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**BUILDING CODES AS BARRIERS TO
SOLAR HEATING AND COOLING OF BUILDINGS**

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Synopsis

This paper discusses the application of building codes to solar energy systems for heating and cooling of buildings, using as typical codes the three model building codes most widely adopted by states and localities. Some potential barriers to solar energy systems are found, federal and state programs to deal with these barriers are discussed, and alternatives are suggested.

Provisions for testing and approval, applicable because the codes do not explicitly provide for solar systems, may require elaborate showings by building permit applicants. These showings, due to building officials' discretion, may vary widely with time and place. Varying requirements could make solar systems less competitive than conventional systems due to the uncertainty, delay, expense, and fragmentation of potential national markets, amounting to an unreasonable burden on interstate commerce. This calls for nationally recognized standards and certification of equipment for ready code approval, like those for conventional heating and cooling systems.

In addition, various specific code provisions pose problems for some solar designs; the building codes should be revised to remove specific impediments and/or to exempt solar systems from such requirements provided they are not required for safety, health, or structural strength.

To remedy this, a federal program is needed to encourage state adoption of standards and acceptance of certification of solar systems for code approval, and to encourage revisions to codes based on model legislation prepared for the federal government by the model codes groups.

Introduction

A building code is a set of regulations relating to building construction that defines terms, sets standards for materials and equipment, tells how materials and equipment may and may not be put together, and provides for enforcement through permits, inspections, etc. The definition provisions can be critically important. For example, "height" may not include heating, ventilating, and air-conditioning equipment on the roof, and "heating appliance" may not include equipment that does not burn fuel or use electricity to produce heat. Definitions may also determine who may do installation; for example, certified plumbers may be required to do all "plumbing" work.

The standards provisions are generally of two types. Specification standards spell out what kinds of materials and equipment may be used, and how. For example, glass for a particular purpose must be tempered and 1/8 inch thick, all gas water heaters must be AGA-approved, or so many nails of a certain kind and size must be used in wood frame constructions. Performance standards, on the other hand, merely spell out what the particular part of a structure must be able to do; for example, certain walls must have a fire resistance rating of one hour. Specification standards are inflexible but easier to administer. Performance standards are flexible and allow for innovation, but require more trained personnel, time, and money to administer.

The enforcement (administrative) provisions of a code are also very important. Before any construction (including not only new construction, but alterations and all but minor repairs to existing buildings), a building permit must generally be obtained. Codes apply even when a permit is not required. Before granting the permit, a building official will decide whether the details in the plan

submitted conform to code requirements. If the plan only calls for materials, equipment, and methods specifically provided for in code specifications standards, approval is routine. If the plan calls for innovative materials or systems, however, the building official has the discretion to approve or disapprove the plans, or require testing and submission of evidence that the construction proposed is in no way inferior to the traditional construction provided for in the code. This takes more time and costs more than the routine procedure, and approval is not assured. The building official may permit alternative materials, equipment, or methods that are as good as those specified in the code, but he is not bound to do so.

In the sections that follow we show how three model codes¹ may be significant barriers to widespread use of solar heating and cooling. These codes are:

- o The Basic Building Code of the Building Officials and Code Administrators, International (BOCA), found mostly in the East and Midwest;
- o The Uniform Building Code of the International Conference of Building Officials (ICBO), found mostly in the West; and
- o The Standard Building Code of the Southern Building Codes Conference (SBCC), found mostly in the South.

According to a 1970 survey by Field and Ventre of local building departments, 63 percent of the 919 cities reporting had adopted one of these three model codes if they had a building code at all.² Since then, a few states have adopted versions of one of these three codes as statewide mandatory building codes: Idaho, Indiana, Massachusetts, Minnesota, Montana, New Jersey, New Mexico, Oregon, and Washington.³ Hence it is reasonable to study these codes as representative of building codes generally. Locally written codes would probably be less flexible and present equal or greater barriers to solar systems. The codes will be discussed in

the order given above. The BOCA code is discussed at considerable length. The ICBO and SBCC codes, no less important, are discussed in less detail to avoid excessive repetition. The reader who is not interested in a detailed examination of model code provisions may wish to skip ahead to the section entitled "Summary of Code Barriers."

BOCA Basic Building Code

The BOCA Basic Building Code has been adopted, often with some local revision, in many cities and counties of the densely populated northeastern and north central states, and in several states as mandatory statewide codes: Connecticut, Michigan, Virginia, and New Jersey. The Maryland state government recommends that local governments within the state adopt this code by reference. Massachusetts has adopted a state-written code patterned on the BOCA code.⁴ In Field and Ventre's 1970 survey, 60 percent of northeastern and north central cities reporting said they used this code.⁵

For our analysis, we used the BOCA Basic Building Code, 6th edition, 1975, and accompanying mechanical code and plumbing code. Although many jurisdictions have adopted earlier editions, it seems unlikely that enough changes affecting solar energy systems have occurred to justify a search through earlier editions. Three broad types of code provisions are discussed: administrative provisions (found in article 1); mechanical equipment provisions (found in articles 11 and 18, and by reference in the BOCA Basic Mechanical Code); and structural, materials, and design requirements (found throughout the rest of the code).

Administrative provisions. The BOCA Basic Building Code applies to all building construction, alterations, additions, etc., except as is otherwise specifically provided (§§ 100.2 and 101.1). The purpose of the code is to ensure

public safety, health, and welfare, insofar as they are affected by building construction: structural strength, adequate exits, sanitary equipment, light and ventilation, fire safety, and the like are covered by the code (§ 100.4). Local zoning codes also regulate structural, fire, and sanitary safety. When the building code and zoning code conflict, the more restrictive code applies (§ 101.5).

When alterations cost more than 50 percent of the current replacement cost of a building, the work done must bring the whole structure up to the requirements for new structures. When the cost is between 25 and 50 percent, the building official decides the extent to which the building must come up to new building standards (§ 106.0). A solar retrofit itself would have to conform to the current requirements, but usually it would not cost enough to affect requirements for the rest of the building. When a major restoration is undertaken, however, the added cost of the solar retrofit could bring this provision into play. Thus, the solar retrofit may sometimes be discouraged. This would not appear an obstacle in the vast majority of retrofit cases.

Building officials not only may require what is specifically called for in the code, but may determine, on a case-by-case basis, any additional requirements essential for structural, fire, or sanitary safety not covered by the code (§ 101.3). Building officials may also adopt regulations to interpret and implement code provisions and designate requirements applicable because of local climatic or other conditions (§ 109.1).⁶ Building officials must promulgate regulations for the use of "new materials" consistent with the code and with accepted engineering practice (§ 108.6).⁷ Accepted engineering practice is defined as what conforms to accepted principles, tests, or standards of nationally recognized technical or scientific authorities (§ 201.0). When specific code provisions or approved rules do not cover a

matter, accepted engineering practice is a set of regulations, specifications, and standards listed in code appendices (appendices B and C). These are specific standards of the American National Standards Institute (ANSI), the American Society of Mechanical Engineers (ASME), the National Fire Prevention Association (NFPA), the American Society for Testing Materials (ASTM), etc., as well as BOCA's Basic Mechanical Code and Basic Plumbing Code (see § 109.2).

Because, as will be shown, there is no set of specific requirements for solar heating and cooling systems in the building code, mechanical code, or plumbing code, nor nationally recognized standards adopted by reference, solar energy systems are subject to the full range of local building officials' discretionary powers. The power to determine special requirements for structural, fire, or sanitary safety may be of limited applicability to solar systems.⁸

The rulemaking power to secure the broad purpose of the code, and to designate requirements because of local climate or other conditions, enables building officials to enact any rules they desire for solar systems, subject, of course, to judicial review. Furthermore, the power to determine rules for the use of new materials appears rather broad. It may encourage standards for solar energy systems comparable to those for other heating and cooling systems. It could be used to require, for example, that all equipment meet nationally recognized standards and bear seals of an accredited authoritative agency, once such standards and agency have been established. Until then, equipment could be required to meet tests analogous to those for conventional systems. This is discussed further in the section on mechanical provisions.

Under the BOCA code, building officials have still another discretionary power. When there are practical difficulties in carrying out structural or

mechanical provisions of the code or approved regulations, building officials may vary or modify the provisions for the particular case if the spirit of the law is observed and safety is assured (§ 110.0). If an application is refused, the applicant for a building permit for a solar system could appeal to a board of appeals, arguing that the proposed solar system is as good or better than the conventional system it would replace or supplement (§ 127.1). The applicant could also argue that the provisions of the code for heating and cooling systems do not fully apply, an argument developed below. If this appeal fails, there is provision for court review (§ 127.6). Nevertheless, a modification and appeals procedure is not a satisfactory alternative to clear advance notice of requirements for solar energy systems. At least, this procedure cannot impose requirements more stringent than those already in the code and approved rules.

Unfortunately, the effect of the broad discretion given building officials, together with a lack of clear provision for solar energy systems, produces considerable room for uncertainty and fragmentation of markets even under these model provisions. The rules promulgated by building officials and the required tests for new materials are likely to vary with time and place, and could promote adoption of solar systems or make them too uneconomic to consider. Variations from the model provisions adopted by local legislatures can aggravate this. Even if nationally recognized standards were not specifically adopted by reference, the mere existence of national standards would not only be persuasive to local building officials and boards of appeals, but also to judges who review permit decisions.

Mechanical provisions. These provisions of the BOCA code are not specifically applicable to solar heating and cooling systems (at least to the

specifically solar parts of these systems; blowers and the like are covered). Application of mechanical provisions to direct or passive solar heating systems (other than blowers, if any) is particularly problematic. The BOCA code provides that when mechanical equipment (heating, air-conditioning, or ventilating equipment) is explicitly covered by the code, or under the approved regulations, the equipment may not be installed without a certificate of approval (§ 103.1). This clearly implies that building officials may issue regulations to cover equipment overlooked by the code. Any equipment for which provision is made, or the installation of which is regulated, may not be installed or altered without a permit (§ 113.1).

Article 11 controls the construction, inspection, and maintenance of all heating, blower, and exhaust systems with respect to structural strength, fire safety, and operation (§ 1100.1). Such systems and equipment constructed, installed, and maintained in accord with the BOCA Basic Mechanical Code are acceptable (the mechanical code is the accepted engineering practice; § 1100.2). Plans and specifications for the installation of a heating appliance, or of a heating, blower, or exhaust system must be submitted to the building official and a permit secured before work is begun (§ 1101.1). A heating appliance is "any device designed or constructed for the generation of heat from solid, liquid or gaseous fuel or electricity" (§ 201.0). Heating system is not defined, but the mechanical code does define central warm air heating system as "a heating system consisting of an air heating appliance . . ." and defines a forced air heating system and gravity heating system in terms of a central warm air heating system (§ M-201.0). (Mechanical code sections begin with M- and plumbing code sections begin with P-; the building code sections have no letter prefix.) Boiler is defined in both the building code and

the mechanical code as "a closed heating appliance intended to supply hot water or steam for space heating. . ." (§§ 201.0 and M-201.0).

This Basic Building Code contemplates a fuel-fired or electric system, not a solar system. Article 11 has requirements for inspections, tests, boiler rooms, gas- and oil-burning equipment, etc., but ultimately they all relate to heating appliances.

In the absence of provision in the building code itself, we may seek provisions in the mechanical code for solar heating systems. The design and installation of all mechanical systems must comply with the mechanical code. Mechanical systems include heating systems, ventilating systems, cooling systems, steam and hot water heating systems, etc. (§ M-100.1). Plumbing systems, sometimes referred to as mechanical systems, are not covered by this code (§ M-100.2)⁹

The purpose of the mechanical code is to establish minimum performance standards, implemented by specific requirements, to protect the public from inadequate, defective, or unsafe installations (§ M-101.1). In line with this purpose, building officials may approve alternative systems to those specifically prescribed if the proposed designs are satisfactory and comply with the code's intent, and if the materials, methods, and work offered are at least the equivalent of that prescribed in strength, fire resistance, and safety as well as quality, effectiveness, and durability (§ M-120.1). Note that these requirements go beyond mere considerations of safety to consumer protection. Because of the lack of data on solar energy systems, it would be difficult—if not impossible—to show quality, effectiveness, and durability equivalent to, for example, a gas heater or electric air-conditioner. A major purpose of the solar demonstration program is to develop a data base for predicting such matters.¹⁰

Building officials might reasonably deny building permits solely because the short-term warranties on systems indicate that manufacturers themselves lack confidence in the systems' durability. In light of the high first cost and lengthy payback period for solar systems, building officials could even require, and courts could well uphold, longer lifetimes and warranties than are given for conventional systems. Building officials must require that sufficient evidence be submitted to substantiate any claims regarding an alternative system's use; they may accept authenticated reports from BOCA or "other recognized authoritative sources" on proposed new materials and systems (§ M-120.1). Recognized authoritative source is not defined, but the intent is probably much the same as in references to nationally recognized testing or inspection agency. This latter term means an agency acceptable to the authorities having jurisdiction, that provides uniform testing and examination procedures under established standards, is properly organized, equipped, and qualified for testing, and has a follow-up inspection service (§ M-201.0). Examples are Underwriters' Laboratories, Inc. (ULI) and the American Gas Association (AGA).

Under the mechanical code, all warm air heating, ventilating, and air-conditioning equipment and appurtenances must be of an approved type (§ M-300.3). All blowers and fans must bear the label of a nationally recognized testing or inspection agency (§ M-318.1). Article 3 of the mechanical code has various requirements for furnace locations (a furnace is "a completely self-contained fuel-fired heating unit. . . ." § M-201.0), appliances on roofs, etc. As with article 11 of the building code, only conventional, nonsolar equipment is contemplated. Article 4 of the mechanical code has various requirements for boilers and steam and hot water heating systems, also contemplating only nonsolar equipment.¹¹ Presumably,

building officials would require solar equipment to meet requirements for piping, such as use of approved materials at the temperatures and pressure intended, conforming to standards listed in appendix C. This should create no problems for solar systems, since they operate at lower temperatures and pressures than do conventional systems.

Cooling equipment is subject to article 18 of the building code and article 8 of the mechanical code. The mechanical code's provisions do not apply to the use of water or air as a refrigerant (§ M-800.1). This means that low technology "solar" systems using nocturnal heat radiation, cool night air, evaporative systems, etc. are not covered.¹² The testing and approval procedures for alternative systems would therefore apply. For high-technology systems using solar collector heat with an absorption refrigeration system, the provisions would apply to the refrigeration part of the system. Since such equipment is the same as for conventional systems (except for typically using H₂O-LiBr instead of ammonia or freon), solar cooling systems should be under no added disadvantage due to the building code. The strictly solar part of a high-technology system would have to meet the testing and approval procedures for alternative systems.

We find then that the mechanical provisions of the BOCA Basic Building Code and Basic Mechanical Code do not specifically apply to solar systems, or at least to their uniquely solar parts like collectors and storage units. Without nationally recognized standards and certification agencies, solar systems are therefore at a potential disadvantage to conventional systems.

Miscellaneous provisions. This is the area of the model code most likely to be amended by adopting jurisdictions to meet local conditions. While reading the following, it should be kept in mind that local requirements could vary considerably.

Height regulations are sometimes mentioned as a potential problem for rooftop collectors. This code does regulate building heights (§ 305.0), but height is measured from the grade to the top of the highest roof beams of a flat roof, or to the mean level of the highest gable or slope of a hip roof (§ 201.0). Evidently, this code does not pose a height regulation problem for rooftop collectors. Zoning laws, however, often limit height of structures and may apply to what is mounted on the roof.

While roof slope is not regulated, the overhang of roof eaves is limited to three feet (§ 311.2). There are similar limitations on awnings (§ 313.2). This may be a problem for some passive designs in which large southern windows collect heat in winter but must be shaded in summer. However, a building official would probably approve a modification of this regulation (under § 110.1).

An impractical demand may be put on solar systems by lighting, ventilating, heating, cooling, and temperature requirements. The smaller the system load, the more competitive solar systems can be, since solar systems require high first costs relative to conventional systems, and the smaller any backup system can be. The code provides standards of natural light (§ 502.1) and natural ventilation (§ 503.1) that may be satisfied by openable windows of specified size relative to room area (§ 506.2) or by alternative devices (§ 506.4) or by artificial light and ventilation (§§ 504.0 and 514.0). The result of these provisions is to increase heat losses or gains through window glass, increase infiltration losses through cracks, or require mechanical systems to bring in outside air. Temperature requirements call for 72° in winter (70° if the BOCA Basic Housing Code is adopted (§ H-400.4)) and 78° in summer, assuming outside temperatures given in the ASHRAE Handbook of Fundamentals (1972) (adopted as a standard by reference in § M-108.1). These all

increase the loads on heating and cooling systems and hence boost the first costs of a solar system. An awareness of this problem is seen in current efforts to develop more energy conserving building standards, such as ASHRAE Standard 90-75, which would greatly reduce average required heating and cooling loads.¹³

The placement of a solar collector poses several possible problems, depending on how the system is to be used: on a roof; as roofing or the roof; as a wall or a wall veneer; as a separate structure on the ground; or as an awning, either supported from the ground or not. Safe support is of course required (§ 701.1). The weight of mechanical equipment must be allowed for in design of new buildings and may require structural changes to existing buildings for solar retrofits (§ 704.2). If structural parts exposed in a retrofit are found to be unsound, they must be made to conform to code requirements (§ 705.3). The costs of such strengthening of framework could be high, but this safety requirement would not, and should not, be waived. Whenever there is reason to question safety for the intended occupancy or use of any structure, the building official may require a load test or accept certified reports of such tests from accredited testing authorities (§ 701.3). As there is no nationally recognized standard or accredited testing authority for solar systems, the building official could impose costly and time-consuming tests of his own devising. The applicant would have to pay for these tests.

Within the bounds of the "fire limits," areas containing congested business, commercial manufacturing, and industrial uses or development, exterior wall fireresistance rating requirements are higher than elsewhere (§ 302.2.3). This may preclude use of some collectors as walls or on walls. Such locations are not prime candidates for wall collectors anyway, unless there is a large space between the collector wall and the next building. If this space is wide, the usual fire limit

restrictions are somewhat relaxed; they are waived if the space is 30 feet or more (§ 302.2.3; and see Table 302).

An allowance for the effect of wind loads must be made for all roof structures (§ 715.2), and special allowance must be made in areas subject to hurricanes or other unusual wind exposures (§ 716.1). Such provisions are clearly necessary for safety.

Structures on roofs within the fire limits or more than 40 feet high must be of noncombustable materials (§ 925.1). Penthouses, and possibly other enclosed roof structures including some collectors, must conform to the requirements for fire resistance applied to walls on the next lower story (§ 925.4). Water tanks holding over 500 gallons must be supported by noncombustable framing if above the lowest floor and be provided with a device for discharge in an emergency (§ 925.8).

Solar collectors and storage units that are preassembled or shipped in knock-down form for assembly at the site would be treated as prefabricated subassemblies under this code (§ 1900.1). Prefabricated subassemblies are subject to the same kinds of rules for approved materials and methods (§ 1900.2), and for new materials tests and evaluation (§ 1900.3), but the rules go even further. When reliable experience records are lacking, building officials may require accelerated tests of prefabricated subassemblies to determine durability, weather tightness, and weather resistance, or they may accept certified reports of approved and recognized testing authorities (§ 1907.3). When existing authoritative test data are unavailable, building officials may also require comparative tests of traditional standard construction (§ 1907.4). This could mean, for example, side-by-side testing of a traditional roof versus a solar collector roof, a most costly testing procedure.

ICBO Uniform Building Code

The ICBO Uniform Building Code has been widely adopted, with local or state amendments, in cities and counties of the West and Midwest, and as a mandatory statewide code in several states (Alaska, Idaho, Indiana, Minnesota, Montana, New Mexico, Oregon, and Washington).¹⁴ According to Field and Ventre's survey, model codes are most evident in the West and South, and 92 percent of 244 western cities responding said they use ICBO's Uniform Building Code.¹⁵

For our analysis, we used the 1976 edition and accompanying mechanical and plumbing codes.¹⁶ As with the BOCA code, many jurisdictions have adopted earlier editions (the 1973 edition in particular), but changes since 1973, which are indicated in the latest edition, are not significant for our purposes.

Administrative provisions. The ICBO code's purpose (§ 102) and scope (§§ 103 and 104) are much the same as BOCA's. Alterations are treated similarly, although keyed to percentage of present building value, rather than BOCA's replacement cost (§ 104 (b), (c), and (d)). Unlike the BOCA code, the ICBO code does not grant building officials the power to impose special requirements on a case-by-case basis or to adopt regulations to supplement the code. In other words, building officials have less discretion to impose unique local requirements. The provisions for testing and approval of alternative materials and methods alone, however, raise nearly as high a potential barrier as under the BOCA code. Building officials may approve any alternative if they find that the proposed design complies with general design and structural strength requirements (loads on roofs, floors, etc.; chapter 23), and that the material, method, or work offered is at least the equivalent of that prescribed in strength, fire resistance, and safety as well as quality, effectiveness, and durability (§ 106). As with the BOCA code, the concern reaches beyond safety

to consumer protection. Building officials must require sufficient proof for any claims regarding the alternative's use (§ 106), and when there is insufficient evidence to show code compliance or to substantiate claims for alternative materials or methods, building officials may require tests by an approved agency at the owner's expense (§ 107). If no appropriate test methods are specified, building officials determine the test procedure.

The ICBO code also creates a five-member board of appeals to determine the suitability of alternative materials and methods (§ 204). Although not spelled out, an applicant for a permit that is denied, or other aggrieved party, may presumably appeal to this board.

Building officials do not appear to have the power to grant modifications, since permits presuming to give authority to violate or cancel provisions of the code are invalid except to the extent that the work or use authorized is lawful (§ 302(c)).

Despite differences from the BOCA code, the ICBO code's administrative provisions also may encourage market fragmentation, uncertainty, delay, and added expense.

Mechanical provisions. Unlike the BOCA code, the ICBO code itself has no provisions for mechanical equipment, except for requiring that habitable rooms in residences be capable of maintaining a temperature of 70 degrees at three feet above the floor (§ 1311 and 1410). In the chapters dealing with the various kinds of occupancies,¹⁷ there are provisions for "special hazards" requiring chimneys and heating apparatus to conform to the Uniform Mechanical Code.

The Uniform Mechanical Code covers heating, ventilating, cooling, and refrigerating systems (§ M-103). (The ICBO codes themselves do not use the M-and

P-prefixes of the BOCA codes; this abbreviated citation is used here for convenience.) As with the BOCA code, various national standards are adopted (§ M-103). There are provisions for alternative materials and methods (§ M-105) and a board of appeals (§ M-203) that are essentially the same as those in the Uniform Building Code (§§ 106 and 204). Heating, ventilating, and cooling appliances must be approved for safe use by building officials or comply with nationally recognized standards as determined by an approved testing agency. Every installer must show that an appliance is constructed in conformity with the mechanical code's requirements. The label of an approved testing agency attached to the appliance is acceptable proof (§ M-502). Absent such a label, the procedures for testing and approval would apply. The provisions in this mechanical code are keyed to listing with a testing agency; installation must conform to the conditions of listing (§ M-504). The code assumes the appliance consumes either fuel or electricity (see, e.g., section M-507: labeling requirements). Under this mechanical code, too, the lack of nationally recognized standards and an approved testing agency to certify compliance and provide listing and labels is a serious liability for solar heating and cooling systems.¹⁸

Miscellaneous provisions. There are quite a few variations here from the BOCA code. Again, we would expect more variation, due to amendments, among adopting jurisdictions.

As with the BOCA code, "height" is defined in terms of the roof, thus ignoring solar equipment on the roof (§ 409). But the ICBO code limits the aggregate area of all penthouses and other roof structures to one-third of the area of the supporting roof (§ 3601(b)). Although it is not clear whether solar collectors would be considered roof structures, examples given (towers, spires, and radio

masts, § 3602) suggest that they would. On the other hand, roof structures are supposed to be constructed with walls, floors, and roof (§ 3601(d)), which would hardly apply, say, to a radio mast. We expect that this one-third limitation would not apply to solar collectors. If it did, building officials would have no power under the code to grant a modification. This may influence their interpretation of the limitation rule.

A roof must be sloped enough to assure water drainage, but there is no limitation on slope (§ 2305(f)). Roof overhangs and awnings are limited to a percentage of yard width (§§ 504 and 1306(d)) and awnings are similarly limited (§ 4506). This may hinder some passive designs. That awnings must be collapsible would probably rule out mounting collectors on them (§ 4506(b)).

There are lighting and ventilation requirements (§§ 605, 705, etc., through 1405) for each occupancy, and minimum heating requirements of 70 degrees three feet off the floor in habitable rooms of residential occupancies (§§ 1311 and 1410). These requirements are higher than necessary for health and comfort, and may make solar equipment somewhat less competitive.

The ICBO code sets minimum load strengths applicable to collectors used as roofs or walls, or mounted on roofs or walls (chapter 23). Unlike the BOCA code, there is no provision for special load tests, but the general testing and approval procedures would apply to collectors on roofs or as wall veneers. Prefabricated construction rules apply only to structural units assembled prior to incorporation in the building (§ 5001(c)). Under these rules, collectors to be used as roofs or walls could be tested for durability and weather resistance (§ 5003).

Such miscellaneous requirements as these do not appear to be particularly serious barriers, especially when compared to potential testing and approval problems generally.

SBCC Standard Building Code

The SBCC Standard Building Code has been widely adopted in southern cities and counties. It has not been adopted anywhere as a mandatory statewide code.¹⁹ According to Field and Ventre's survey, 56 percent of southern cities responding said they used this code.²⁰ The Florida Solar Energy Center reports that all but three counties in Florida are now using this code.²¹

For our analysis, we used the 1976 edition of the building code and accompanying mechanical and plumbing codes.

Administrative provisions. The SBCC code has administrative provisions very similar to those of the BOCA code. Its statement of purpose (§ 101.2) and scope (§§ 101.3 and 101.4) are much the same. As under the BOCA code, building officials may set requirements for strength, stability, safety, or health for situations not specifically covered (§ 103.5). Likewise, alternative materials and methods may be authorized by the building official. The alternative must be shown to be at least the equivalent of that prescribed in strength, fire resistance, and safety as well as quality, effectiveness, and durability (§ 103.6). Building officials may require tests by an approved agency at the expense of the applicant (§ 104). Building officials' actions are subject to review by a board of adjustments and appeals (§§ 111-113). Building officials do not, however, have the rulemaking power of officials under the BOCA code. The board of adjustments and appeals, instead of the building official, as under the BOCA code, may vary the application of any provision to any particular case when the enforcement of the provision would do a manifest injustice and be contrary to the spirit and purpose of the code or the public interest, or when the board feels that the building official's interpretation should be modified or reversed (§ 113.1(a)). Thus, there is some possibility for relaxing the code's rules, but only after the delay involved in an appeal.

Mechanical provisions. As with the other codes, the SBCC code adopts its companion mechanical code for heating, ventilating, and cooling equipment (§ 801.1) and plumbing code for "plumbing" (§ 808). There is an additional Standard Gas Code for installation of consumer gas piping and gas appliances. Again, solar energy systems are not specifically mentioned or provided for, and there are the usual provisions for testing and approval of equipment not specifically approved by the code. The lack of generally recognized standards and testing procedures, along with a lack of listing, may cause the same fragmentation, uncertainty, delay, and expense described earlier.

Miscellaneous provisions. The SBCC code also includes various provisions that might be considered minor barriers. For example, as a variant from the other codes, the SBCC code states that when the aggregate area of all roof structures exceeds one-third of the roof area, the building's height is measured to the top of the highest roof structure (§ 402.2(a)). Such miscellaneous provisions would have to be kept in mind while designing a building, but would probably have no great impact on use of solar equipment.

Summary of Code Barriers

All three major model building codes give the building officials under them considerable discretion in application of the codes, especially to materials, equipment, and methods not specifically provided for. Under the BOCA and SBCC codes, building officials may determine, on a case-by-case basis, any additional requirements considered essential for safety in situations not covered by the codes. Under the BOCA code, building officials may also adopt regulations to interpret and implement code provisions and designate requirements applicable because of local climatic or other conditions; this rulemaking power could be used to either

promote or discourage solar equipment, at the building officials' discretion. Under the ICBO and SBCC codes, such rulemaking power is not granted.

Under all three model codes, building officials may approve the use of other materials, equipment, or methods than those specifically authorized. Any alternative must be shown, to the building officials' satisfaction, to be at least the equivalent of that prescribed in the codes in strength, fire resistance, and safety as well as quality, effectiveness, and durability. Demonstrating that these six criteria have been met may be difficult, and having to demonstrate this in a different way for each building official, in each jurisdiction, for each installation, may be infeasible. In this showing, building officials may require testing, at the applicants' expense, by approved testing facilities (chosen by the building officials) using approved test methods (chosen by the building officials unless methods are specifically provided for in the code). For many other kinds of equipment, nationally recognized standards, test methods, and listing agencies are specified in the codes. For solar energy systems, however, such standards, methods, and agencies have not yet come into being, let alone gained code approval. There are standards, such as the ASHRAE standards, but these are not appropriate to the needs of building codes. This is discussed further below.

So long as the spirit of the law is observed and safety is assured, the building official under the BOCA code and a board of appeals under the SBCC code can modify the application of the codes to particular cases. Grant of a modification is discretionary under these codes; it is not available under the ICBO code.

Under all three model codes, the applicant can appeal to a board of appeals from any unfavorable ruling by the building official. Appeals would involve additional cost, delay, and possibly further elaborate showings.

All three model codes have special provisions for heating, ventilating, and cooling appliances. In addition to the building code provisions, each code has a companion model mechanical code concerned primarily with such appliances. These appliances must be approved by building officials or comply with nationally recognized standards as determined by an approved testing agency. The label of an approved testing agency attached to the appliance is accepted as proof of compliance. Application of these provisions is problematic due to the definition of "heating appliance," etc. In any event, there is no agency to certify compliance, and—as yet—no nationally recognized standards with which to comply. Thus, solar energy systems are at a disadvantage to conventional heating and cooling systems, for which a showing of code approval can be as simple as showing a label. Solar energy equipment is subjected to the kinds of requirements for alternative systems discussed earlier.

The effect of these provisions of the model codes is to give the building officials under them such discretion that there is great potential for fragmentation of markets as well as for delay, additional expense, and uncertainty in the processing of permit applications.

While the lack of standards may be the most important building code barrier to solar systems, there are other possible barriers. Unrealistically high demand on solar heating systems for buildings may result from the model codes' high minimum temperature requirements and from large minimum ventilation and light requirements. Limitations on overhang of roofs and awnings may interfere with best passive solar designs. Standards for prefabricated assemblies may require costly accelerated tests of prefabricated assemblies to determine weather tightness and weather resistance. Other problems seen in the literature on solar

systems, but not found in the model codes, are limitations on building height preventing collectors on roofs, chimney and plumbing clearances, retroactive application of current standards to existing buildings in retrofit situations, roof slope requirements, using collectors as roofing or walls instead of on roofs or walls, and inspectors' unfamiliarity with solar energy systems.²²

Probability of Realization of These Barriers

Although these potential barriers due to testing and approval procedures and other various requirements do exist, they have not been reported as a serious practical problem for solar equipment users so far. Some delay in processing building permits has occurred but we know of no documented cases of excessive delays or insoluble problems.²³

Our review of the literature revealed the frequent assumption that because there is no specific provision for solar heating and cooling systems in building codes, there is no barrier in the codes.²⁴ Steven Rivkin has said that "rather than serving as a retardant, existing building codes have no bearing at all on the development of solar systems."²⁵ Rivkin's statement seems contrary to his description in The Building Code Burden²⁶ of the difficulties in adopting innovations.

For example, plastic pipe for waste drains and plumbing vents is a much less radical innovation than a solar system. It can easily be shown to be the equal of the cast-iron pipe it is offered to replace for these purposes. Plastic pipe has been adopted by builders wherever permitted because it is cheaper to buy and install; but plumbers and cast-iron pipe producers have resisted its use for this very reason. The pressure of labor organizations and cast-iron pipe producers has made the widespread adoption of this innovation slow and difficult.²⁷

If serious difficulties can occur with such a simple item as pipe, which is so similar to its counterpart, the possibility of problems with solar energy systems with their unique collectors can hardly be remote. It is possible that building officials will continue to look upon solar systems in a friendly way, and never literally apply the codes to them. We suggest that building codes may not have yet been seen as a barrier to solar equipment because solar systems in general have not been economically competitive with the usual fuel-burning and electric equipment, and have not substantially threatened labor. If the channels for manufacturing, marketing, and installation of solar equipment turn out to be the same as for currently used heating and cooling systems, less resistance may be encountered than with other innovations. It seems more likely that as solar systems gain popularity there will be persons, in either labor or supply of competing systems, who will lobby for strict application of the codes. At that point, if opposing forces become organized before building codes can be modified to accomodate solar equipment in the same way as conventional equipment, it may be much more difficult to change the codes. Such being the case, it would be better to act as soon as possible to revise codes, rather than too late.

Solutions

Solar heating and cooling are not specifically provided for in these model codes, nor, presumably, in the thousands of local codes based on, or similar to them. The ideal solution to this problem would be nationally recognized standards and testing procedures for the various kinds of solar energy systems and nationally recognized accreditation agencies to certify compliance with these standards and grant listings. These standards would be adopted by reference in all local and state building codes, and listing would be accepted as sufficient proof of code approval if

the equipment were installed in compliance with the conditions given in the listing. This would put solar energy systems on the same footing with other heating and cooling systems.

Although testing and approval procedures appear to be the most important barrier in building codes, various specific building code provisions could pose problems for some solar designs. Some examples have already been suggested; the local variants of codes are likely to produce many others. To deal with this, either the codes could be revised with an eye to removing such barriers, or the codes could, under appropriate circumstances, exempt solar energy systems from application of particular provisions so long as the requirements of safety, health, and structural strength are met. The two approaches could be combined for the most effective results.

Standards for building codes. The purpose of building codes is to ensure public safety, health, and welfare insofar as they are affected by building construction. Their main concerns are structural strength, exits, sanitary equipment, light, ventilation, and fire safety. While concerned primarily with safety and health, they also, as indicated earlier, have incidental concern with protecting consumers and occupants of structures from inadequate performance, in terms of the effectiveness, durability, and reliability of materials, components, and systems.

In solar energy systems, the only unique component is the collector. Once heat is collected, it is transported, stored, and utilized by means that have in general been long used in conventional energy systems.²⁸ Thus it is primarily collectors that can be problematic under building codes. Where performance of whole systems must be approved, as with space heating systems, however, the

whole system may be affected; but the usual standards for other systems should generally be applicable without impeding solar equipment's use. Pipes, ducts, valves, storage tanks, controls, wiring, etc., are already provided for, even though their use may be novel.

The principal hazards to health and safety with solar energy systems are of several kinds. First there is the risk of leakage or explosion due to damage from high temperatures, pressures, corrosion, other component failure, or impact, and risk of human contact with hot surfaces or broken glazing. There is also some risk of contamination of drinking water with toxic coolants if plumbing is not properly installed or designed (nontoxic coolants are available), and there are potential structural problems leading to failure from high wind or snow loads if collectors are not made strong enough or not securely mounted.

The extent of these hazards would vary somewhat depending on the application. Applications for heating of buildings using flat-plate collectors or passive (indirect) systems involve much lower temperatures and pressures than applications using focusing collectors (used mostly in absorption cooling), which are potentially more hazardous than flat-plate collectors because of higher temperatures and pressures. It may thus be appropriate for building codes to treat the different kinds of hazards differently, requiring separate standards for materials and equipment depending on the temperature and pressure used in the application.

A main need of building codes is for specific standards, which are lacking for solar energy systems. The codes need standards for materials, equipment, and installation. Equipment standards for solar equipment must include performance standards and test methods for collectors, storage, and whole systems, not only for

thermal performance (output for a given solar radiation input), but for factors relating to health, safety, and structural strength. For solar heating and cooling of buildings, the federal government has developed standards for both commercial and residential applications for use in the solar heating and cooling demonstration program. These standards are being used as the basis for developing private-sector standards that will eventually become nationally recognized standards appropriate for adoption by building codes. Unfortunately, the private standards that have been developed so far—ASHRAE 93-77 and 94-77²⁹—only concern the thermal performance ratings of solar collectors and storage. No guidance is given on the crux of building code concern—health, safety, and structural strength. Standards for these rating factors and for installation are still needed, and they will have to be in a form appropriate for building code use.

Certification of compliance with standards. Certification of compliance can be handled in a number of ways. Manufacturers could be permitted or required to certify compliance with the standards themselves, under penalty of either civil or criminal sanctions for false certification. A trade association could certify compliance based on submissions from manufacturers, with periodic testing by an independent laboratory of samples out of production to assure and verify the accuracy of submissions. The Air-Conditioning and Refrigeration Institute will be doing this soon for thermal performance of collectors and storage devices based on the ASHRAE standards; the institute has more than fifteen years' experience certifying equipment in this way.³⁰

While these kinds of certification may be useful, especially for certifying performance for purposes of building consumer confidence, they would not satisfy the usual building code requirements for listing by an approved testing agency.

Under the three model codes, the certification needs to be done by a testing agency qualified and equipped for experimental testing, and maintaining an adequate periodic inspection of current production; listing of such organizations is not granted on the producer's representations alone, but on the basis of testing, including safety tests. (The national model building code groups also grant product approvals that can be accepted uniformly by building officials under their model codes.) Certification by such an agency, whether private, state, or federal, would be much preferred to either self-certification or voluntary certification (whether or not subject to serious sanctions).³¹ Self-certification might be used as a stopgap measure, but it would hardly be a satisfactory long-run solution to the need for certification.

Federal role in solution. There are several possible roles for the federal government in providing for solar standards, certification, building code acceptance of the standards and certification, and removal of various other building code impediments to solar energy systems. Current federal efforts cooperate with and encourage private development of standards and certification, but there is no announced plan to force standards on the states or localities or to encourage adoption other than by persuasion. Low temperature thermal applications are rapidly becoming popular, especially water and space heating. The risk of the potential barriers increases as popularity grows, since it may be in someone's interest soon to call for strict application of building codes to solar installations. Although possible, we would not recommend a federal solar building code, or even federally-mandated standards applicable to all states and localities. This is discussed further later. A coordination and certification of state building code programs for solar energy would make sense, however.

Alternative state programs. (1) Standards. Alternative state programs should be acceptable so long as the variations in their code requirements are based on state and local conditions and do not unreasonably burden interstate commerce in solar equipment. It would be best if states adopted statewide mandatory requirements for acceptance of solar energy systems that complied with the latest version of the federal standards until the private-sector standards have been developed, and then with those standards thereafter. A recently enacted Minnesota law in essence does this.³² This law requires a state agency to promulgate standards for systems for heating and cooling of buildings based on the federal interim criteria (the current federal standards at the time the law was passed), and then to update them as later federal standards are developed, or as new technology becomes available. This effectively adopts the latest federal standards, which should be acceptable under a federal certification program. To protect against attack on grounds of unconstitutional delegation of powers to the federal government (to legislate in an area of state responsibility), the Minnesota law has the state administrative agency adopt the new versions of the federal standards as they develop. This mechanism also facilitates changes in response to new technologies that might not be reflected in the federal standards. "Reasonable conformance" language in the law allows for some leeway to adapt to local conditions. Model legislation should be written along such lines and also provide for the adoption of industry's consensus standards once they are developed. A mechanism for drafting model legislation is discussed later.

(2) Certification. As mentioned earlier, there might be private, local, state, or federal certification of solar equipment. Different aspects of systems could be certified by different agencies. For our purposes here, it is sufficient that a state

offer to accept certifications that will not place an undue burden on interstate commerce. States will of course want to test for matters bearing on safety, health, and structural strength; from a building codes perspective, as long as certification results in code approval, it need not include testing for thermal performance rating, which is more a concern for consumer protection. So long as the standards applied and test methods used are reasonably consistent, predictable, and not unreasonably costly, the federal government should permit the states to require them.

In this country, certification has traditionally been a private-sector function of test labs like Underwriters Laboratories. But federal certification of solar equipment for heating and cooling of buildings has been recommended.³³ Indeed, the federal government, which developed solar standards in the first place, may be best able to apply the standards for certification. Early experience with federal certification of systems for the HUD demonstration program proved unsatisfactory, however, and that may lead to opposition both within and outside the government to any federal certification program.³⁴ The federal government, in any event, has not wished to pass on the relative merits of one commercial product versus another, which certification inevitably involves. A study might be made of whether federal, state, or private certification is most feasible and desirable from the broad perspective of best encouraging adoption of solar energy systems. This should not be necessary for purposes of removing the building code barriers, however.

State certification for ratings of thermal performance of collectors based on federally-developed standards is underway in Florida by the Florida Solar Energy Center at Cape Canaveral. It should be satisfactory for a state to choose to do its own certification in this way, so long as the standards and methods are appropriate,

and provided the certification results in statewide code approval. State certification is particularly appropriate where there is a statewide mandatory code: Oregon has what is called "Spec house" approval for new methods or materials; the State Building Code Department approval is good throughout the state under a statewide mandatory code (ICBO code based).³⁵ Statewide acceptance may be problematic if the state lacks a mechanism for enforcement against local officials. In Washington, the State Building Code Act is not backed by monitoring or penalties for nonenforcement; such a situation is hardly satisfactory. Even self-certification by manufacturers, provided there is some mechanism for assuring that it is done honestly, should be adequate for removing the code burden, provided all code jurisdictions in the state will accept that as equivalent to code approval.

(3) Various code impediments. There are basically two broad approaches to deal with various specific building code provisions posing problems for solar energy systems. States could write statewide mandatory codes revising building codes to remove the problem provisions or exempt solar systems from application of particular provisions so long as the requirements of safety, health, and structural strength are met. Or they could have programs delegating responsibility to the local level, with state agency review of the local solutions. The former approach is most natural when the state has already adopted a statewide mandatory building code, as several have, but should also be possible where localities have responsibility for building codes. The latter approach may be more appropriate where the states have a wide variety of local climates and kinds of construction. Either approach should be acceptable as long as it is properly done. This would be most feasible if the states had models to work from and to adapt, if necessary, to local conditions.

Drafting needed models. It would be best for the federal government to bring together the model building codes organizations to develop the models and suggest circumstances in which various options might reasonably be accepted by the federal government. An effort to develop models is underway now.

The National Bureau of Standards, with funds from the Department of Energy, has awarded contracts for the development of model code provisions for solar heating and cooling. The awards went to BOCA, ICBO, SBCC, the National Conference of States on Building Codes and Standards (NCSBCS), the Council of American Building Officials, the National Institute of Building Science, the American Institute of Architects Research Corporation, and the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE). This effort is to result in uniform code provisions for adoption by states and localities covering safety and health requirements. Recently the Department of Energy has broadened the opportunities for participation in this process by inviting comments from industry, labor, consumers, states, and local governments at hearings in May of 1978. In developing the model provisions, the contractors will use the comments received and the federal standards developed in the Solar Heating and Cooling Demonstration Program as well as privately developed and other government developed solar energy standards and codes (such as the IAPMO Code discussed in the Appendix below).³⁶

This is similar in pattern to the earlier effort to adapt ASHRAE's Standard 90-75, Energy Conservation in New Building Design into a building code format.³⁷ ERDA contracted with NCSBCS to bring together the major national building code organizations to develop a model code for energy conservation in buildings. The new procedure for drawing on comments of other interested parties will hopefully produce more widely acceptable—and adopted—results.

The Department of Energy has awarded a contract to the Solar Energy Research and Education Foundation (SEREF) of the Solar Energy Industries Association to develop a solar collector rating, certification, and labeling program. SEREF's program is to establish standards of reliability, durability, and safety—not just standards of thermal performance. There will be an accreditation procedure to assure that labs will test with accuracy and consistency.³⁸ Although we cannot be sure at this point, this will probably result in what is needed to satisfy building code certification requirements.

The code provisions being developed could be offered to states and localities as models for adoption or adaptation along with the standards and building codes incentives, if any. It would appear that only energy conservation, however, would be a desirable building codes incentive to solar energy systems; other incentives seem better left to subsidies, loans, loan guarantees, property tax exemptions, or income tax deductions or credits.

Also included in this program should be models for state programs, when appropriate, to delegate responsibility to localities subject to state review, and recommendations on how to promote most effectively the prompt acceptance of solar energy systems and other energy saving construction technology.

Compelling or encouraging state adoption. Federal legislation could make adoption of the results of such a program mandatory nationwide, or make adoption by the states voluntary, but with incentives to make state adoption likely. The great advantage of the first of these options is that it would most quickly result in uniform nationwide standards. The federal enactment of even a national solar building code, although unprecedented, could be sustained by the courts, assuming it is properly drafted, as within the broad powers of Congress to regulate

commerce. Opposition to such precedent-setting legislation (even in so limited a field as solar standards), however, might be overwhelming. It may be nonetheless desirable for the Department of Energy to study the feasibility and desirability of a mandatory as opposed to a voluntary program with or without incentives. The other option of leaving the states the choice of whether to adopt the standards and model code provisions would no doubt have less opposition. But achievement of the national uniformity of a mandatory program would be unlikely.

The most reasonable approach would appear to be to encourage state adoption, with generous incentives for states to do so. An alternative would be to pass legislation requiring states to set their own standards and revise their building codes by a specified date, or face federally-determined standards and codes set for them. This could be a fast solution, but would be much more likely to yield enough local variation to prove a burden on interstate commerce in solar energy systems.

Performance codes. There have been other suggestions for changes in building codes to promote innovation in general and solar systems in particular. Most notable is the proposal for performance-oriented building codes.³⁹ Such codes could provide the flexibility needed for solar systems. However, building code departments, which would presumably administer the codes, are usually only funded for, and experienced in, administering straightforward specification codes.⁴⁰ Even if the performance code only applied to solar systems, the limited funding and experience of building officials might be overtaxed, and potential solar system users would still be left in a disadvantageous position relative to users of familiar conventional systems. For this reason, it makes sense to essentially integrate solar systems into the present specification-oriented codes in the manner suggested above.

APPENDIX

IAPMO's Uniform Solar Energy Code

This code is currently the only model code for solar heating and cooling systems from the model-code-generating organizations. Eyeing the need for a uniform solar energy code for the thousands of Uniform Code jurisdictions, IAPMO (The International Association of Plumbing and Mechanical Officials) passed a resolution at the September 1975 Annual Business Conference to form a committee to draft a basic solar energy document. The first edition of the code was published in mid-1976. IAPMO adopted the code at the September 1976 Annual Business Conference. It was adopted without substantial amendment to the draft. IAPMO admits the imperfection of the code in its foreword, but offers it for adoption anyway. IAPMO urges users of the code to suggest any amendments they find necessary, so that uniformity can be maintained and other jurisdictions benefit.

Although it was laudable of IAPMO to try to provide a model code for solar heating and cooling systems, we believe that this particular version should not be adopted at all. There are too many errors, omissions, and lack of particular standards. The most disappointing aspect of this effort is that it is not keyed to the evolving federal standards and developing private-sector standards for solar heating and cooling systems, but goes off on a tangent of its own. Even for its limited scope, this code is seriously flawed. (For another criticism of this code see "Solar Energy Code: From Flaw to Law" and "IAPMO Publishes 'Uniform Solar Energy Code'," CRC 3 (No. 3. 1976): pages not numbered, a periodical by the American Institute of Architects Codes and Regulations Center.)

Unfortunately, the IAPMO Code has, according to IAPMO, been adopted in a number of jurisdictions, including Los Angeles City, Los Angeles County, and other areas of Southern California as well as some parts of Arizona and elsewhere.

A chapter-by-chapter analysis follows.

The very title, Uniform Solar Energy Code, is unsuitable: this code only covers some aspects, mostly plumbing components, of the active solar heating and cooling of buildings. It does not provide for photovoltaics, for example, beyond a short definition (§ 117(d)), or for passive systems at all. But the sweeping definition of solar systems would include photovoltaics and other systems not provided for: "Solar System — As used in this Code, is any configuration of equipment and components to collect, convey, store and convert the sun's energy for a purpose" (emphasis added, § 120(f)). Even for solar heating and cooling, this code is not as comprehensive as the Intermediate Minimum Property Standards for Solar Heating and Domestic Hot Water Systems developed by the NBS for HUD. A more suitable name would have been "Uniform Solar Heating and Cooling Code." Even better, it could have taken the form of amendments to the Uniform Mechanical Code and Uniform Plumbing Code.

Chapter 1* defines terms used in the code. Some of its definitions are not very helpful. For example, absorbtion refrigeration is defined as a cooling system

* The inconsistencies in labeling of chapters, sections, and paragraphs in this code bear noting. According to the table of contents, the code consists of "Part One" and "Appendices." There is no part two. Although the first chapter is labeled "Part I," the second is labeled "Chapter 1," and the third, "Chapter 2," etc. The sections in part one are labeled "10.1" to "10.5" and "20.13." The sections in what are titled Chapters 1 through 9 are labeled "sec. 101" through "sec. 901," except that in chapter 2 they are lettered rather than numbered. Generally, paragraphs are labeled "(a)," "(b)," etc., but the paragraphs of sections 20.3, 20.5, 20.6, 101, and 301 are not labeled at all. Section 402 begins with three unlabeled paragraphs, then has a fourth labeled "(a)" and a fifth "(b)." This makes citing paragraphs needlessly untidy: for example, "§ 301, second unlabeled paragraph." There is no labeling of parts within the appendices, which make up half the code.

operated by a solar system (§ 102(b)). Does this mean that any solar-operated cooling system is an absorption system for purposes of the code, such as an electric air-conditioner operated on power from solar cells? (Surely it does not mean that a gas-fired absorption refrigeration system is a solar system.) Because the code is not keyed to the federal solar heating and cooling demonstration program, technologically simpler systems of "solar cooling" are ignored, such as nocturnal heat radiation. (See § 3(2) of the Solar Heating and Cooling Demonstration Act of 1974, Pub.L. 93-409.) There is no definition of tank, or storage tank, although this term is used repeatedly (e.g., §§ 20.6 and 601).

Chapter 2, on the quality of materials, is helpful because a table in it lists nationally recognized materials standards that would apply to many plumbing-type parts of a solar system. Standards cover pipes, valves, certain water heaters, pressure vessels, and a few miscellaneous components. They do not cover such important components as glass and plastic for glazing or aluminum for collectors. This latter item may be just an oversight or it may reflect lobbying by the Copper Development Association, author of the appendix. This chapter also provides approval procedures for alternative materials (especially paragraphs (e) through (j)).

Chapter 3 provides general requirements for plans and for certain aspects of installation, mostly piping and leak testing. When required, plans must be both prepared and certified by a registered professional engineer (§ 301, second unlabeled paragraph). It is not clear why architects could not do such work. This may merely reflect the composition of the drafting committee, in which engineers were represented but architects were not (Foreword).

In existing buildings where solar installations are to be altered, repaired, or renovated, the code allows deviations from its provisions if necessary and first

approved by the building official (§ 304). To permit approval of deviations by the building official is contrary to the usual practice under the uniform codes and seemingly inconsistent with the code's own provision that approval of any plans or specifications does not sanction any violation of the code (§ 20.5, seventh unlabeled paragraph). (Section 20.5 should, but does not, refer to section 304 as an exception, if that is what is intended.)

All welding must be done by approved welders and conform to unspecified, nationally recognized standards (§ 316(c)). There is no provision in this code, however, for the approval of a particular group to install solar systems generally. This is in contrast to IAPMO's Uniform Plumbing Code, which specifies approved plumbers for all plumbing work (§ P-2.2).

Chapter 4 provides more requirements for piping, including several provisions to avoid contamination of drinking water by water from solar system lines (§§ 401 and 402). The provisions of this chapter seem reasonable, except that use of PVC or other plastic pipe would require approval as an alternative material. (Section 403 permits use of copper, copper alloy, galvanized malleable iron, or galvanized steel pipes.)

Chapter 5 has similarly reasonable provisions for joints and connections.

Chapter 6 provides for tanks. This chapter refers to storage tanks, heat exchanger tanks, prefabricated tanks, gravity tanks, concrete tanks, metal tanks, and expansion tanks (open expansion tanks and airtight or closed type tanks). Unfortunately, none of these terms are defined. Storage or heat exchange tanks must be constructed in accord with unspecified nationally recognized standards approved by the building official (§ 601(a)(4)). Tank covers must be capable of supporting an earth load of at least 300 pounds per square foot, unless buried more

than three feet deep (§ 601(a)(6)). This seems to apply even if tanks are not buried. All devices attached to or within a tank must be accessible for repair and replacement (§ 601(a)(7)). Accessible is defined as having access, but this may first require the removal of an access panel, door, or other obstruction (§ 102(d)). Unless several feet of earth is the equivalent of an access panel or door under this code, this implies that a buried tank may not have any devices (not even pipes!) connected to it.

Chapter 7 provides for collectors—the one unique element in solar energy systems—in just over a single page. One remarkable provision requires collectors to be located to take advantage of the sun (§ 702(b)). Such a superfluous provision is of little help and invites ridicule. This chapter sets out several unspecific requirements that would baffle rather than guide designers and building officials. To be useful, this chapter needs references to existing standards, or needs to set its own performance standards. For example, collectors manufactured as a complete component must be listed by an "approved listing agency" (§ 701(h)). Frames and braces exposed to the weather must be constructed of materials "suitable" for exterior locations (§ 701(a)). Glass used in collector construction must be "tempered" (§ 701(e)), and plastic used in collector construction must be "suitable" (§ 701(f)). These requirements are not unreasonable, yet without mention of a listing agency (if any exists), or without specific standards for frames and braces, tempered glass, or plastics, the requirements have no utility.

The collector assembly must be capable of withstanding stagnant conditions (high solar flux/no flow) (§ 701(g)). Again, this is reasonable, but much too general. On the other hand, a specific requirement that collectors mounted on the ground must be installed at least six inches above ground level (§ 701(c)) may be too

specific for climates without snow or for climates with deep snow and heavy drifting.

Chapter 8 provides insulation requirements for pipes, ducts, and tanks. For ducts, section 802 refers the user to the Uniform Mechanical Code. The standards for insulation show a lack of understanding of either insulation principles or the need to leave design decisions to the designer. The formula for calculating the thickness of insulation on pipes does not consider the thermal conductivity of the insulating material used (§ 801(f)). This does not appear to have been a typographical error since the errata sheet provided in October, 1976, corrects certain typographical errors in the formula, but still ignores thermal conductivity. Whether copper or fiberglass is used as "insulation," the same thickness is required. And the formula does not directly compute the insulation thickness: the user must solve an equation after making certain substitutions. This is simple algebra, but the formula offered should directly yield the desired answer. The formula, had the assumptions been correct, should have been restated as $L = r_o (q_o / q_s - 1)$, where L is the insulation thickness, instead of $q_o = q_s (r_s / r_o)$, where the thickness is not a term.

Tanks must be insulated so that no more than 2 percent of the stored energy will be lost in 12 hours (§ 803). Here, tank probably means any heat storage unit. (Elsewhere the term usually seems to refer just to heat storage units holding water. See, for example, §§ 309 2(d).) This standard means that the insulation must be good enough that only half the energy in the tank would escape through the insulation in more than 17 days of storage. Since storage capacity is often only for one or two days (rarely beyond three or four days), this requirement is probably too stringent. The "losses" from the tank may be intended, for example, to heat that portion of the building where the tank is located, and may not be lost. Or, if only

short-term storage is needed, relatively little insulation would be necessary. In any event, this standard ignores the role of the designer in deciding what is appropriate.

Another serious error in this code is the equation and example given "for illustrative purposes only." The example assumes that useful heat energy is stored in a tank as long as it is above zero degrees, either Celsius or Fahrenheit. This means, incorrectly, that the amount of heat in the tank depends on the unit of measurement preferred by the user. Furthermore, no useful heat is stored in a tank below the design minimum temperature of the space to be heated, if heat is to be applied to the inside air, or below the outside air temperature (which is not necessarily at zero degrees, Celsius or Fahrenheit) if heat is to be applied to outside air. This procedure also does not directly compute the desired result. Instead, the user is told to first use one formula twice, to compute heat stored at the beginning temperature and at the end of 12 hours, and then to use those results in another formula to compute heat loss. A better approach would be to use a single formula. Given the code's assumptions, which are not correct, the procedure could have been simplified to:

$$(\text{heat loss}) = (\text{change in temperature in 12 hours} / \text{starting temperature}).$$

Chapter 9 provides simply that solar system ducts be installed in accord with Uniform Mechanical Code requirements (§ 901). Design decisions are wisely left to the designer.

Appendix A to the code offers a way to compute collector size. The material is copyrighted by the Copper Development Association Inc., an association that represents manufacturers of copper solar equipment. The method assumes too much that should be left to the designer: that the collector is of copper, that it is water-cooled, and that there are about 1.5 to 2.0 gallons of water in heat storage

for each square foot of collector (at 64). This method not only overlooks the common air-cooled collectors, aluminum collectors, and rock storage, it also ignores the effects of heat generated indoors by appliances, lights, and people, and heat collected by windows, which can be substantial in a good passive design (at 61). These assumptions could result in the sale of more copper collector than is needed. (This may explain the Copper Development Association's assumptions.)

There should be no provisions in a solar heating and cooling code—even in its appendix—that favor one technology or material over another without regard to performance characteristics and cost effectiveness. This code implies, however, that copper, water-cooled collector systems are the norm. The building official or designer is given no guidance for evaluating the design of competing systems. This appendix has been offered only as a guide, not as specific requirements, but it should not have been included at all.

The last part of the code, appendix B, simply provides for conversion of customary units into metric.

Although a model code for solar heating and cooling systems is needed, this particular version should not be adopted as a supplement to the other Uniform Codes or to any other code. It has too many errors and omissions, and it lacks particular standards and reference to the federal and private-sector standards for solar heating and cooling systems. It may be useful, however, in the efforts to develop model provisions discussed earlier.

NOTES:

1. The National Building Code of the American Insurance Association has not been so widely adopted as the BOCA, ICBO, and SBCC Codes. For this reason, it has not been discussed in the text; the same kinds of results would obtain under that code as under the others. The Uniform Solar Energy Code of the International Association of Plumbing and Mechanical Officials is discussed in the appendix. This code is a newly written code with such flaws that it should be withdrawn until it can be completely rewritten. In any event, it has not yet seen wide adoption.
2. Charles G. Field and Steven R. Rivkin, The Building Code Burden (Lexington, Mass.: D.C. Heath and Co., Lexington Books, 1975), p. 43.
3. Information supplied by the Office of Building Standards and Codes Services, National Bureau of Standards.
4. Information supplied by the Office of Building Standards and Codes Services, National Bureau of Standards.
5. Field and Rivkin, The Building Code Burden, p. 43.
6. But such rules may not waive working stresses or fire resistive requirements of the code or violate accepted engineering practice involving safety (§ 109.1).
7. New materials is not defined; we assume this would include innovative equipment as is used in solar systems. Regulations may be made effective four weeks after the intention to adopt them has been published, and after a public hearing (§ 109.3).
8. A number of specific code provisions apply structural requirements, as shown later. Solar heating and cooling systems pose, if anything, less of a fire hazard than conventional systems using fire and electricity. Sanitary requirements, such as that the water and antifreeze in the system be kept out of the drinking water supply, should be no major problem.
9. The BOCA Basic Plumbing Code and the plumbing provisions of the Basic Building Code, article 17, do not apply to solar space heating and cooling systems. Although there is what could be called plumbing in solar systems, the codes do not apply to chilled water piping used in comfort cooling, or to hot water piping for building heating (§ P-100.2). Water supply and drainage connections to and from the system, of course, are plumbing (ibid.). Solar hot water heaters are plumbing, but there is nothing in this code that would appear to prevent use of solar hot water heaters (see, e.g., § P-1606.0), provided there is a backup system to assure that minimum temperature requirements are met (120 degrees F, § P-201.0). All automatic gas and electric hot water tanks must be listed by the AGA or ULI (§ P-1606.4.5). The same kinds of requirements for testing and approval of alternative systems as for space heating and cooling equipment could be imposed.

10. See, letter from Ronald D. Scott, Assistant Director for Heating and Cooling, Division of Solar Energy of ERDA, to Solar Age, printed in Solar Age 2, (August 1977): 4; Energy Research and Development Administration, A National Plan for Energy Research, Development and Demonstration: Creating Energy Choices for the Future 1 (ERDA 76-1, 1976): 63, 64.

Standards requiring durability may be crucial to solar development, lest solar systems suffer the loss of public confidence like the heat pumps marketed throughout the South in the 1950s and 1960s. See Howell's pessimistic scenario for solar energy: John R. Howell, "The Implementation of Solar Energy Technology—The Next 25 Years" (Paper presented at Solar Energy Barriers and Incentives Conference, Houston, Tex., April 19-24, 1976), pp. 6-8, especially p. 7.

11. BOCA Standards for boilers and pressure vessels are found in the American Society of Mechanical Engineers' Boiler and Pressure Vessel Code (1979), adopted by references. The impact on solar equipment of this and other such standards is discussed in General Electric Co., Survey to Define Impact of Statewide Building Codes on Solar HVAC Systems, Commercial Buildings (ERDA Contract No. E (11-1)-2683, Philadelphia, Pa.: July 1976).
12. Solar Heating and Cooling Demonstration Act of 1974, § 3, 42 USC § 5502.
13. The 1976 code changes adopted by BOCA include energy provisions based on ASHRAE Standard 90-75. They are probably not widely adopted yet.
14. Information supplied by the Office of Building Standards and Codes Services, National Bureau of Standards.
15. Field and Rivkin, The Building Code Burden, pp. 42, 43.
16. The Uniform Mechanical Code is by ICBO and IAPMO—the International Association of Plumbing and Mechanical Officials. The Uniform Plumbing Code is by IAPMO alone.
17. Occupancy means "the purpose for which a building, or part thereof, is used or intended to be used" (§ 416).
18. As under the BOCA code, the piping within a solar space heating or cooling system is not "plumbing," but the supply and drain piping would be (§ P-117(i)). Water heaters other than gas water heaters must be made in accord with approved standards satisfactory to the building official. These standards are not spelled out, but the usual testing and approval provisions for alternatives should apply (§ P-1306(a), putting solar water heating equipment at the same disadvantage as space heating or cooling equipment.
19. Information supplied by the Office of Building Standards and Codes Services, National Bureau of Standards.
20. Field and Rivkin, The Building Code Burden, p. 43.

21. Florida Solar Energy Center, Solar Energy Commercialization at the State Level: The Florida Solar Energy Water Heater Program (FEA Cooperative Agreement No. AC-05-50053-00; FSEC-76-3; Cape Canaveral, Florida: March 1977), p. 13.
22. See William Thomas, Alan Miller, and Richard Robbins, "Legal Issues Related to Use of Solar Energy Systems" (August 1976 draft of forthcoming article in the American Bar Foundation Research Journal); Richard L. Robbins, "Law and Solar Energy Systems: Legal Impediments and Inducements to Solar Energy Systems," Solar Energy 5 (November 5, 1976): 371, 376. For a fuller listing of impacts on details of solar energy systems designs, see GE Survey cited in note 11 above.
23. Office of Technology Assessment, Application of Solar Technology of Today's Energy Needs (Prepublication Draft; Washington, D.C.: June 1977), p. VI-1.
24. Mary Schiflett, "State and Municipal Legal Impediments and Incentives to the Use of Solar Energy" (Paper presented at Solar Energy Barriers and Incentives Conference, Houston, Tex., April 19-24, 1976), p. 7.
25. AIA Research Corporation, Early Use of Solar Energy in Buildings, 2 vols. (Washington, D.C., August 1976), 2: II-32.
26. Field and Rivkin, The Building Code Burden, generally.
27. See ibid., pp. 37, 57, 58, 80, 81, 85, 87, 90, 92, 96, 97; Alan Hirshberg and Richard Schoen, "Barriers to the Widespread Utilization of Residential Solar Energy: The Prospects for Solar Energy in the U.S. Housing Industry," Policy Sciences 5 (1974): 464.
28. For pipes and ducts this seems obvious. Thermal storage is not unique to solar energy systems. For a discussion of thermal storage for conventional energy systems, see R. T. Tamblin, "Thermal Storage: A Sleeping Giant," ASHRAE Journal 19 (June 1977): 53.
29. American Society of Heating, Refrigerating and Air-Conditioning Engineers, ASHRAE 93-77: Method of Testing Solar Collectors Based on Thermal Performance (1977) and ASHRAE 94-77: Method of Testing Thermal Storage Devices Based on Thermal Performance (1977).
30. Elizabeth McPherson, "Some News is Better Than None," Solar Age 2 (March 1977): 24, 27.
31. Local certification is also possible, but hardly desirable. Pinellas County, Florida, is reportedly certifying systems, using locally written standards, which call for inspection visits to factories to make certain that standards are being upheld! See, FSEC study cited in note 21, p. 36, 37. Other localities may be doing this as well.

32. Minn. Stat. § 116H.127 (1976): "The building code division of the department of administration in consultation with the agency shall promulgate rules by December 31, 1976, concerning quality and performance standards which are in reasonable conformance with the Interim Performance Criteria for Solar Heating and Combined Heating/Cooling Systems and Dwellings, National Bureau of Standards, January 1, 1975; and the Interim Performance Criteria for Commercial Solar Heating and Combined Heating/Cooling Systems and Facilities, National Aeronautics and Space Administration, February 28, 1975, to insure that within the existing state of development, solar energy systems as defined in section 2 of this act, which are sold or installed within this state, are effective and represent a high standard of quality of material, workmanship, design, and performance. The department of administration in consultation with the energy agency shall modify existing standards and promulgate new standards subsequent to December 31, 1976, as new technology and materials become available, or as standards are revised by the federal government.

"Manufacturers or retailers of solar energy systems shall disclose to each bona fide potential purchaser of a system the extent to which the system meets or exceeds each quality standard."

33. E.g., Elizabeth C. Moore, "No News is Bad News," Solar Age 1 (December 1976): 10, 13.
34. E.g., Bruce Anderson, "A Government Stamp for Solar Products?" Solar Age 2 (September 1977): 2.
35. GE Survey, note 11 above, p. 48.
36. National Bureau of Standards News Release (TN-4962, Washington, D.C.: September 27, 1977), and 43 Federal Register 15485 (FR Doc. 78-9823, Washington, D.C.: April 13, 1978).
37. National Conference of States on Building Codes and Standards, Inc. Code for Energy Conservation in New Building Construction (McLean, Va.: December, 1977).
38. "SEIA's SEREF Gets DOE Contract for Nation's First Collector Rating Program," Solar Energy Intelligence Report 3 (Silver Spring, Md.: No. 35, October 10, 1977): 227.
39. See, e.g., Field and Rivkin, The Building Code Burden.
40. Richard Schoen, Alan S. Hirshberg, and Jerome M. Weingart, New Energy Technologies for Buildings (Cambridge, Mass.: Ballinger Publishing Co., 1975), p. 115.

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