gain (DHSG) or the heat storage capacity of the building (HS).¹⁰³ DHSG is roughly based upon Hour's Solar Heat Gain (HSHG) or the amount of energy transmitted through an area of glazing oriented to a particular direction in one hour¹⁰⁴ and SCV or Solar Climatic Variable which

94. Davis, Calif., Ordinance No. 784, § 3(A),(B) (Oct. 15, 1975). The thermal performance of the building must meet those requirements.

95. *Id.* Table 2.

96. STRATEGY REPORT, *supra* note 53, at 19.

97. Davis, Calif., Ordinance No. 784, Table 2 (Oct. 15, 1975.)

98. Davis, Calif., Resolution No. 1833, § 5(A)(4) (Oct. 15, 1975).

99. *Id.* § 5(A)(2).

100. *Id.*

101. *Id.* § 5(A)(4).

102. *Id.*

103. *Id.* § 5(A)(2).

104. *Id.* § 5(A)(5)(iii).

represents an approximation of possible available sunshine during the winter heating season of November through March in Davis.¹⁰⁵

The thermal performance standard for summer focuses on heat gain. The Total Days' Heat Gain (TDHG) cannot exceed the standards in Table 2 of the ordinance¹⁰⁶ and is based upon this formula: TDHG = (DHG - HS)/FA.¹⁰⁷ Daily Heat Gain or DHG is based upon the weighted sum of calculations of Heat Gain or HG at three or five heat gain calculation hours depending upon the orientation of the building.¹⁰⁸ Heat gain or HG is calculated by combining Heat Gain through windows or glazing (WHG) and Heat Gain through opaque surfaces (OHG).¹⁰⁹ The calculation also takes into account shading by using a shading coefficient (SC),¹¹⁰ cross-ventilation¹¹¹ and the heat storage capacity of the building (HS).¹¹²

The ordinance as enacted, however, is much narrower in scope than the Strategy Report, despite the thermal performance standard in Path II. The study anticipated the residential use of solar energy¹¹³ and included proposals for solar energy tradeoffs.¹¹⁴ A few comparisons between the proposed and enacted ordinance illustrate the compromise that was made. For example, the thermal performance standards in the ordinance are more generous. The Strategy Report recommended a maximum Total Daily Heat Gain (TDHG) of 48 BTU's per square foot per day,¹¹⁵ the ordinance permits from 91 to 118 BTU's.¹¹⁶ In addition, the Strategy Report was more comprehensive because it applied to most construction,¹¹⁷ while the ordinance is applicable only to multiple and single-family detached dwellings.¹¹⁸ Furthermore, the ordinance is restricted to new construction only,¹¹⁹ and thus avoids the problems

105. *Id.* § 5(A)(5)(i).

106. Davis, Calif., Ordinance No. 784, Table 2 (Oct. 15, 1975).

107. Davis, Calif., Resolution No. 1833, § 5(B)(2) (Oct. 15, 1975).

108. *Id.* § 5(B)(4)(a), (b).

109. *Id.* § 5(B)(5).

110. *Id.* § 5(B)(5)(ii).

111. *Id.* § 5 (B)(6).

112. *Id.*

113. STRATEGY REPORT, *supra* note 53, at 34-49.

114. *Id.*

115. *Id.* at 19.

116. Davis, Calif., Ordinance No. 784, Table 2 (Oct. 15, 1975).

117. STRATEGY REPORT, *supra* note 53, at 19.

118. Davis, Calif., Ordinance No. 784, § 3 (Oct. 15, 1975).

119. *Id.*

associated with the retrofitting or rehabilitation of old and existing buildings.¹²⁰ The Strategy Report also investigated the entire pattern of residential energy use¹²¹ and examined alternative transportation systems, energy efficiency standards in home appliances,¹²² complete implementation of solar heating and cooling,¹²³ and potential changes in land use regulation.¹²⁴

CONCLUSION

Building codes can be an effective means to implement an energy conservation program in construction. Conventional but effective energy conservation design features can supplement building codes or readily be incorporated into them. Energy conservation standards should be subjected to cost analysis to determine whether an economically feasible combination of requirements and/or techniques has been provided.¹²⁵ Needless to say, an energy conservation program should be carefully drafted to minimize the possibility of administrative abuse and the imposition of unnecessary costs.¹²⁶

The Davis ordinance has only been in effect for about two years. It is both flexible and specific in its requirements without being restrictive.¹²⁷ The prospect for significant energy conservation is excellent.

120. *E.g.*, PETERSEN, *supra* note 12. *See also* J. COHEN & R. WHITE, ENERGY CONSERVATION IN BUILDINGS: THE NEW YORK METROPOLITAN REGION 25-27 (Environmental Law Institute Occasional Paper Series 1, July, 1975).

121. STRATEGY REPORT, *supra* note 53, at 28-29.

122. *Id.* at 3-8.

123. *Id.* at 39-49. *See also* DIVISION OF SOLAR ENERGY, ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION, NATIONAL PROGRAM FOR SOLAR HEATING & COOLING (1975).

124. STRATEGY REPORT, *supra* note 53, at 28-38.

125. *See* PETERSEN, *supra* note 12, at 41; Socolow, *supra* note 5 at 318. *See also* H. FRAKER & E. SCHORSKE, ENERGY HUSBANDING IN HOUSING: AN ANALYSIS OF THE DEVELOPMENT PROCESS IN A RESIDENTIAL COMMUNITY (Center for Environmental Studies, 1972). Newer residential units demonstrate poor thermal capacity because of poor general design and construction methods rather than specific construction or maintenance problems. The authors concluded that effective energy conservation must combine strategies and attack the *general* poor energy efficiency of buildings.

126. PETERSEN, *supra* note 12, at 41. *See also* LOW-COST, ENERGY EFFICIENT SHELTER FOR THE OWNER AND BUILDER 43-71 (E. Eccli ed. 1975).

127. In addition, the ordinance refers extensively to scientific and technological data. *E.g.*, Davis, Calif., Ordinance No. 784, §§ 1(D), 2 (A)-(B) (Oct. 15, 1975). It also includes an extensive research bibliography. *Id.* Bibliography of Past Research on the Thermal Aspects of Building Design in the Davis Climate. The ordinance also contains a list of accepted references. Davis, Calif., Resolution No. 1833, § 2(M) (Oct. 15, 1975).

An experimental program¹²⁸ using similar design features achieved an average sixty percent reduction in residential energy consumption when compared with houses built according to FHA Minimum Property Standards.¹²⁹ Key features of the program included increasing insulation, restricting window area to eight percent of the floor area, weather-stripping, installation of a centralized heating and cooling system, and attic ventilation. When similar modifications are used in the retrofitting of existing housing, comparable savings in energy consumption are realized.¹³⁰

A recent study¹³¹ comparing buildings constructed and operated according to practices current in 1973 with hypothetical buildings built according to the specifications of ASHRAE's Energy Conservation Standard 90-75 concluded that the latter would cost *less* to build than conventionally designed buildings.¹³² This finding, if substantiated by actual experience, will eliminate one of the principal objections to energy conservation modifications, the "prohibitive" cost¹³³ of either the modifications themselves or the necessary technology. In this context the Davis ordinance and similar proposals can only become more attractive as alternative energy strategies.

128. ENERGY CONSERVATION HOUSES, *supra* note 81 (statistical breakdown).

129. *Id.*

130. *E.g.*, PETERSEN, *supra* note 12, at 6.

131. *See* ARTHUR D. LITTLE INC., ENERGY CONSERVATION IN NEW BUILDING DESIGN, AN IMPACT ASSESSMENT OF ASHRAE STANDARD 90-75 (Conservation Paper 43B, Federal Energy Administration, 1976).

132. *Id.* at 7.

133. *See* PETERSEN, *supra* note 12. *See also* OFFICE OF TECHNOLOGY ASSESSMENT, AN ANALYSIS OF THE ERDA PLAN AND PROGRAM 191 (Oct. 1975). (report identified minimum first cost syndrom as principal nontechnical barrier to energy conservation in buildings).

APPENDIX A

ORDINANCE NO. 784

AN ORDINANCE ESTABLISHING ENERGY CONSERVATION
PERFORMANCE STANDARDS FOR RESIDENTIAL CONSTRUCTION
WITHIN THE CITY OF DAVIS

THE CITY COUNCIL OF THE CITY OF DAVIS DOES HEREBY ORDAIN AS
FOLLOWS:

Section 1. Findings.

A. The people of the State of California face the likelihood of a major energy shortfall and the certainty of rapidly rising energy costs due to uncertainties about present and future supplies of natural gas, and the inability of powerplant construction to keep pace with the rising demand for electricity. Energy demand for the heating and cooling of residential structures has been rising faster than demand in other sectors and rising household energy bills are becoming an increasing economic burden for lower and middle income families.

B. The State of California has adopted an energy and noise insulation standard under the provisions of the California Administrative Code, Title 25, Chapter I, Subchapter 1, Article 5. This standard will make an important contribution to improving housing in the State, but due to the unique characteristics of the Davis climate, the State regulations are deemed to be inadequate for use in the City of Davis.

C. Many years of research at the University of California at Davis have established the following facts:

(1) An experimental room with large windows facing west regularly achieved temperatures in excess of 140°F during the summer in Davis. The problem of unshaded windows is inadequately dealt with in the State code. Consequently, dwellings which will overheat to such an extent that they are unfit for human habitation may be built under the State standard.

(2) It has been found in experimental structures in Davis that solar heat gains from properly oriented windows can significantly reduce the need for heating in the winter. This factor is not credited in the State code.

(3) It has been found that the thermal capacity or heat storage ability of the building itself can help to ameliorate daily temperature extremes of both summer and winter. This factor is not accounted for in the State code.

D. From 1973 to 1975 the City of Davis commissioned a study which corroborated the experimental results described above by extensively studying the performance of actual buildings in Davis. Both the thermal performance and actual energy use were examined. It was found that:

(1) Some dwellings became dangerously hot (100-110°F) in the summer due to direct solar heat gains through large east or west facing windows, while identical dwellings with north or south facing windows remained comfortably cool (75-80°F) and, therefore, used substantially less energy for cooling.

(2) Dwelling units with south windows exposed to winter sun were significantly warmer during the winter (over 10°F warmer on cold sunny days) and used significantly less energy for heating than dwelling units with windows facing other directions.

(3) Some dwelling units with windows on only one side had no through ventilation and would not cool at night even on cool, windy, summer evenings, thereby requiring expensive cooling system operation.

E. As part of the above mentioned study, the Davis climate was examined in light of the needs for energy conservation and the following findings were made:

(1) The daytime maximum temperature during July, the hottest month of the year, averages 95° F; however, the nighttime minimum averages 55.3° F. These nighttime lows are caused by thermally induced sea breezes originating over the Pacific Ocean which flow into portions of the Central Valley through the Carquinez Straits. These local climatic factors were found to all but eliminate need for summertime air conditioning in residential buildings if the following conditions are met:

- (a) The windows are protected from direct solar radiation;
- (b) The walls, floors and ceilings are adequately insulated;
- (c) Adequate thermal storage capacity is provided within the structure; and
- (d) Cross-ventilation for summer nighttime cooling is provided.

(2) During January, the coldest winter month, the average 24-hour outside temperature is 45.3° F. On the average, Davis receives sun for fifty-six percent (56%) of the time possible during the five winter months. The frequency and duration of winter sunshine is such that the need to heat residential buildings is substantially reduced if the following conditions are met:

- (a) The walls, floors and ceilings are adequately insulated;
- (b) Adequate south-facing glass exposed to the winter sun is provided; and
- (c) Adequate thermal storage capacity is provided within the insulated shell of the structure.

F. Due to the above stated factors, it has been found that:

(1) Considerably better minimum performance levels can be required in Davis than provided for by the State code without unduly restricting designs and raising costs, or requiring new technologies.

(2) The present State code allows the construction of buildings that will be unfit for human habitation in the event of the interruption in gas or electrical service during one of the frequently occurring hot or cold weather events. Therefore, the present State code, by its failure to adequately address the heat loss and heat gain considerations of glazing and glazing orientation, does not adequately deal with the Davis climatic conditions.

(3) Considerable reduction in the real cost of housing can be achieved in buildings with good thermal performance by lowering utility bills. In addition, the initial costs of improving the structure's thermal performance is usually offset by the resultant savings due to the smaller capacity heating and/or cooling equipment required for a thermally efficient structure.

Section 2. Definitions.

The following words and phrases shall have the meanings respectively ascribed to them by this section:

A. "Winter Design Day" shall refer to a day upon which it shall be assumed, for purposes of structural heat loss calculations, that all of the following climatological conditions exist:

(1) The sun's path and resultant angles of direct sunlight shall be those which occur on December 21 of each year at latitude 38° 32' North. These angles can be approximated by using latitude 40° North data. (See Table 1.)

(2) The sun's intensity through glazing shall be calculated for December 21 of each year at latitude 38° 32' North; this can be approximated by using latitude 40° North data. (See Table 1.)

(3) The 24-hour average outside temperature is 45° F.

(4) For the sake of determining the external air film coefficient, the wind speed shall be assumed to be 15.0 m.p.h. in accordance with ASHRAE procedures.

B. "Summer Design Day", as used in this ordinance, shall refer to a day upon which it shall be assumed, for purposes of structural heat gain calculations, that all of the following climatological conditions exist:

(1) The sun's path and resultant angles of direct sunlight shall be those which occur on August 21 of each year at latitude 38° 32' North. These angles can be approximated by using latitude 40° North. (See Table 1.)

(2) The sun's intensity through glazing shall be calculated for August 21 of each year at latitude 38° 32' North; this can be approximated by using latitude 40° North data. (See Table 1.)

(3) The outside temperatures on August 21 shall be assumed to be, at each hour, Pacific Standard Time, as follows:

Time A.M.	Temp. °F	Time P.M.	Temp. °F
1:00	66	1:00	95
2:00	64	2:00	99
3:00	61	3:00	100
4:00	60	4:00	99
5:00	59	5:00	98
6:00	59	6:00	95
7:00	67	7:00	91
8:00	72	8:00	87
9:00	78	9:00	81
10:00	82	10:00	77
11:00	87	11:00	73
12:00	91	12:00	68

(4) For the sake of determining the exterior air film coefficient, the wind speed shall be 15 m.p.h. in accordance with ASHRAE procedures.

C. "Floor Area" shall refer to the total habitable area of a dwelling unit (expressed in square feet) which is within the exterior face of the insulated shell of the structure and which is heated or cooled.

Section 3. Minimum Performance Standards Adopted.

The City of Davis hereby adopts minimum standards for the thermal performance of buildings to be constructed within the City of Davis. In order to achieve maximum thermal performance, standards have been carefully adjusted to the special problems and opportunities of the Davis climate. These standards shall apply to all residential structures designated Group H and Group I in the Uniform Building Code.

A. Winter Performance Standard. For a winter performance standard the Total Days Heat Loss per square foot of floor area during the winter design day shall be as follows: For single-family, detached structures designated U.B.C. Group I, see Table 2; for multiple dwellings, U.B.C. Group H, the Total Days Heat Loss shall not exceed one hundred twenty (120) BTU's per square foot of floor area. Commonwall Group I structures shall meet Group H standards. The resolution establishing methods of compliance with the performance standards will allow for numerically increasing the permissible standard on the basis of surface areas in common in order to equitably deal with the variability which occurs in this class of dwelling units.

B. Summer Performance Standard. For a summer performance standard, the Total Days Heat Gain per square foot of floor area during the Summer Design Day shall be as follows: For single-family, detached structures, U.B.C. Group I, see Table 2; for multiple dwellings U.B.C. Group H, the Total Days Heat Gain shall not exceed forty (40) BTU's per square foot of floor area. Commonwall Group I structures shall meet Group H standards. The resolution establishing methods of compliance with the performance standards will allow for numerically increasing the permissible standard on the basis of surface areas in common in order to equitably deal with the variability which occurs in this class of dwelling units.

Section 4. Methods of Compliance with Performance Standards to be Established by Resolution.

Standard methods for calculating the performance of a proposed structure to determine compliance with the standards of this ordinance shall be adopted by resolution of the City Council.

Section 5. Administration and Enforcement.

A. The provisions of this ordinance and the resolution establishing the methods of compliance shall be administered by the Building Official of the City of Davis.

B. No building permit shall be issued by the Building Official for any new structure subject to this ordinance unless such structure is found to be in compliance with the winter and summer performance standards hereby established.

Section 6. Partial Exemption.

Structures designated U.B.C. Group I to be built on lots which are unimproved with structures and for which a tentative subdivision map has been approved prior to September 1, 1974, shall be exempt from glazing shading requirements adopted by resolution pursuant to Section 4 of this ordinance. To the extent that the exemption from glazing shading requirements causes a structure to exceed the performance standards established by Section 3 of this ordinance, such incremental excess shall be permitted.

Section 7. Partial Exemption.

Structures designated U.B.C. Group I to be built on lots which are unimproved with structures and for which a tentative subdivision map has been approved prior to January 1, 1976, but after September 1, 1974, and which lots front upon a portion of street having an axis between 292.5° and 067.5° true (N67.5° W and N67.5° E) and 247.5° and 112.5° true (S67.5° W and S67.5° E), shall be exempt from glazing shading requirements adopted by resolution pursuant to Section 4 of this ordinance. To the extent that the exemption from glazing shading requirements causes a structure to exceed the performance standards established by Section 3 of this ordinance, such incremental excess shall be permitted.

Section 8. Variances.

A. Purpose. The purpose of a variance is to allow variation from the strict application of the requirements of this ordinance and implementing resolutions where, by reason of the exceptional narrowness, shallowness or unusual shape of a specific piece of property, or other extraordinary situation or condition of such piece of property, or of the use or the development of property immediately adjoining the property in question, the literal enforcement of the requirements of this ordinance would involve practical difficulties or would cause undue hardship unnecessary to carry out the spirit and purpose of this ordinance. In most cases, the variance shall only relate to the allowable area of unshaded glazing permissible under the resolutions implementing this ordinance.

B. Application. Application for a variance shall be made by the property owner or the Board of Building Appeals or the Community Development Director on a form prescribed by the City, and shall be accompanied by a fee as prescribed by resolution adopted pursuant to City Code Section 29-12.1, no part of which shall be refundable. No fee shall be charged if the variance is initiated by the Board of Building Appeals or the Community Development Director.

C. Maps and Drawings. Maps and drawings required to demonstrate that the conditions set forth in this ordinance apply to the subject property, together with precise and accurate legal descriptions and scale drawings of the property and existing buildings, and other data required, shall be submitted with the application for a variance.

D. Grounds for Granting. The Board of Building Appeals may grant a variance only when all of the following conditions are found:

(1) That any variance granted shall be subject to such conditions as will assure that the adjustment thereby authorized shall not constitute a grant of special privilege inconsistent with the limitations upon other similarly situated properties which were developed under the limitations of this ordinance.

(2) That because of special circumstances applicable to the subject property, the strict application of this ordinance is found to deprive subject property of privileges enjoyed by other similar properties which were developed under the limitations of this ordinance.

(3) That the authorizing of such variance will not be of substantial detriment to adjacent property, and will not materially impair the purposes of this ordinance or the public interest.

(4) That the condition or situation of the subject property or the intended use of the property for which the variance is sought is not so general or recurrent in nature as to make reasonable or practicable the formulation of a general regulation for such conditions or situations.

(5) That there are not available reasonable alternative construction methods which will bring the proposed structure into compliance with the performance standards of this ordinance.

E. Grounds for Granting—Examples. The following types of physical or topographical factors are examples of conditions which may justify the grant of a variance from the glazing shading requirements to be established by resolution as provided by Section 4 of this ordinance:

- (1) Overriding off-site view considerations which are determined to add appreciable incremental value to the subject property.
- (2) Minimum size lots with fixed and adverse orientation problems.
- (3) Adverse lot orientation dictated by street or utility improvements of similar physical limitations where such limitations are in existence prior to the adoption of this ordinance.

F. State Standards. No variance shall be granted under this section which will result in a structure which exceeds the then existing State of California residential energy conservation standards.

G. Notice of Variance Hearing. Upon the filing of an appeal, the Building Official shall provide written notice of the filing of the appeal to all persons interested in the matter and shall cause notice of public hearing to be published in a newspaper of general circulation.

H. Review of the Decision. The decision of the Board of Building Appeals to grant or deny the application shall be subject to appeal in accordance with the resolution establishing the Board of Building Appeals.

Section 9. Appeals.

Any person aggrieved by a determination of the Building Official in the application of this ordinance may appeal such determination to the City of Davis Board of Building Appeals. Such appeal shall be in writing and shall be filed with the Building Official within fifteen (15) days of the determination appealed. All appeals shall be accompanied by payment of a fee in the amount set forth in the City's Community Development fee schedule.

Upon the filing of an appeal, the Building Official shall provide written notice of the filing of the appeal to all persons interested in the matter and shall cause notice of public hearing to be published in a newspaper of general circulation.

In consideration of an appeal, the Board of Building Appeals shall have authority to determine the suitability of alternate materials and methods of construction and to provide for reasonable interpretation of the provisions of this ordinance and implementing resolutions, provided, however, that no alternate material nor method of construction shall be approved which results in a reduction in the performance standards established by this ordinance for both summer and winter conditions.

The decision of the Board of Building Appeals shall be subject to appeal in accordance with the resolution establishing the Board of Building Appeals.

TABLE 2*

DETACHED GROUP I DWELLING UNIT THERMAL STANDARDS

Floor Area (sq.ft.)	Winter Heat Loss (BTUs/[sq.ft.] [day])	Summer Heat Gain (BTUs/[sq.ft.] [day])
500	363	118
1000	239	103
1500	208	98
2000	192	95
2500	182	93
3000	176	91

NOTE: Direct interpolation shall be used for floor areas not shown.

*Table 1 omitted.

Section 11. Conflicting Ordinances Repealed.

All ordinances or portions of ordinances which conflict with the provisions of this ordinance are, to the extent of such conflict, hereby repealed.

Section 12. Effective Date.

This ordinance shall become effective on and after the ninetieth (90th) day following its adoption.

PASSED AND ADOPTED by the City Council of the City of Davis on this 15th day of October, 1975, by the following vote:

AYES Councilmen Black, Holdstock, Stevens, Tomasi, Mayor Poulos.

NOES None.

ABSENT: None.

/s/ JOAN G. POULOS
Mayor

ATTEST:
City Clerk

APPENDIX B

ORDINANCE NO. 787

ORDINANCE AMENDING SECTION 6 OF ORDINANCE NO. 784 (ORDINANCE ESTABLISHING ENERGY CONSERVATION PERFORMANCE STANDARDS FOR RESIDENTIAL CONSTRUCTION WITHIN THE CITY OF DAVIS) RELATING TO ENERGY CONSERVATION PERFORMANCE STANDARDS FOR RESIDENTIAL CONSTRUCTION ON LOTS CREATED PRIOR TO SEPTEMBER 1, 1974

THE CITY COUNCIL OF THE CITY OF DAVIS DOES HEREBY ORDAIN AS FOLLOWS:

SECTION 1. Section 6 of Ordinance No. 784 is hereby amended to provide as follows:
Section 6. Partial Exemption.

Structures designated U.B.C. Group I to be built on lots which are unimproved with structures and for which a tentative subdivision map has been approved prior to September 1, 1974, shall be exempt from requirements adopted by resolution pursuant to Section 4 of this ordinance. To the extent that the exemption from requirements causes a structure to exceed the performance standards established by Section 3 of this ordinance, such incremental excess shall be permitted.

SECTION 2. This ordinance shall become effective concurrently with Ordinance No. 784.

PASSED AND ADOPTED by the City Council of the City of Davis on this 5th day of November, 1975, by the following vote:

AYES Councilmen Black, Holdstock, Stevens, Tomasi, Mayor Poulos.

NOES None.

ABSENT: None.

/s/ JOAN G. POULOS
Mayor

ATTEST:
City Clerk

APPENDIX C

RESOLUTION No. 1833, SERIES 1975

RESOLUTION ADOPTING PROCEDURES FOR COMPLIANCE WITH THE ENERGY CONSERVATION PERFORMANCE STANDARDS FOR RESIDENTIAL CONSTRUCTION WITHIN THE CITY OF DAVIS

WHEREAS, the City of Davis has, by ordinance, established certain energy conservation performance standards for new residential construction within the City of Davis; and

WHEREAS, the ordinance which establishes energy conservation performance standards provides that standard methods for determining compliance of proposed buildings shall be established by resolution;

NOW, THEREFORE, BE IT RESOLVED by the City Council of the City of Davis as follows:

Section 1. Application.

Compliance with the energy conservation performance standards established by the City of Davis shall be determined by reference to the provisions of this resolution and any amendments thereto.

Section 2. Definitions.

For purposes of this resolution and the energy conservation performance standards ordinance of the City, the following words and phrases shall have the meanings respectively ascribed to them by this section:

A. R Values. ($1/U=R$) Thermal Resistance (R) is the measure of the resistance of a material or building component to the passage of heat. The units of measurement are: (Hours) (Degrees Fahrenheit) (Square Feet)/BTU. The resistance value (R) of mass-type insulations shall not include any value for reflective facing. (NOTE: For reflective foil insulation, use ASHRAE procedures only. Calculate both the winter and summer composite resistance value and use whichever is less.)

B. Composite Thermal Resistance (R_c) is the sum of each of the resistance values of the parts of an assembly of materials which together form an external skin element of the structure. For example, a commonly used wall is one which has an interior air film, one-half (1/2) inch thick plaster board, three and one-half (3-1/2) inches batt insulation, stucco, and finally, an exterior air film, all of which have R values which are added together to derive the R_c value for the wall element.

C. Orientation. The compass directions are designated as follows when the attached tables are used:

North	337.5° - 022.5°
Northeast	022.5° - 067.5°
East	067.5° - 112.5°
Southeast	112.5° - 157.5°
South	157.5° - 202.5°
Southwest	202.5° - 247.5°
West	247.5° - 292.5°
Northwest	292.5° - 337.5°

D. Exterior Surface Area. The area for each dwelling unit of walls, ceilings, suspended floors, glazing, doors, etc. enclosing conditioned spaces and exposed to ambient climatic conditions.

E. Heavy Exterior Building Elements. The walls, suspended floors and/or ceilings which contain a heat storage capacity of 30 BTU's/Day for each square foot of surface

area are considered to be heavy (see definition K). Only those materials located on the interior side of insulation materials may be counted. (An eight [8] inch thick lightweight concrete block wall with exterior insulation slightly exceeds these requirements.)

F. Color. Surfaces with a Munsell lightness value of 6.0 to 10.0 are to be considered light in color. Surfaces with a Munsell lightness value of 9.0 to 10.0 are to be considered very light in color. Unpainted wood surfaces are to be considered light in color. The Building Inspector shall prepare two (2) representative collections of materials and surface covering materials, one with Munsell lightness values greater than 6 and one of materials with Munsell lightness values greater than 9. These collections shall be available for inspection by the public.

G. Glazing. All vertical, horizontal, and tilted translucent or transparent exterior building elements shall be considered glazing with a thermal resistance and daylight transmittance as specified by the manufacturer or as calculated by ASHRAE methods or other reliable references or procedures.

H. Shading Coefficient. The ratio of the solar heat gain through a shading-glazing system to that of an unshaded single-pane of double strength window glass under the same set conditions.

I. Hour's Solar Heat Gain. The amount of energy transmitted through an area of glazing oriented to a particular direction in one (1) hour. The following formula is used for calculation:

$$\text{HSHG} = (\text{SC}) (\text{SHGF}) (\text{A})$$

Where:

HSHG = Solar Heat Gain through the glazing for one (1) hour BTU's/hour

SC = Shading Coefficient

SHGF = Solar Heat Gain Factor for the hour from attached Table 1 (BTU's/square foot of glazing) using December 21 for winter and August 21 for summer.

A = Area in square feet of glazing exposed to the sun (square feet).

J. Solar Heat Gain Factor. The number of BTU's of solar energy transmitted through one (1) square foot of clear 1/8-inch glass in one (1) hour. This is determined by using the attached Table 1 which applies to 40° North latitude and the eight (8) compass orientations (see definition C).

K. Heat Storage Capacity. The mass located inside the insulated shell of the structure that fluxes through a temperature cycle each day in summer and winter, absorbing heat during overheated periods and storing it for release during underheated periods. Heat storage capacity shall be estimated by the following procedure:

$$\text{HS} = (\text{WM}) (\text{SH}) (\Delta\text{T})$$

Where:

HS = Heat Storage Capacity (BTU's/Day)

WM = The weight of the materials (lbs.) inside the insulated shell of the building to a depth yielding a resistance of R-1, except in the case of slab floors where only the slab itself is credited.

- SH = Specific Heat of those materials
(BTU's/[lb.] [degree F])
- ΔT = Temperature flux; 5° F will be the maximum allowable for calculation purposes, except that light weight frame construction will be allowed to flux 10 F. (In order to determine the heat or cold available for storage, see Path II, Section 5.)

This total stored heat may be subtracted from the day's heat loss or gain to yield the adjusted Total Day's Heat Loss or Total Day's Heat Gain. Mass located in exterior elements to which the Equivalent Temperature Differential Method (E.T.D.) is applied to calculate summer heat gain shall not be included in the summer heat storage capacity credit.

L. Floor Area. Total habitable area of a dwelling unit (expressed in square feet) which is within the exterior face of the insulated shell of the structure and which is heated or cooled.

M. Accepted References. The following are useful and acceptable references:

Handbook of Fundamentals 1972, American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. (ASHRAE), N.Y., N.Y., 1972.

Architectural Graphic Standards, Charles G. Ramsey and Harold R. Sleeper, John Wiley & Sons, Inc., N.Y., N.Y., Sixth Edition, 1970.

Design with Climate, Victor Olgyay, Princeton University Press, Princeton, New Jersey, 1963.

Concepts in Thermal Comfort, David Egan, Tulane University, School of Architecture, New Orleans, Louisiana, 1972.

Thermal Design of Buildings, Tyler Stuart Rogers, John Wiley & Sons, Inc., N.Y., N.Y., 1964.

Sun Angle Calculator, Libbey-Owens-Ford Company, Toledo, Ohio, 1975.

Section 3. Standard Methods of Building Performance Calculation.

A. There are hereby adopted two (2) alternative standard methods of determining compliance with the City of Davis energy conservation performance standards. The two (2) alternative standard methods shall be referred to as Path I and Path II approaches.

B. Structures utilizing either Path I or Path II shall comply with the following:

(1) Infiltration. All swinging doors and windows opening to the exterior or to unconditioned areas such as garages shall be fully weatherstripped, gasketed or otherwise treated to limit infiltration. All manufactured windows and sliding glass doors shall meet the air infiltration standards of the 1972 American National Standards Institute (A134.2, A134.3 and A134.4), when tested in accordance with ASTM E 283-73 with a pressure differential of 1.57 lbs./ft.² and shall be certified and labeled.

(2) Loose Fill Insulation. When blown or poured type loose fill insulation is used in attic spaces, the slope of the roof shall be not less than 2-1/2 feet in 12 feet and there shall be at least 30 inches of clear headroom at the roof ridge. ("Clear headroom" is defined as the distance from the top of the bottom chord of the truss or ceiling joists to the underside of the roof sheathing.) When eave vents are installed, adequate baffling of the vent opening shall be provided to deflect the incoming air above the surface of the material and shall be installed at the soffit on a 45-degree angle. Baffles shall be in place at the time of framing inspection. When loose fill insulation is proposed, the R value of the material required to meet these regulations shall be shown on the building plans or calculation sheet.

(3) Pipe Insulation. All steam and steam condensate return piping and all continuously circulating domestic or heating hot water piping which is located in attics, garages,

crawl spaces, underground or unheated spaces other than between floors or in interior walls shall be insulated to provide a maximum heat loss of 50 BTU/hr. per linear foot for piping up to and including 2-inch and 100 BTU/hr. per linear foot for larger sizes. Piping installed at depth of 30 inches or more complies with these standards.

Section 4. Path I (Prescriptive Method).

Buildings meeting all of the following criteria will fulfill the required energy conservation aspects of this code with no overall performance calculations required.

Calculations using the applicable methods outlined in Path II may be employed to demonstrate compliance of alternatives to any particular section of Path I. Thermal trade-offs between sections of Path I must be done by using Path II or by referring to approved thermal trade-offs table developed by the Building Inspector.

A. Walls. All exterior walls (excluding windows and doors) shall use R-11 batt insulation between studs. Group H structures must have light colored walls or shaded walls. Fifteen percent (15%) of the wall area may be dark colored to allow for trim and color accents. (Group I structures have no wall color requirement.)

Exceptions:

(1) All exterior walls shall achieve a composite resistance value (Rt) of 10.52 if the insulation is not penetrated by framing and Rt of 12.50 if the insulation is penetrated by the framing or furring. (California Administrative Code, Title 25, Chapter 1, Subchapter 1, Article 5, Section 1094[a].)

(2) Heavy walls with exterior insulation not penetrated by furring or framing shall have an Rt of 7.36, and Rt. of 8.75 if the insulation is penetrated by furring or framing.

(3) Group H structures with dark colored walls shall increase their applicable Rt requirements by twenty percent (20%).

B. Roof/Ceilings; Ceiling/Attics. All roof/ceilings and ceiling/attics must use insulation achieving a minimum resistance of R-19 for the insulation itself. Group H occupancies having roof surfaces unshaded on August 21, at 8:00 a.m., 12:00 noon, or 4:00 p.m., shall be no darker than No. 6 on the Munsell color chart. Unshaded roof areas on Group I occupancies shall be no darker than No. 4 on the Munsell color chart. Roofs having unshaded areas and color darker than No. 6 or No. 4 respectively must increase the total insulation to yield R25 for the insulation itself.

Exceptions:

(1) All roof/ceilings and/or ceiling/attics sections shall achieve a composite resistance value (Rt) of 16.67 if the insulation is not penetrated by framing or furring and Rt of 20.0 if the insulation is penetrated by the framing or furring. (California Administrative Code, Title 25, Chapter 1, Subchapter 1, Article 5, Section 1094[c].) Blown insulation (loose fill type) shall be considered to be penetrated by the framing.

(2) The roof/ceiling and/or ceiling/attic sections of the dwelling unit as a whole may be insulated to values greater and/or less than required in (1) above if the resulting heat loss equals or is less than that which would occur if the values required in (1) above were met, or if the thermal resistance values of the ceiling areas satisfy the following equation:

$$\begin{aligned} 1/Rt \text{ required} &= (\text{Area A/Total Area}) (1/Rt \text{ achieved}) \\ &+ (\text{Area B/Total Area}) (1/Rt \text{ achieved}) \\ &+ \dots + (\text{Area N/Total Area}) (1/Rt \text{ achieved}) \end{aligned}$$

(3) In Group H occupancies, roof/ceilings or ceiling/ attics located beneath dark colored roofs shall achieve composite resistance values (Rt) 30% greater than the values in (1) and (2) above, i.e., Rt = 21.67 and Rt = 26.00 respectively. In Group I occupancies, roof/ceilings or ceiling/attics located beneath roofs that are darker than Munsell Color No. 4 shall achieve composite resistance values (Rt) 30% greater than the values in (1) and (2) above, i.e., Rt = 21.67 and Rt = 26.00 respectively.

C. Floors. Suspended floors over a ventilated crawl space or other unheated space shall have insulation with a minimum resistance of R-11. Concrete slabs on grade require no insulation.

Exceptions:

(1) Suspended floors over an unheated space shall achieve a composite resistance value (Rt) of 10.52 if the insulation is not penetrated by framing, and Rt of 12.50 if the insulation is penetrated by framing.

(2) Heavy suspended floors with exterior insulation shall achieve a composite resistance value (Rt) of 7.36 for insulation not penetrated by framing members, and Rt of 8.75 for insulation penetrated by framing members.

D. Glazing Area. In Group H occupancies, exterior single-pane glazing (windows, skylights, etc.) may not exceed 12-1/2% of the floor area. Exterior double-pane glazing may not exceed 17-1/2% of the dwelling unit's floor area. In Group I occupancies, a glazing constant of 20 square feet in single-pane glazing and 28 square feet in double-pane glazing may be added to the percentage figures allowed above.

Exceptions:

(1) A combination of single and double-pane glazing may be used so long as the area of the single plus the area of the double glazing divided by 1.4 is not greater than 12-1/2% (plus 20 square feet for Group I occupancies) of the dwelling unit's floor area.

(2) A combination of single and/or double-pane glazing with interior shutters may be used to increase the allowed glazing provided that:

(i) The interior shutters are of a permanent construction and installed so that they are operable, and tight fitting or weatherstripped so that a seal is created.

(ii) The areas in each treatment do not exceed those allowed by the following procedure.

$$GC + (FA)(.125) = \text{Area}_s + (\text{Area}_D)(.64) + (\text{Area}_{shut})/Rt$$

Where:

GC = Glazing constant (square feet) taken at 20 square feet in Group I and zero in Group H occupancies.

FA = Floor Area (square feet).

Area_s = Area in single-pane glazing (square feet).

Area_D = Area in double-pane glazing (square feet).

Area_{shut} = Area in interior shuttered glazing (square feet).

Rt = The composite resistance of the shutter-glazing systems.

(3) When the area of glazing allowed by application of (1) or (2) is exceeded, the excess area will be considered justified if all the following conditions are met:

(i) Glazing must be south facing. If it is mounted other than vertically, it must be tilted at least 30° up from the horizontal to face south.

(ii) It must be clear. (Shading coefficient numerically greater than or equal to .80 for the glazing itself.)

(iii) It must receive full direct sun from 10:00 a.m. to 2:00 p.m. (P.S.T.) on December 21.

(iv) For each square foot of glazing being justified, the building must contain a heat storage capacity (HS) equivalent to 750 BTU's/Day, located inside the insulated

shell of the structure, and not covered with insulation materials such as carpet yielding an Rt of 1.0 or greater. The following will allow a quick method for calculation of mass needed for each square foot of exempted glazing:

- 59 Square feet of interior stud partition wall (2" x 4"s - 16" o.c. with 1/2" gypsum two sides).
- 117 Square feet of exterior stud wall or ceiling (2" x 4"s - 16" o.c. with 1/2" gypsum inside, insulation, and various external treatments).
- 21 Square feet of 8-inch lightweight concrete block masonry exterior wall insulated externally, cores filled for structural support only.
- 15 Square feet of concrete slab floor provided with a steel trowel finish, exposed aggregate, tile (vinyl, asbestos, or ceramic), terrazo, or hardwood parquet not greater than 1/2-inch thick.

(NOTE: Lightweight stud frame walls are assumed to flux 10°F; heavy walls are assumed to flux 5 F. See Definitions E and K.)

E. Glazing Shading.

(1) All glazing which is not oriented to the north must be shaded to protect it from direct solar radiation for the hours of 8:00 a.m., 12:00 noon, and 4:00 p.m. (P.S.T.), August 21. Glazing facing SE or SW must also be checked for shading at 10:00 a.m. for SE and 2:00 p.m. for SW in addition to the standard three hours. For each check hour the area of glazing not shaded is calculated and accumulated. In Group H occupancies the total accumulated amount of unshaded glazing may not exceed 1.5% of the dwelling unit's floor area. In Group I occupancies the total accumulated amount of unshaded glass may not exceed 3% of the dwelling unit's floor area. Shading shall be demonstrated to the satisfaction of the Building Inspection Division of the Community Development Department. Drawings showing shadows cast by shading systems, or scale models suitable for use in the solar-ranger setup by the Building Inspection Division, or the use of approved shade screen systems may be employed to demonstrate compliance. Tinted, metalized, or frosted glass shall not be considered self-shading.

(2) Interior mounted shutters meeting the following specifications may be utilized to meet the shading requirements:

(i) The exterior oriented side must be very light in color (Munsell of 9.0 or greater) and flat.

(ii) The shutters must be tight fitting or all cracks or edges in the system must be weather stripped to create a seal.

(iii) The shutters must be opaque.

(iv) A composite resistance value of $R_t=1.0$ for the shutters must be achieved.

(3) Exterior mounted shading systems meeting the following specifications may be utilized to meet the shading requirements:

(i) They shall be of permanent materials and construction. A permanent frame with sheathing having a life expectancy of five years minimum must be provided and guaranteed by the builder.

(ii) For the required design hour, the shading device must be capable of intercepting 100% of the direct beam solar radiation, or provide a minimum shading coefficient of 0.2 or less. If the shading system at a design hour does not perform to these standards, then the portion of the glazing which is left exposed is to be calculated and added to the accumulated unshaded glazing total.

(4) Other types of shading systems are allowed if they comply with either of the following:

(i) All on-site and off-site obstructions to the sun, providing 80% attenuation of the direct solar beam, may be considered as external shading devices and may be accounted for in the summer shading calculations. (NOTE: If during the life of the structure the off-site obstructions to the sun used to achieve shading standards com-

pliance are modified or removed, then the structure may be found to be in violation of the Code if other compensating obstructions to the sun or shading devices have not been deployed.)

(ii) A shading system may be temporary, provided that it is designed and constructed to function to the standards above and built to last until its function is replaced by plantings. Plan and elevation drawings must show expected plant configuration and accurately state the number of years required for the projected plant growth. Final occupancy permits shall not be issued until the specified plants are in place.

F. Ventilation for Summer Night Time Cooling. Where design of the dwelling unit is such that openable windows may only be provided along one elevation, mechanical cross ventilation must be installed to provide 15 air changes per hour ducted to the exterior.

Section 5. Path II (Performance Method).

Buildings regulated by the Residential Energy Conservation Code that do not meet the criteria of Path I must be calculated by a registered architect, engineer, building designer, or other qualified person to show that the proposed building will not exceed the standards set forth in Section 3 of Ordinance No. —. The required calculation schedule is outlined below. (NOTE: More precise calculations may be submitted using ASHRAE or other comprehensive methods provided that the same design days are used.)

Commonwealth U.B.C. Group I dwelling units may increase the permissible thermal standards for Heat Loss or Heat Gain using the following equation:

$$TS = TS_H + (TS_I - TS_H) (1 - SAC/[1.5] [FA])$$

Where:

TS = The Thermal Standard which is applicable to the dwelling unit (BTU's/[sq. ft.] [Day])

TS_H = The Thermal Standard for Group H structures (BTU's/[sq. ft.] [Day])

TS_I = The Thermal Standard for a detached Group I dwelling unit of the same floor area (BTU's/[sq. ft.] [Day])

SAC = The Surface Area in Common with other dwelling units such as ceilings, walls, and floor (square feet)

FA = The dwelling unit's Floor Area (square feet)

A. Winter Calculations.

(1) The Total Day's Heat Loss shall not exceed the standards set in the Residential Energy Conservation Ordinance, Section 3.

(2) Winter heat loss calculations shall be based on the following formula:

$$TDHL = (DHL - SHGC)/(FA)$$

Where:

TDHL = Total Day's Heat Loss (BTU's/[sq. ft.] [Day])

DHL = Day's Heat Loss (BTU's/Day)

SHGC = Solar Heat Gain Credit (BTU's/Day)

FA = Floor Area of dwelling unit (sq. ft.)

(3) The Design Day for sun angle considerations is December 21 at latitude 40°N or 38° 32'N. The outside daily temperature average for December and January is 45°F,

yielding a 23°F difference between the inside (68°F) and the outside (45°F) average daily temperatures. The number of degree hours in the design day is the temperature difference times 24 hours or 552 for Davis. This figure is used as described in Paragraph (4)(i) below. (NOTE: This design, outdoor condition, is not intended to be for equipment sizing, but rather is meant to serve the purpose of performance design for energy conservation by more closely predicting the long term average conditions and energy use of the structure. Equipment sizing will require additional standard peak load calculations.)

(4) Calculation of Day's Heat Loss (DHL): Winter heat loss is determined by the composite resistance (Rt) of the exterior building surface to heat transfer to the outside air from the heated interior spaces.

$$\text{DHL} = \text{HL} + \text{SHL}$$

Where:

DHL = Day's Heat Loss (BTU's/Day)

HL = Heat Loss from outside surface elements
(except slab) (BTU's/Day)

SHL = Slab on grade Heat Loss (BTU's/Day)

(i) The heat loss for all surfaces (except slabs on grade) facing the outside air or unheated spaces may be determined by the following formula:

$$\text{HL} = (A_1/R_{t_1}) (552) + (A_2/R_{t_2}) (552) + \dots + (A_n/R_{t_n}) (552)$$

Where:

HL = Heat Loss from exterior surface element
except a slab on grade (BTU's/Day)

A = Area of the exterior surface element (sq. ft.)

Rt = The element's composite thermal resistance
([hours] [Deg. F] [sq. ft.]/BTU)

552 = Davis Design Day Degree Hours ([Deg. F]
[hours]/Day)

All exterior elements (walls, ceilings, doors and suspended floors) which are exposed to unheated enclosed or partially enclosed spaces shall be calculated as if they are exposed to outside conditions, or the temperature difference may be altered according to accepted ASHRAE procedures for surfaces adjacent to unheated spaces.

(ii) Concrete slab floors on grade lose heat in direct relation to the perimeter dimension in linear feet. The following formula applies:

$$\text{SHL} = (F) (P) (552)$$

Where:

SHL = Heat Loss from Slab (BTU's/Day)

F = The thermal conductivity of the edge of the slab with $F = 0.81$ (BTU/[foot] [hour] [Deg. F]) where no insulation is used and $F = 0.55$ where slab is insulated with edge insulation of $R = 4.5$ minimum. The insulation shall come within one inch of the top of the slab and extend sixteen inches below grade.

- P = Perimeter dimension (feet)
 552 = Davis Design Day Degree Hours ([Deg. F]
 [hours]/[Day])

(5) Calculation of Solar Heat Gain Credit (SHGC). Direct use of solar energy is dependent on the Day's Solar Heat Gain (DSHG) through the glazing, the Heat Storage (HS) characteristics of the building, and the Solar Climatic Variable (SCV). The following steps are to be followed to calculate the SHGC:

(i) Calculate the Day's Solar Heat Gain (DSHG), by adding up the Solar Heat Gain for each daylight hour of December 21 design day for each square foot of glazing receiving sun.

$$\text{DSHG} = (\text{HSHG}_1 + \text{HSHG}_2 + \dots + \text{HSHG}_n) \text{ (SCV)}$$

Where:

DSHG = Day's Solar Heat Gain (BTU's/Day)

HSHG = Hour's Solar Heat Gain. HSHG is found according to the procedure described in Definition I. The number of hours added depends on the hours of sunlight on the glazing surface in question. (BTU's/hour)

SCV = Solar Climatic Variable (no units). SCV = 0.56 for Davis. This was determined by averaging the mean fraction of possible sunshine available for each month of the winter heating season (November, December, January, February, March)

(ii) Calculate the Heat Storage capacity of the building (HS). (See Definition K for calculation procedure.)

(iii) Then the Solar Heat Gain Credit (SHGC) (BTU's/Day) equals:

SHGC = DSHG or HS, whichever is less.

B. Summer Calculations.

(1) The Total Day's Heat Gain (TDHG) shall not exceed the standard set in the Residential Energy Conservation Ordinance, Section 3.

(2) Summer heat gain calculations shall be based on the following formula:

$$\text{TDHG} = (\text{DHG} - \text{HS})/\text{FA}$$

Where:

TDHG = Total Day's Heat Gain₁(BTU's/[sq.ft.] [Day])

DHG = Day's Heat Gain (BTU's/Day)

HS = Heat Storage (BTU's/Day)

FA = Floor Area of the dwelling unit (sq. ft.)

(3) The calculations below are based on the design day cited in the Residential Energy Conservation Ordinance taken at the five hours of 8:00 a.m., 10:00 a.m., 12:00 noon, 2:00 p.m., and 4:00 p.m.

(4) The Day's Heat Gain (DHG) is based on the weighted sum of calculations done at each of the five heat gain calculation hours (see equation [a] below). Structures without elevations oriented to the intercardinal directions may delete calculations for 10:00 a.m. and 2:00 p.m. and equally weigh the remaining three calculation hours by multiplying them by four (see equation [b] below). The following two weighted sun equations hold respectively.

$$(a) \text{ DHG} = ([\text{HG}_{8:00 \text{ a.m.}}] [3] + [\text{HG}_{10:00 \text{ a.m.}}] [2] + [\text{HG}_{12:00 \text{ noon}}] [2] + [\text{HG}_{2:00 \text{ p.m.}}] [2] + [\text{HG}_{4:00 \text{ p.m.}}] [3])$$

or

$$(b) \text{ DHG} = ([\text{HG}_{8:00 \text{ a.m.}} + \text{HG}_{12:00 \text{ noon}} + \text{HG}_{4:00 \text{ p.m.}}] [4])$$

Where:

DHG = Day's Heat Gain (BTU's/[Day])

HG = Heat Gain at the hour calculated (BTU's/hour)

(NOTE: More detailed analysis of Heat Gain may be done by calculating each hour's heat gain for the daylight hours. The digits "2", "3" and "4" in equations (a) and (b) above have the units of hours.)

(5) The Heat Gain (HG) may be calculated by using the following formula:

$$\text{HG} = \text{WHG} + \text{OHG}$$

Where:

HG = Heat Gain (BTU's/hour) at one of the design hours.

WHG = Heat Gain through Windows (BTU's/hour)

OHG = Heat Gain through Opaque surfaces (BTU's/hour)

(i) Heat Gain through Opaque surfaces. Calculations will be based on the Total Equivalent Temperature Differential Method (TETD) as described in ASHRAE Handbook of Fundamentals 1972, Chapter 22, pages 411-417. The TETD appropriate for the wall or roof section is found in attached Tables 2 and 3. Since the average Davis design day temperature is 5°F less than that used by ASHRAE, 5°F should be subtracted from the TETD values given in attached Tables 2 and 3 in accordance with ASHRAE procedures, as shown in the calculation below. (The interior temperature is assumed to be 75°F in accordance with ASHRAE.) The Heat Gain through Opaque surfaces is calculated as follows:

$$\text{OHG} = A_1(\text{TETD}-5)/\text{RT}_1 + A_2(\text{TETD}-5)/\text{Rt}_2 + \dots + A_n(\text{TETD}-5)/\text{RT}_n$$

Where:

OHG = Heat Gain through opaque surfaces at the calculation hour (BTU's/hour)

A = Area of the outside surface element (sq. ft.)

Rt = The element's composite thermal Resistance ([hours] [Deg. F] [sq. ft.]/BTU)

TETD = The element's Total Equivalent Temperature Difference from attached Tables 2 and 3

(ii) Glazing. Summer Heat Gain through windows (WHG) shall be calculated using the following formula:

$$WHG = ([A] [SC] [SHGF] + [\Delta T] [A]/Rt)_1 + (A \dots)_2 + \dots + (A \dots)_n$$

Where:

- WHG = Direct solar heat gain plus conducted heat gain through windows at the calculation hour (must be done for each wall or roof section with glazing). (BTU's/hour)
- A = Area of glazing surface being calculated (sq. ft.)
- SC = Shading Coefficient (see Definition H). (Unitless)
- SHGF = Solar Heat Gain Factor at the hour being calculated. (BTU's/[hours] [sq. ft. of glazing])
- Rt = Thermal Resistance of the glass (0.9 for single weight glass and 1.7 for double-pane). ([hours] [Deg. F] [sq. ft.]/BTU's)
- ΔT = Difference between the outside and the inside temperatures, with 75°F being taken as the inside temperature. (Deg. F)

(6) Heat Storage Capacity (HS). Where the building design provides for ventilation in minimum conformance with Section 4 F, credit can be taken for the Heat Storage capacity of the structure. (NOTE: When calculating the heat storage capacity for the summer, no credit may be taken for exterior elements.)

Section 6. Fees.

The following schedule of fees shall be applicable for the checking of plans for conformity with the performance standards of the Residential Energy Conservation Code:

Path I (No Exceptions)	No Charge
Path I (Exercising Exceptions)	\$20.00
Path II	\$25.00

PASSED AND ADOPTED by the City Council of the City of Davis on this 15th day of October, 1975, by the following vote:

AYES : Councilmen Black, Holdstock, Stevens, Tomasi, Mayor Poulos.

NOES : None.

ABSENT: None.

/s/ JOAN G. POULOS
Mayor

ATTEST:

/s/ HOWARD L. REESE
City Clerk

