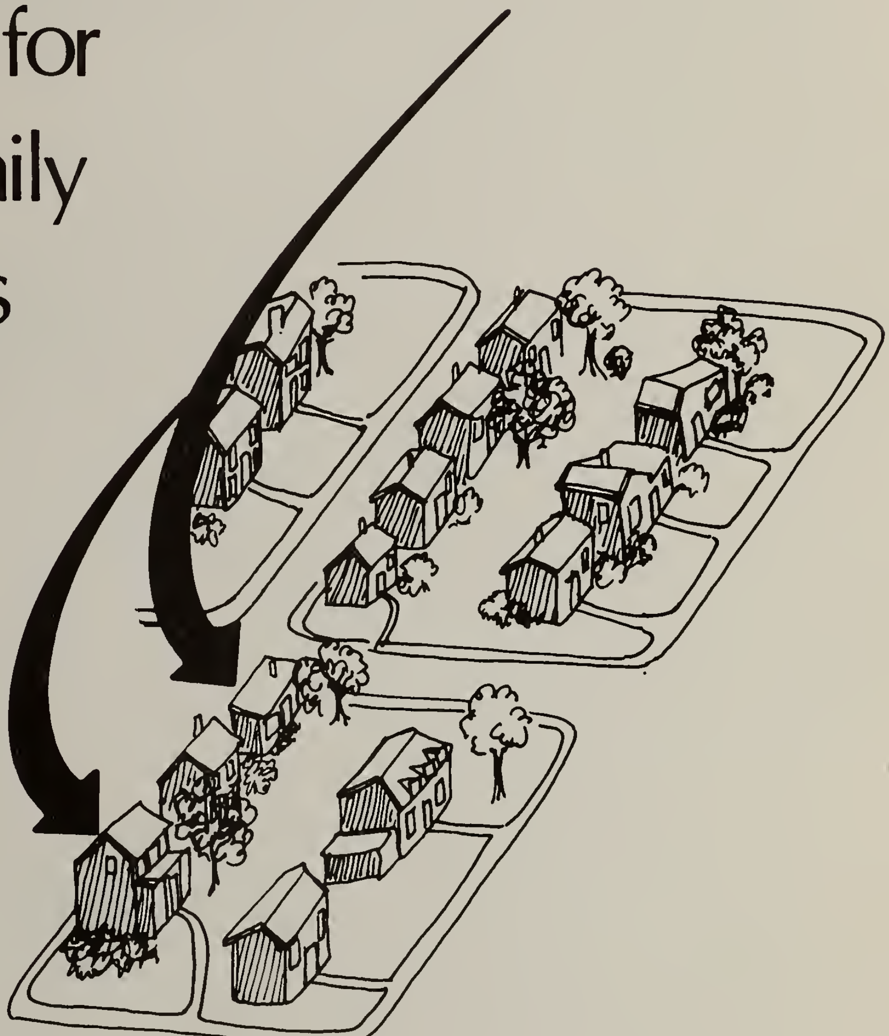
NBSIR 80-2161

A "Reference Building" Approach to Building Energy Performance Standards for Single-Family Residences



October 1980

Center for Building Technology
National Engineering Laboratory
National Bureau of Standards
U.S. Department of Commerce

NBSIR 80-2161

A "REFERENCE BUILDING" APPROACH TO BUILDING ENERGY PERFORMANCE STANDARDS FOR SINGLE-FAMILY RESIDENCES

Stephen R. Petersen
Building Economics and Regulatory Technology Division
Jim L. Heldenbrand
Building Thermal Performance Division

Center for Building Technology
National Engineering Laboratory
National Bureau of Standards
Washington, D.C. 20234

October 1980

Prepared for:

Building Codes and Standards Branch
Office of Buildings and Community Systems
U.S. Department of Energy
Washington, D.C. 20545

U. S. DEPARTMENT OF COMMERCE, Philip M. Klutznick, Secretary
Luther H. Hodges, Jr., Under Secretary
Jordan J. Baruch, Assistant Secretary for Productivity, Technology, and Innovation
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, Director

ABSTRACT

A reference building approach to building energy performance standards (BEPS) is described in this report which could serve as a framework for the further development of energy standards for new single-family residences. Each proposed new building design would be compared with a reference building design and operating profile. In order to comply with the standard, the design energy requirements of the new building would not be allowed to exceed those of the reference building, when evaluated by a parallel modeling process. The reference building design would include reference component performance specifications, a reference envelope configuration, and reference seasonal efficiency specifications for the mechanical equipment. A modular energy budget based on space heating and cooling requirements, hot water requirements, mechanical system efficiencies, and fuel weighting factors is proposed which would serve as the means of comparison. Alternatively, building designs which equal or exceed the individual specifications of the reference building design would automatically comply with the standard.

PREFACE

This report is one of a series documenting NBS research and analysis efforts in developing energy and cost data to support the Department of Energy/National Bureau of Standards Building Energy Conservation Criteria Program. The work reported in this document was performed under the Building Energy Performance Criteria project and supported by DOE/NBS Task Order A008-BCS under Interagency Agreement No. EA 77A 01-6010.

ACKNOWLEDGEMENTS

Although the authors assume full responsibility for the content of this report, we wish to acknowledge that the concepts described are an extention of earlier work by the National Bureau of Standards and the American Society of Heating, Refrigerating and Air-Conditioning Engineers, and of current NBS project team activity in which complementary efforts that are covered in other reports were provided by the other team members, Paul R. Achenbach and James P. Barnett.

We also gratefully acknowledge that the quality of this report has benefitted significantly from the comments of the editorial readers, especially the constructive criticism received from Dr. Jack E. Snell, Dr. Preston E. McNall, Mr. James G. Gross, Mr. Robert R. Jones, and Mr. Kalev Ruberg.

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

Page

EXECUTIVE SUMMARY

This report outlines a Reference Building Approach (RBA) to the further development and eventual implementation of building energy performance standards (BEPS) for single-family housing. The reference building approach directly links design energy budgets to a set of component performance specifications through the use of a reference building design. This approach is an outgrowth of the "alternate path" approach originally described by NBS in 1974 (NBSIR 74-452) and further developed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers in ASHRAE Standard-90 (Section 10) and derivative model codes and regulations. The RBA could be used by the Department of Energy (DoE) in future revisions of its BEPS program for residential buildings.

The primary compliance path for the reference building approach to BEPS (RBA-BEPS) is the demonstration of equivalent thermal performance between a proposed and corresponding reference building design. The characteristics of the reference building designs needed for such a comparison would be described in the RBA-BEPS document, rather than in the supporting documentation. The user could be free to use any approved evaluation technique to demonstrate equivalence, but would be required to use the same evaluation techniques for both the reference and proposed buildings. For many residential buildings, simple, steady-state calculation procedures may be sufficient to demonstrate equivalency.

As an alternative path to facilitate compliance with the RBA-BEPS, pre-calculated design energy budgets (or certain portions of energy budgets) for a number of typical applications, based on specified evaluation techniques, could be provided in supporting documentation. Utilization of these published energy budget data would require the use of a standard evaluation technique in order to demonstrate compliance, similar to the current DoE-BEPS approach. Proposed building designs which meet or exceed the component performance specifications of the reference building design would automatically comply with the standard.

Two major steps are needed to provide reference building designs for the RBA-BEPS suggested in this report:

(1) Reference component performance specifications need to be developed for each envelope component, including ceiling, walls, windows, floors and doors, and seasonal performance specifications need to be developed for certain energy-using equipment (furnace, air conditioning, and water heating systems). These could be similar to the current Federal Housing Administration's Minimum Property Standards and the proposed DoE Appliance Efficiency Standards, respectively. Alternatively, life-cycle cost analysis could be used to establish such specifications for the RBA-BEPS.

(2) A reference building envelope configuration is needed to provide sufficient data to model the design energy requirements of the building, once the reference component performance specifications are identified. This

reference configuration would include specifications of building shape and orientation, window size and orientation, and air infiltration rates, all of which would vary with building size. The size of the reference building is not fixed but would be specified to closely match that of the proposed building design.

Once the annual space heating and cooling requirements and water heating requirements of the reference building design have been calculated for a given climate and operational profile, the annual weighted energy budget (EB) can be calculated as

$$EB = \frac{AHR}{\eta_h} \cdot F_h + \frac{ACR}{\eta_c} \cdot F_c + \frac{AWR}{\eta_w} \cdot F_w ,$$

where

AHR = Annual heating requirements of the reference building design,
ACR = Annual cooling requirements of the reference building design,
AWR = Annual water heating requirements of the reference building design,
η = reference seasonal efficiency of the service equipment type selected,
F = fuel weighting factor, and subscripts

h = heating,
c = cooling, and
w = water heating.

All energy utilization would be calculated at the building boundary. The fuel weighting factors would be provided by DoE if desired in order to make the summation of different energy types, in the same thermal units, more consistent with differences in production and distribution costs incurred in delivering the energy to the building site. These fuel weighting factors are similar in concept to those used in the current DoE-BEPS approach, but their usage in deriving a design energy budget is more explicit in the reference building approach.

At the compliance stage, design substitutions could be made at any level in the energy budget equation. For example, envelope component design changes that do not increase AHR or ACR above that of the reference building design could be made without reference to the entire energy budget as long as the equipment installed matches or exceeds the reference equipment specifications. The use of higher efficiency heating equipment can be substituted for a reduced level of envelope performance without requiring an analysis of the hot water system, if the latter matches or exceeds the reference efficiency specification of water heaters. However, an increase in the hot water system efficiency above the reference efficiency would allow reductions in both furnace and envelope performance levels if desired.

The RBA-BEPS offers several possible improvements to the current DoE-BEPS approach.

(1) It provides more information to the user since it provides a tangible reference building design as a starting point.

(2) It can be linked directly to component performance standards.

(3) A number of approved evaluation techniques could be used to demonstrate compliance without demonstrating equivalence to each other.

(4) In many cases, simple trade-offs could be made between components without performing an energy analysis for the entire building.

(5) Any published energy budget values would be directly verifiable by independent sources.

(6) The RBA-BEPS energy budget would vary with building size and does not rest on the assumption of direct proportionality between building size and energy usage.

(7) The RBA-BEPS provides a ready framework for establishing design energy performance requirements that vary with differences in certain significant component specifications, e.g., floor type and generic heating and cooling equipment type.

1. INTRODUCTION

1.1 BACKGROUND AND PURPOSE

The U.S. Department of Energy (DoE) is required by Congress to develop building energy performance standards (BEPS) for new buildings with the explicit purpose of achieving the maximum practicable energy savings that can be economically justified.[1] The resulting BEPS will place a limitation on the energy requirements of new buildings as calculated at the design stage. This limitation would most likely be expressed in terms of an annual weighted design energy budget. For example, in the currently proposed DoE-BEPS procedures for residences, as detailed in DoE's Notice of Proposed Rulemaking[2] (NOPR), the total number of Btu per square foot of gross floor area per year allowed for space heating and cooling and domestic hot water is specified by building type and geographic location. Implementation of the DoE-BEPS means that the design plans for a new building can require no more energy than that specified for the same building type and climate in the BEPS. This comparison would be based on a prescribed methodology (the "Standard Evaluation Technique") defined by DoE in the documentation supporting BEPS.

The energy budget is not meant to ration energy usage; rather it is intended to ensure that new buildings are designed to be considerably more energy conserving than most existing buildings when operated in a specified fashion. Unlike the building energy standards which have been promulgated by various Federal, State, and local government agencies in recent years, BEPS does not have specific thermal performance requirements for each building component. Instead, builders are free to incorporate any means of reducing energy requirements at the design stage as long as the overall building energy performance goals are achieved. This design freedom is expected to encourage both cost-saving and innovative technology in new building design. The BEPS legislation also provides that State and local governments may provide alternative standards of a prescriptive or component nature if it can be demonstrated that they result in equivalent energy savings.

While the building energy performance concept is no longer new, the technical framework needed to support the practical application of BEPS is still in the developmental stage. Considerable advances in the state-of-the-art have been made by DoE since it has undertaken the task of developing BEPS at the Federal level. The purpose of this report is to expand the state-of-the-art by outlining a reference building approach (RBA) for residential buildings that could be used in further developing the BEPS concept over time. In particular,

---

[1] "Energy Conservation Standards for New Buildings Act of 1976," Public Law 94-385, Title III.

[2] "Energy Performance Standards for New Buildings; Proposed Rulemaking and Public Hearings," Federal Register, Vol. 44, No. 250, November 28, 1979, pp. 68119-68181.

it addresses certain technical aspects of the DoE-BEPS that have been perceived as shortcomings by the authors and others.[1] For example:

- It is difficult for the user to understand exactly what is required in terms of specific building practices without extensive computer modeling. Thus the potential impact of the DoE-BEPS on new housing design requirements is difficult to evaluate as well. The DoE program plan calls for development of equivalent prescriptive or component performance criteria and manuals of acceptable practice. Until these become available, however, these difficulties will persist.

- The basic methodology for demonstrating design compliance with DoE-BEPS is probably too complex for most residential applications. An energy analysis for the entire year is needed in order to evaluate even simple design trade-offs among envelope components. However, the development of simplified alternative paths for compliance is planned by DoE.

- The methodology and data base used to establish the energy budgets are not specified sufficiently to allow independent verification of the energy budget numbers.

- The assumption of direct proportionality between energy use and building floor area appears to work reasonably well for cold climates but can result in significant errors for differently sized buildings in warm climates.

- Differences in floor construction (e.g. slab-on-grade, crawl space, and heated or unheated basement) are not accounted for and can, in some cases, lead to significant differences in building energy use.

- The published energy budget is an artifact of the computer modeling procedures. Unless the same evaluation procedure is used in demonstrating compliance, there may be significant differences under the current approach in the energy requirements attributed to certain design features.

- Energy requirements for hot water are based on national average rather than on regional or local inlet temperatures.

---

[1] Many of these points have been addressed in statements made on the proposed BEPS submitted to DoE during hearings held in Washington, D.C., on March 24, 1980. This includes statements by the National Institute of Building Sciences, The American Consulting Engineers Council, American Institute of Architects, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, National Society of Professional Engineers, and the National Conference of States on Building Codes and Standards.

° Insufficient research data on building energy performance was collected in developing the energy budgets.

The RBA-BEPS approach has several specific attributes that may gain it more widespread public acceptance from quarters that support the basic BEPS concept but find the current approach difficult to understand and apply. While it is closely tied to component-oriented performance standards, RBA-BEPS is a true building performance standard that, like BEPS, will encourage innovation and cost-savings in achieving overall energy conservation goals in new building design. However, because it is directly referenced to component-oriented standards, RBA-BEPS formulation is expected to be easier to comprehend and use. Rather than providing a single energy budget number on a Btu/ft^2 basis, the energy budget for a proposed building design in a given geographic region would be based on the thermal performance of an equivalent size reference building design that is well defined in terms of component specifications. This approach therefore could allow the use of any approved building energy analysis method rather than requiring that compliance be demonstrated with a Standard Evaluation Technique or equivalent. As a result, many design trade-offs between components may be readily determined using simple, steady-state analytical techniques, without performing an energy analysis for the whole building. In addition, any published energy budget numbers could be verified by independent sources since the design assumptions on which they are based would be made explicit in the standard.

The scope of this report is limited to a description of a proposed reference building approach to the development of building energy performance standards for single-family residences. Examples are provided to illustrate this approach. Implementation will require some additional research and the resolution of a number of policy issues that remain.

1.2 ORGANIZATION

The reference building approach to BEPS proposed in this report is based on the development of a reference building design to which a proposed building design is compared in order to demonstrate compliance with the standard. In section 2 the development of the reference building design is discussed and examples are provided. Development of the reference building design requires the identification of a reference building envelope configuration, a set of reference component performance specifications, and reference seasonal equipment efficiencies for energy-using subsystems. Representative climate and operational profile data and acceptable methods for calculating annual space heating and cooling requirements and water heating requirements are also discussed in section 2. In section 3 the computational procedures for arriving at an actual energy budget are outlined. Some important issues which remain to be resolved before the RBA-BEPS can be fully specified are outlined in section 4. Conclusions and recommendations for further research are provided in section 5.

2. REFERENCE BUILDING DESIGN APPROACH

2.1 ESTABLISHMENT OF A REFERENCE BASIS FOR BEPS

To date, energy conservation standards promulgated by the Federal government have been prescriptive or component performance oriented.[1] Prescriptive standards specify precisely the materials and methods to be used in satisfying design objectives. Component performance standards provide considerably more flexibility to the user than prescriptive standards since they specify only the minimum performance goal to be achieved by each component without specifying the materials and methods to be used. BEPS are a logical step in the further development of flexible energy standards. Instead of specifying energy-related performance levels for each component, only the overall design energy performance requirements of the building are specified in the standard. The builder is then free to select dollar-saving or aesthetic-improving design details which together satisfy those overall requirements.

The building energy performance concept is an outgrowth of the "alternative path" approach originally described by NBS in 1974[2] and futher developed by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers in ASHRAE Standard-90 (Section 10) and derivative codes and regulations. The National Conference of States on Building Codes and Standards (NCSBCS) had requested the development of these building energy conservation criteria using a performance-oriented rather than a prescriptive approach.

In making the transition from prescriptive to component performance standards, thermal performance requirements must be compatible with practical materials and methods for conserving energy. This linkage is necessary to assure that the specified performance requirements can be achieved without undue economic burden on the builder or owner, yet are effective enough to warrant promulgation in the first place. In recent years economic analysis of specific materials and methods for improving component energy performance has been explicitly utilized to determine acceptable component performance requirements that vary with geographic region, and in some cases, with energy type as well.[3] The builder may of course use any materials or methods that accomplish the same design goal.

---

1 Examples of such standards for single-family residences are the U.S. Department of Housing and Urban Development (HUD) FHA Minimum Property Standards and Farmers Home Administration (FmHA) "Thermal Performance Standards."

2 J.L. Heldenbrand, Design and Evaluation Criteria for Energy Conservation in New Buildings, NBSIR 74-452, National Bureau of Standards, Washington, D.C., 1974.

3 Both HUD and FmHA have based recent changes in their thermal performance standards on life-cycle cost analyses.

In developing energy conservation standards at the whole building level, compatibility with accepted building techniques and methods for conserving energy is also desirable. However, a large number of combinations of materials and methods are available for construction at the whole building level. This makes the linkage of energy budgets to specific building practices more difficult than for the component performance or prescriptive approaches. The actual envelope configuration must be specified in order to determine the design energy requirements of a given building. The minimum configurational data needed include the building geometry and orientation, and the window and door areas and orientation. In addition, the rate of air infiltration, which is dependent in part on the exterior wall areas and the joining of the envelope components, must be specified. In larger buildings, zoning may also need to be specified.

In existing component and prescriptive standards, government agencies and standards-making organizations appear to have been reluctant to prescribe such a standardized building envelope configuration for representative building types. This may be due to the lack of objective guidelines for such a prescription, the concern that new buildings would become stereotyped, the site-specific nature of many building designs, and the intrusion into architectural design freedom. However, the reference building approach largely avoids these problems since it does not actually prescribe energy conserving configurations, but only references them in establishing acceptable norms of overall building energy performance. Again, the builder is free to design as he sees fit, provided the resulting building design requires no more energy than the referenced norm. A manual of acceptable practices which would provide a variety of alternative house designs that use no more energy than the reference building design would also be useful in promoting design diversity.

2.2 REFERENCE BUILDING ENVELOPE CONFIGURATION

BEPS can be directly equated to a set of component performance specifications once reference building envelope configurations are specified. The reference configuration for a detached residence would have a specified geometry (i.e., aspect ratio and number of stories), which might vary as a function of floor area or other measure of building size; a specified compass orientation; specified window areas and orientations; door size and orientation specifications; and reference air leakage (infiltration) rates.[1] Table 1 provides, for illustrative purposes only, an example of the reference building envelope configuration (RBEC) specifications for single-family detached houses based on arbitrarily assigned values. The specification of RBEC's is relatively new in concept and is not entirely objective in detail. Using the services of the NAHB Research Foundation or the American Institute of Architects Research Corporation, for example, typical envelope configurations could be

---

[1] Internal mass could also be specified for use in load determination programs which are sensitive to this design parameter.

TABLE 1. Reference Building Envelope Configuration: Single-Family Detached House (Example)

Gross Floor Area[a]	Stories	Aspect Ratio[b]	Window Area[c]				Door Area[d]	
			S	W	N	E	S	N
< 800 ft^2	1	1.4	7.5%	1%	5.5%	1%	20 ft^2	20 ft^2
800 - 1399 ft^2	1	1.5	7.5%	1%	5.5%	1%	20 ft^2	20 ft^2
1400 - 1999 ft^2	2	1.4	7.5%	1%	5.5%	1%	20 ft^2	20 ft^2
2000 - 3000 ft^2	2	1.5	7.5%	1%	5.5%	1%	20 ft^2	20 ft^2

Air Infiltration Rate (cfm)

Winter: (0.56 cfm) (perimeter[e] in feet) (number of stories)

Summer: (0.28 cfm) (perimeter[e] in feet) (number of stories)

This provides approximately 450 cfm of air in winter and 225 cfm in summer in an 800 ft^2 house, which is considered to be sufficient for a family of four.[f]

---

[a] Conditioned spaces only

[b] Long walls face north and south

[c] Percent of gross floor area; includes sliding glass doors

[d] Does not include sliding glass doors

[e] Perimeter = $(\sqrt{\text{floor area/aspect ratio}})$ (1 + aspect ratio) (2)

[f] P.R. Achenbach, Functional Performance Requirements for the Environmental and Service Systems in Detached Housing and Their Impact on Building Energy Use, Contract Report, August 22, 1980, Section 7.2.3 (Unpublished draft in editorial review).

developed. Concensus on some details may be difficult to achieve if they are not representative of typical house designs or are too restrictive in terms of allowing for design alternatives that result in the same overall energy performance level. However, some reasonable guidelines can be stated:

(1) The building shape should be representative of good design practice and avoid an excessive surface area to volume ratio. A cube-shaped house has the least surface area to volume ratio but is not a common design. Thus the reference configuration will likely be rectangular, but not "L" shaped, for example. As the floor area is increased there should be a trend toward two stories.

(2) The reference building should be oriented with longer walls and larger windows facing in the most advantageous direction. (The most energy efficient building and window orientation is south for heating and north for cooling.) Glazing on the end walls of a house typically represents only a small fraction of the total amount of glazing in most housing developments. (If a building lot will not practically accommodate the most advantageous orientation of a new house, an additional allowance for annual heating and cooling requirements might be given if the energy budget would otherwise require inordinate amounts of insulation or multiple glazing to comply.)

(3) Minimum air exchange rates should be specified to assure that occupant health and building moisture control will not be sacrificed for other design advantages.

2.3 REFERENCE COMPONENT PERFORMANCE SPECIFICATIONS

Once the RBEC is specified, overall building energy performance requirements can be directly linked to a set of reference component performance specifications (RCPS). The RCPS will vary with climate and possibly with the generic type of space heating used (e.g., the RCPS for electric resistance heating could be made more stringent than those for electric heat pump or gas heating). U-values for some components could also be varied by construction type where there are significant differences in thermal performance (e.g., U-values for slab floors on grade may be specified differently from floors over crawl spaces or floors over basements). The RCPS can be adopted directly from existing component performance standards or a new set of RCPS can be developed. Life-cycle cost analysis can be applied directly to the development of RCPS, and as a result, the BEPS standard can be shown to be consistent with life-cycle-cost-minimizing design practices.[1] Table 2 provides an example of an RCPS, based on the current HUD Minimum Property Standards.

2.4 REFERENCE SEASONAL EQUIPMENT EFFICIENCY SPECIFICATIONS

The seasonal efficiency of building mechanical systems should be referenced in the calculation of energy budgets. This may include space heating and cooling equipment, water heating equipment, and possibly lighting fixtures. Reference efficiencies would be specified separately by generic equipment type (e.g., oil, gas, electric heat pump, electric resistance, etc.). Ideally the overall system efficiency, including the distribution system (ductwork or piping), should be referenced. Seasonal efficiency values should be specified, rather than steady-state efficiency values, since annual energy usage is more closely related to the former. These seasonal efficiency values should be specified by geographic region, since there can be significant variation in seasonal efficiency due to differences in climate, especially for heat pumps. An illustrative example of the reference seasonal energy efficiency specifications for furnaces, air conditioners, heat pumps, and water heaters is shown in table 3.

The DoE, in support of its Appliance Efficiency Program, is currently developing minimum seasonal energy efficiency standards for furnaces, heat pumps, air conditioners, and domestic water heaters. These minimum standards could be used as the basis for the reference specifications. However, since the seasonal efficiency values used in the DoE standards are based on U.S. average climate data, regional equivalents may need to be developed in order to better reflect regional climate differences and their effects on seasonal energy efficiency. In geographic regions with extreme heating or cooling requirements, the reference seasonal efficiencies for furnaces or air conditioners might be raised above those specified in the DoE Appliance Efficiency Program, based instead on life-cycle cost considerations more reflective of those regions.

The combination of reference building envelope configuration, component performance specifications, and seasonal energy efficiencies for specified building mechanical systems is referred to as the "reference building design" in the RBA-BEPS. Each proposed building design will have a corresponding reference building design that can be uniquely identified. The reference building design is the actual core of the RBA-BEPS; energy budgets which are calculated from the reference building design are, in effect, artifacts of the energy analysis program and the representative climate and operational profiles used in the analysis. Energy budgets are calculated primarily to

---

[1] For more information on the use of economic analysis in developing BEPS, see S. Petersen, The Role of Economic Analysis in the Development of Energy Standards for New Buildings, NBSIR 78-1471, National Bureau of Standards, Washington, D.C., 1978, and H. Marshall and S. Petersen, "Economics and the Selection and Development of Energy Standards for Buildings," Energy and Buildings, 2 (1979), pp. 89-99.

TABLE 2. Illustrative Reference Component Performance Specifications[a]

Annual Heating Degree Days	U-Value (Btu/ft^2 · °F)									
	Ceiling		Wall[b]		Floor[c]		Glass[d]		Doors	
	E.R.[e]	F.F.[f]	E.R.	F.F.	E.R.	F.F.	E.R.	F.F.	E.R.	F.F.
< 1000	.05	.05	.08	.08	.08	-	1.13	1.13	.55	.55
1000-2499	.04	.05	.07	.08	.07	-	.69	1.13	.55	.55
2500-4499	.03	.04	.05	.07	.05	.07	.69	1.13	.55	.55
4500-6999	.03	.03	.05	.05	.05	.47	.47	.69	.34	.55
> 7000	.026	.03	.05	.05	.05	.45	.47	.69	.34	.34

a Based on HUD FHA Minimum Property Standards, April 1978.

b For detailed load analysis programs, reference absorptance, thermal mass, and stud-spacing is needed. Alternative U-values for masonry walls might be provided.

c Floors over unconditioned spaces. Separate specifications for slabs are needed.

d Shading coefficients for windows (winter and summer) should be specified.

e Electric resistance heating.

f Fossil fuel heating, including heat pumps.

TABLE 3. Illustrative Reference Seasonal Equipment Efficiency Specifications[a]

Furnaces			
	Gas	Oil	Electric Resistance
	76%	77%	100%
Central Air Conditioners			Electric
			2.35 (COP)
Heat Pumps			Electric
Heating			b
Cooling			2.25 (COP)
Water Heaters			
	Gas	Oil	Electric
	60%	60%	85%

---

[a] These efficiency specifications should include distributional losses, but in a well-designed house these may be quite small.

[b] Seasonal efficiency factors for heat pumps in the heating mode should be specified by local climate factors.

demonstrate equivalency in energy performance between the proposed building and the reference building. The procedure for calculating energy budgets is discussed in section 3. The remainder of this section discusses the need for representative climate and operational profile data and procedures for calculating annual space heating and cooling requirements and water heating requirements.

2.5 REPRESENTATIVE CLIMATE DATA

In order to determine the annual heating and cooling requirements of the reference building design in a particular geographic location, representative climate data for that location must be available. For simplified, steady-state calculation procedures, heating degree day, cooling "bin" hour, and average daily solar gain data by compass orientation may be sufficient. Such data could be made available for any region in the United States, based on existing records. For more sophisticated analyses of the annual heating and cooling requirements of new buildings, hourly climate records are needed for the 8760 hours of the year.

Although this climate data should be reasonably representative of long-term average climate conditions, this is not critical to initial implementation of RBA-BEPS. The climate data will be used only in demonstrating that the proposed building design uses no more energy than the reference building design when operated in the same type of climate, not to establish the actual long-term energy consumption of the building. The relative energy performance of the proposed and reference buildings may vary somewhat with major variations in climate, but is expected to be reasonably constant in a specific climate zone. Thus, while hourly climate profile data may not be available for all regions of the United States, climate data which is reasonably representative for all regions could be developed, using Test Reference Year[1] (TRY) or Typical Meterological Year[2] (TMY) data records. BEPS users could be free, however, to use any climate data source available to them, provided they can show that it better represents the long-term climate profile in the locality in which their new building will be constructed.

In addition to conventional climate data for establishing space heating and cooling requirements, inlet (ground) water temperatures to the water heater are required on both a regional and seasonal basis. These data are needed to calculate energy use for providing hot water.

---

[1] E. Stamper, "Weather Data," ASHRAE Journal, 19, 2:47, February 1977.

[2] Solmet User's Manual (Volume 1), TD-9724, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Washington, D.C., August 1974.

2.6 REPRESENTATIVE OPERATIONAL PROFILE

In addition to climate data, the calculation of annual space heating and cooling requirements and water heating requirements is dependent on detailed operational profiles. An operational profile includes occupancy schedules, thermostat settings, and internal heat release from occupants, appliances and lighting on an hourly basis, as well as daily hot water consumption in both volume and output temperature. The thermostat settings should be consistent with established comfort indexes and representative of reasonable energy-conserving behavior on the part of the building occupants. For illustrative purposes only, table 4 provides a representative operational profile for the reference building envelope configurations shown in table 1. Appendix A outlines research activities needed to improve the operational profiles used in evaluating building energy performance.

As with climate data, a representative operational profile is desirable, but it is not as critical to RBA-BEPS because it is used only in demonstrating equivalent performance between the new and reference building design when both are operated according to the same profile. In addition, a provision might be made to allow the use of any operational profile that can be shown to better represent the expected long-term use of the new building. However, the same operational profile must be used in calculating the design energy requirements of both the proposed and reference building designs. Of course, precalculated annual design energy budgets would not be applicable in this case.

2.7 COMPUTATION OF ANNUAL SPACE HEATING AND COOLING REQUIREMENTS AND WATER HEATING REQUIREMENTS

In section 3, a methodology for calculating a design energy budget based on the reference building design is proposed. This methodology requires that the annual space heating and cooling requirements (AHR and ACR, respectively) and annual water heating requirements (AWR) be known for the reference building design. (AHR, ACR, and AWR are system output requirements and do not reflect energy conversion losses.)

The values calculated for AHR and ACR can vary significantly, depending on the computational methodology employed. (Calculation of AWR is considerably more deterministic than the calculation of AHR and ACR.) In the current BEPS approach, the DOE-2 building energy analysis program[1] is employed to calculate the AHR and ACR of a prototype house in order to establish a design energy budget. (However, only the overall energy budget itself is published. The prototype building design is not described in the proposed DoE standard.) In order to demonstrate compliance, the energy requirements of the proposed building design must also be evaluated using

---

[1] DOE-2 Reference Manual, LA-7689-M, LBL-8706, Los Alamos Scientific Laboratory, Los Alamos, NM, 1979.

TABLE 4. Illustrative Operational Profile Data

Thermostat settings: Heating - 68°F day

60°F night setback (8 hrs)

Cooling[a] - 78°F

Hourly internal heat release schedules:[b]

Appliances -

Lights -

Occupants -

Hot water usage:

Gallons/day - 60

Output temperature - 120°F

---

[a] No cooling energy is calculated when t_o is less than 78°F since this is much more sensitive to occupant behavior assumptions than to building design.

[b] To be determined on an hourly basis and as a function of building size. See J. Barnett, Energy Analysis of a Prototypical Detached Single-Family Residence: The Effects of Climate, House Size, Orientation, and Internal Heat Release, NBSIR (in review), for more complete internal heat release profile data.

the Standardized Evaluation Technique based on the DOE-2 program.[1] In the RBA-BEPS approach, any computational methodology approved by DoE could be used in order to demonstrate the relationship between the thermal performance of the proposed and reference building designs. Appendix B summarizes some of the research needed for improved building energy calculation procedures.

In the simplest of cases, direct trade-offs between the thermal performance of two components (e.g., walls and windows) could be evaluated without considering the remainder of the building design, provided that the remaining design features meet or exceed the corresponding reference component performance specifications. The added flexibility means that many more designers will be able to actually use the BEPS concept in new building design.

For the computational methodologies most commonly used, schedules of AHR, ACR, and AWR, expressed as a function of building size, can be generated in order to eliminate the need to compute this data for the reference building design. An example of such a schedule for the AHR and ACR, generated using the NBS Load Determination[2] (NBSLD) program for the Phoenix climate[3] is shown graphically in figure 1. In this figure, the AHR and ACR can be obtained for any given size, single-story house in this geographic region, having the same general shape and component performance specifications. Additional schedules could be generated for other climates, component performance specifications, and for other computational methods. These schedules could provide a convenient method for determining the AHR, ACR, and AWR for the reference house design, as well as providing information about the relationship between functional energy requirements and building size. When such schedules are used in calculating a design energy budget, the same computational methodology, climate data, and operational profile used in their development must be used in determining the design energy requirements of the proposed building.

It should be noted in figure 1 that neither the AHR nor the ACR for a larger house are proportional to the AHR or ACR of a smaller house in Phoenix, when

---

[1] The possibility of using other computer programs is being examined by DoE. However, compliance must be demonstrated with respect to the DOE-2-generated energy budget rather than to the reference building design itself. Since different algorithms are used in each program for evaluating building components, use of a different program may result in accepting a design that would not be acceptable if the DOE-2 program were used, even though the different program may be validated as generally equivalent to DOE-2.

[2] T. Kusuda, NBSLD, the Computer Program for Heating and Cooling Loads in Buildings, BSS 69, National Bureau of Standards, Washington, D.C., 1975.

[3] The NBSLD computations of AHR and ACR are based on J. Barnett, Energy Analysis of a Prototypical Detached Single-Family Residence: The Effects of Climate, House Size, Orientation, and Internal Heat Release, NBSIR (in review), National Bureau of Standards, Washington, D.C.

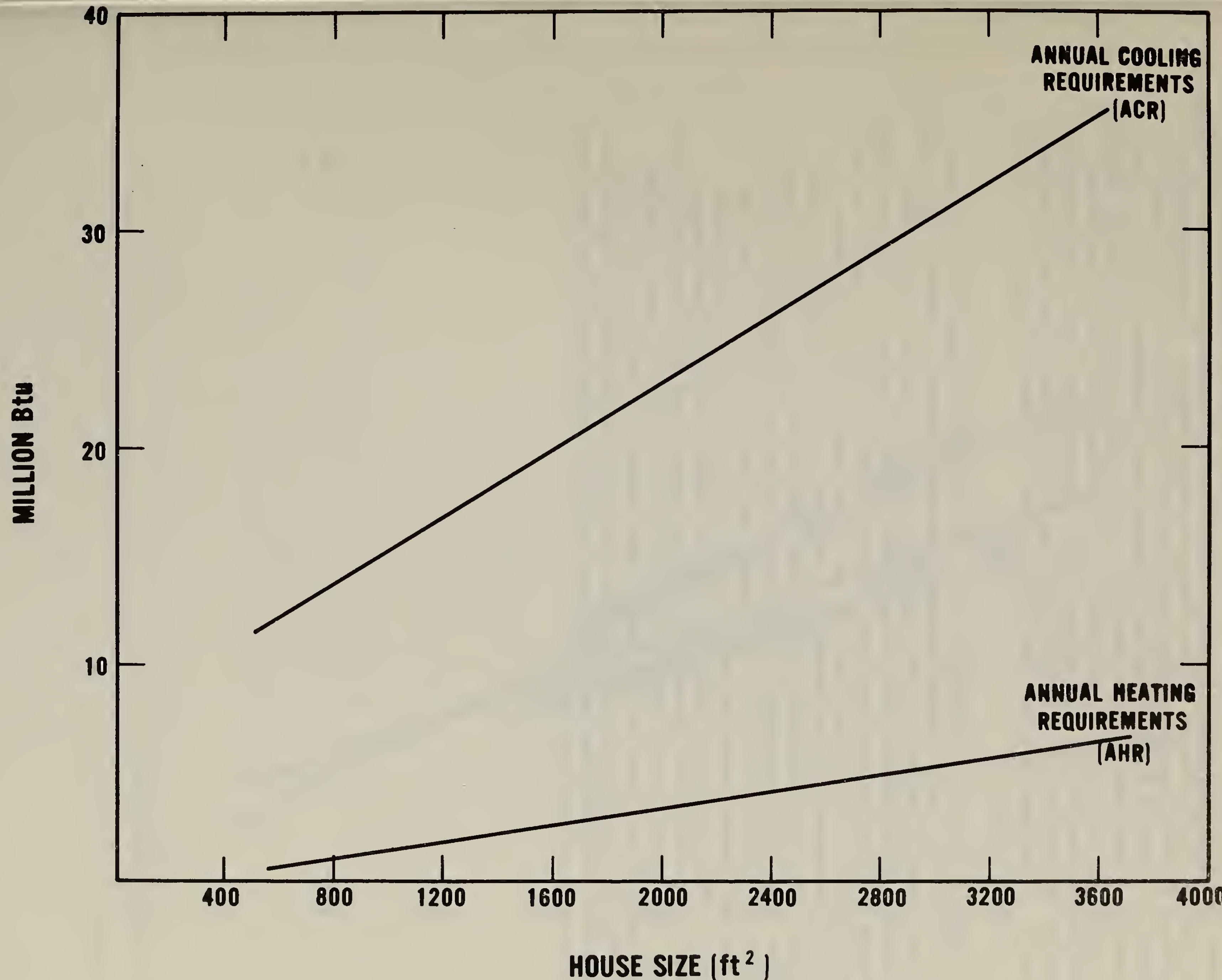


Figure 1. AHR and ACR for a Single-Family House in Phoenix.

compared on a square-foot-of-floor-area basis. While in colder climates AHR tend to be proportional to house size, ACR are not typically proportional to house size in any climate. In warm climates, the assumption of proportionality may introduce significant errors into the energy budget. In the currently proposed DoE-BEPS approach, the specification of an overall annual energy budget in terms of Btu/ft^2 implies a proportional relationship. As a result, a greater energy budget is allowed for large houses, and lower energy budget for small houses, than can be justified on the basis of a detailed thermal engineering analysis of houses that differ primarily by size. This conclusion is based upon the assumptions and analysis results given in the Barnett study.[1] A further illustration of this result is shown in figure 2, which is based on figure 1.

In figure 2, the line designated "computed energy requirements" is the sum of AHR and ACR, each divided by a corresponding seasonal equipment efficiency. (A heat pump is assumed in this case, with $\eta_h = 2.0$ and $\eta_c = 2.4$.) While the energy requirements line is reasonably linear in shape, it does not pass through the origin, implying that the energy requirements for space heating and cooling are not proportional to the house size. This relationship is directly addressed in the RBA-BEPS. Also shown is the "normalized energy budget" line that represents the current BEPS methodology; i.e., an energy budget that is proportional to house size, based on the thermal analysis of a 1200 ft^2 house. Note that for houses less than 1200 ft^2 in size, the normalized energy budget is tighter than the design energy requirements of those house sizes, while above the 1200 ft^2 size, the normalized energy budget is looser. For example, the energy budget line is 25 percent greater than the computed energy requirements line for a 2400 ft^2 house. The RBA-BEPS approach outlined in this report more accurately reflects the effects of size on design energy requirements since AHR, ACR and AWR are calculated separately and are based on a reference building design having the same size as the proposed building design.

---

[1] Op. cit.

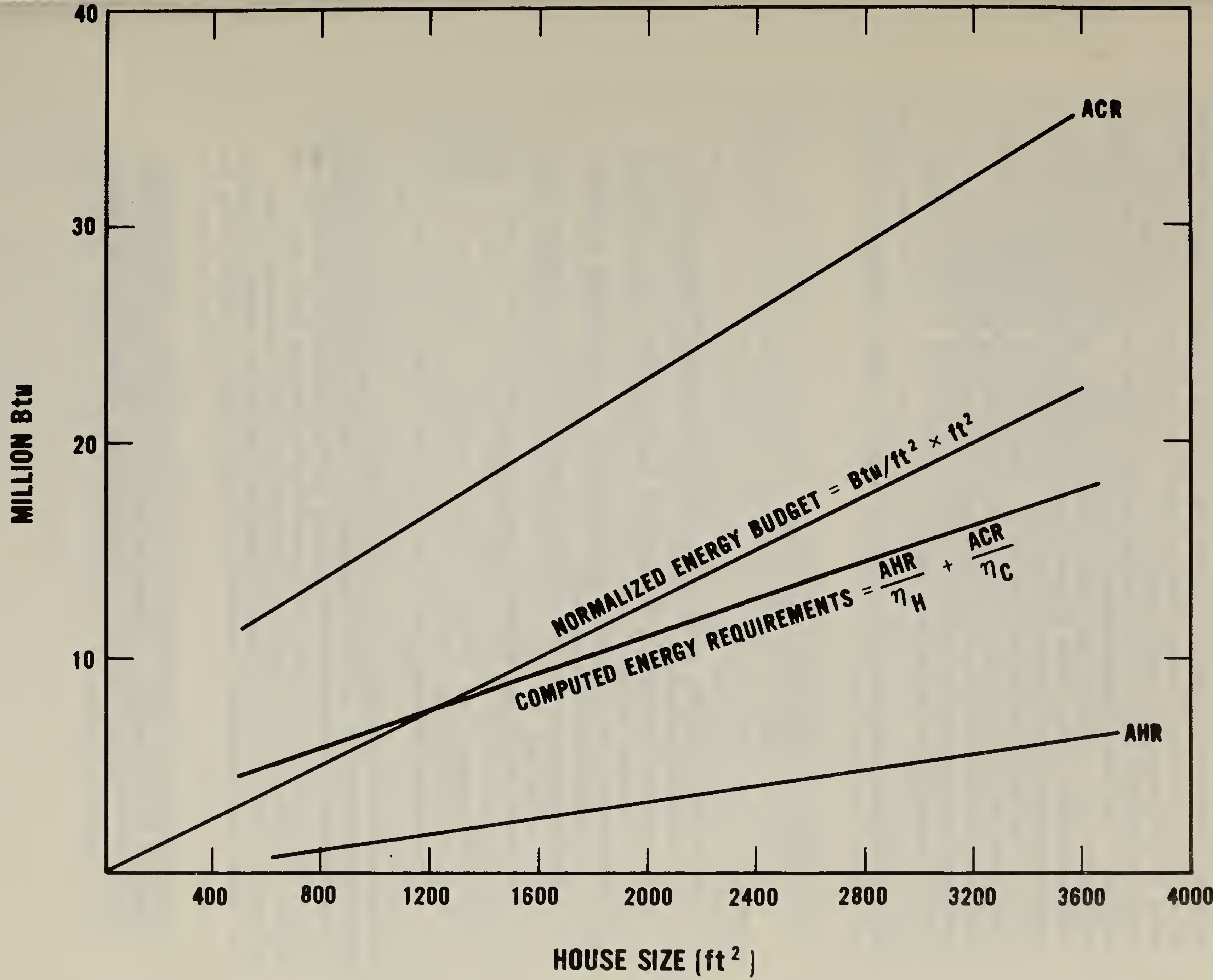


Figure 2. Normalized Energy Budget and Computed Energy Requirements for a Single-Family House in Phoenix (Illustrative).

3. CALCULATION OF DESIGN ENERGY BUDGETS

In this section, the suggested reference building approach (RBA) for determining the actual design energy budget is outlined. In general, there are too many potential combinations of BEPS evaluation factors to produce a comprehensive set of energy budget values for each climate and building type. While energy budget values may be published for certain building sizes, climates, equipment specifications, and building simulation techniques, these would serve primarily as informational or educational resources rather than as the core of the actual BEPS document. However, the energy budget evaluation procedure in the reference building approach is quite simple once the annual space heating and cooling requirements and water heating requirements for the equivalent-sized reference building design (RBD) are known (see section 2.7) and certain other evaluation factors are set forth.

The design energy budget (EB, in million Btu[1]) in the reference building methodology is calculated as:

$$EB = \frac{AHR}{\eta_h} \cdot F_h + \frac{ACR}{\eta_c} \cdot F_c + \frac{AWR}{\eta_w} \cdot F_w ,$$

where

AHR = Annual heating requirements of the reference building design (in million Btu),
ACR = Annual cooling requirements of the reference building design (in million Btu),
AWR = Annual water heating requirements of the reference building design (in million Btu),
η = reference seasonal efficiency of the service equipment type selected,
F = fuel weighting factor, and subscripts

h = heating
c = cooling, and
w = water heating.

The reference seasonal energy efficiency data for each mechanical system would be published in the BEPS document on a regional basis, as discussed in section 2.4. Regional fuel weighting factors would also be published in the BEPS document for each non-renewable fuel/energy type used in residential buildings (e.g., gas, oil, electricity, coal, propane). Such weighting factors would be used to provide a method of summing different fuel types when measured in equivalent thermal units at the building (or

---

[1] It should be noted that this is actually a "weighted" energy budget; i.e. the energy budget, although expressed in Btu terms, is not specified in terms of actual measured Btu but Btu adjusted by the fuel weighting factors.

site) boundary that accounts for differences in production and distribution costs (both direct and indirect) incurred in delivering the energy to the building site. DoE would assign these weights based on research and policy analysis[1].

The design energy budget calculated in the reference building approach is "modular", in that it is built up from less aggregated measures of building energy performance. It is intended to allow extensive design substitutions among all building components and energy using systems of a proposed building (falling under control of the energy budget), so long as the overall energy budget is not exceeded. However, if no air conditioning is to be installed and mechanical air conditioning is not locally required to satisfy specified minimum comfort conditions, the air conditioning "module" ($ACR \cdot F_c/\eta_c$) could be removed from the calculation process. In such a case the resulting energy budget would be based on the space heating and water heating modules only. Other energy usage modules (e.g., lighting) could be added to the energy budget calculation procedure, as deemed appropriate by DoE.

Figure 3 demonstrates the parallel process by which both the corresponding design energy budget and the design energy requirements of a proposed building design are calculated. The designer of the proposed building specifies the building type, size (e.g., floor area), geographic location and generic equipment types to be used for space heating, space cooling, and water heating equipment. Based on the input data, the standard specifies a reference building design and fuel weighting factors which serve as the basis for determining the design energy budget. The reference building design includes the reference building envelope configuration, envelope component performance specifications, and equipment performance specifications. The AHR, ACR, and AWR corresponding to the reference building design can then be calculated using an approved computational method and specified climate data and operational profile. Alternatively, AHR, ACR, and AWR can be directly obtained from a precalculated data base, corresponding to the same building size and climate. The design energy budget can then be calculated, using equation (1) as shown. The same reference climate data base, operational profile, fuel weighting factors, and computational methodology are used to calculate the design energy requirements of the proposed building. The design energy requirements of the proposed building are then compared with the design energy budget in order to determine compliance with the standard. If the design energy requirements are equal to or less than the design energy budget, the proposed building design is in compliance with the standard.

---

1 Some guidelines for developing fuel weighting factors are discussed in Weber, Stephen F., The Effects of "Resource Impact Factors" on Energy Conservation Standards for Buildings, BSS 114, U.S. Department of Commerce, National Bureau of Standards, 1978.

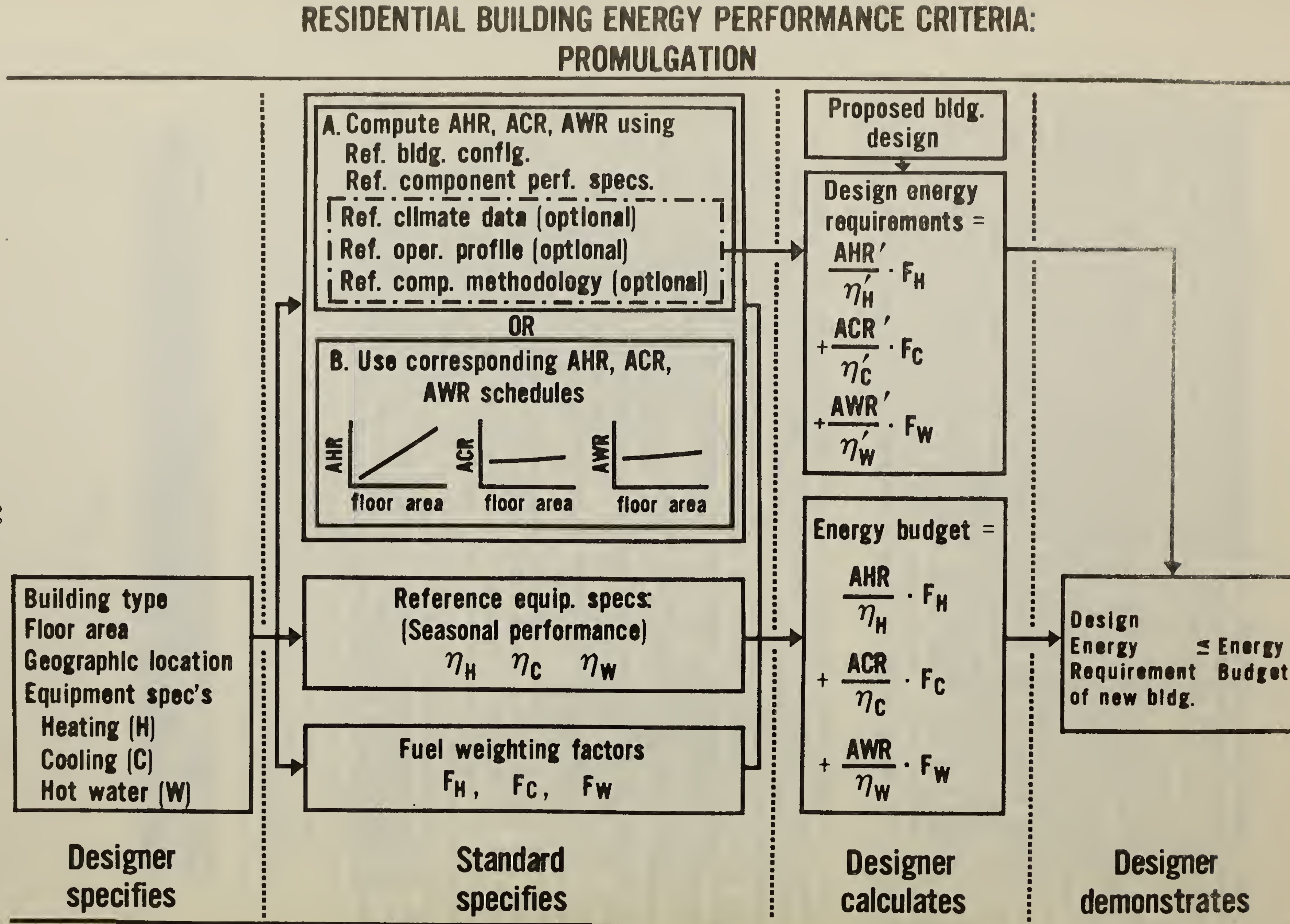


Figure 3. Residential Building Energy Performance Standard Computational Procedures.

One of the primary purposes of a standard is to convey information to the parties using the standard. Energy budgets alone provide little insight into implications for new building design. As a result, it is difficult at present to comment on any more than the basic structure of the DoE-BEPS, since few people have the necessary tools or time to analyze the inherent tightness or looseness of the published energy budgets. The RBA-BEPS, on the other hand, are more easily interpretable in this respect. The reference building approach, being linked in an explicit manner to reference envelope and equipment performance specifications and a reference building envelope configuration, provides specific information about acceptable building design practices. While the reference building approach requires several computations in order to establish a design energy budget, the modular nature of the computational process helps to identify the major determinants of design energy requirements in a well-designed building. The reference building design provides a useful starting point from which to examine design trade-offs that will not increase overall design energy requirements. In research and journalistic reports which analyze the potential impact of BEPS on new building design, considerably more insight into the actual changes in new building designs that are likely to be needed can be gained without extensive computer modeling. The task of developing manuals of acceptable practice (i.e., cookbook approaches to BEPS conformance) will also be easier since reference building designs will be established for a number of basic housing types and sizes and for a wide range of climates.

4. SOME REMAINING ISSUES

While the reference building approach provides a theoretical framework for the development of building energy performance standards, actual implementation will require the resolution of a number of important issues that extend beyond the scope of this report. Technical research in many cases can provide valuable information regarding the sensitivity of resulting building design requirements to a variety of alternative solutions. Ultimately, however, these are largely policy-related issues which require consideration of the original intentions of the BEPS legislation (Pubilic Law 94-385), the practicability of the results, and consensus from the various interest groups associated with the home building industry. Some of these issues are listed below.

(1) To what extent should certain envelope design criteria, such as building shape and orientation and window size and orientation, be fixed in the reference configuration so as to improve the overall energy performance of the reference building? If they are too loose, the resulting standard will not have an energy conservation advantage over component performance standards. If they are too tight, the resulting standard may require conservation measures that cannot be cost justified in some applications. Should an exceptions procedure be made in such a case?

(2) To what extent should the reference building design incorporate systems using renewable energy resources (e.g., passive or active solar heating) in response to Public Law 94-385, which mandates that BEPS encourage the use of nondepletable energy resources? Should only those systems which can be shown to be cost effective on a life-cycle basis be incorporated into the reference building design?

(3) To what extent should a reference building design (RBD) be differentiated to correspond more closely to a proposed building design? In this report it was suggested that the size of the RBD be the same size as the new building (e.g., the square footage of floor area would be the same on both). Similarly, the reference equipment efficiencies would be based on the generic system types used (e.g., gas, oil, electric). Should these equipment efficiencies be further differentiated (e.g., resistance heating specified separately from heat pump heating)? It was suggested that the reference floor performance specifications could be differentiated by floor type (e.g., slab-on-grade versus wood floor over a crawl space), since this variable can have a significant effect on overall building energy performance. Should this be extended to other envelope components (e.g., masonry versus wood-frame walls)? The reference building design would likely be differentiated by house type (e.g., detached vs. attached housing). To what extent should this be further differentiated (e.g., duplex, triplex, "rowhouse", etc.)?

(4) Can the reference building approach be used for housing types other than single-family houses (e.g., low-rise and high-rise apartments)? Can this same approach be useful in developing BEPS for commercial and institutional buildings as well?

(5) If alternative evaluation techniques are allowed for use in establishing the energy budget and demonstrating compliance, what criteria should be established to authorize the use of any particular evaluation technique proposed by users?

(6) Calculating the energy budgets at the building boundary has the advantage of relating to metered energy use, but calculating at the source relates more to national energy conservation goals. Can the controversy associated with use of some form of fuel weighting factors be resolved?

(7) If life-cycle costing is used as the basis for establishing the RBD specifications, can consensus be achieved on the building operational profiles to be used in the analysis? For example, should night setback be assumed? What other financial analysis criteria should be assumed in such a generalized life-cycle cost analysis?

5. CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

The reference building approach (RBA) to BEPS discussed in this report may, in the opinion of the authors, provide a practical basis for improving building energy performance standards over time for single-family residences. This approach is tied to a reference building design and the precalculated energy budget number becomes optional. The RBA-BEPS provides additional information and flexibility to the user, yet it can achieve the same potential energy conservation goal as the current DoE approach. RBA-BEPS based on a reference building design are not meant to entirely replace component performance standards for new building design but rather to augment them so that design trade-offs can be made at the whole building level if they do not increase design energy usage.

Much of the research needed to implement the reference building approach has already been undertaken by DoE in pursuing its goal of BEPS for single-family housing. This work could be used to provide reference component performance specifications that are life-cycle cost effective. Alternatively, HUD FHA Minimum Property Standards, which were developed using life-cycle cost analysis, could be utilized for this purpose. Reference equipment performance specifications are currently being developed at DoE in support of its Appliance Efficiency Program. A major task remaining is to develop a methodology for specifying reference building envelope configurations. Since this is a potentially controversial concept, assistance from the home building industry is essential in converging on consensus specifications for the reference buildings. In addition, a number of other research topics that relate to the determination of building energy performance at the design stage are outlined in appendix A and appendix B.

This reference building approach to BEPS may also be useful for commercial and institutional building applications. However, it is suggested that the process first be successfully demonstrated for single-family housing before attempting to apply it to larger and more complex building types.

REFERENCES

Achenbach, P.R., Functional Performance Requirements for the Environmental and Service Systems in Detached Housing and Their Impact on Building Energy Use, Contract Report, August 22, 1980. (In Review).

Barnett, J., Energy Analysis of a Prototypical Detached Single-Family Residence: The Effects of Climate, House Size, Orientation, and Internal Heat Release, NBSIR, U.S. Department of Commerce, National Bureau of Standards, Washington, D.C. (In Review).

DOE-2 Reference Manual, LA-7689-M, LBL-8706, Los Alamos Scientific Laboratory, Los Alamos, New Mexico, 1979.

"Energy Conservation Standards for New Buildings Act of 1976," Public Law 94-385, Title III.

"Energy Performance Standards for New Buildings; Proposed Rulemaking and Public Hearings," Federal Register, Vol. 44, No. 250, November 28, 1979.

Heldenbrand, J.L., Design and Evaluation Criteria for Energy Conservation in New Buildings, NBSIR 74-452, U.S. Department of Commerce, National Bureau of Standards, Washington, D.C., 1974.

Kusuda, T., NBSLD, The Computer Program for Heating and Cooling Loads in Buildings, BSS 69, U.S. Department of Commerce, National Bureau of Standards, Washington, D.C., 1975.

Marshall, H.E., and Petersen, S.R., "Economics and the Selection and Development of Energy Standards for Buildings," Energy and Buildings, 2 (1979).

"Minimum Property Standards for One-and Two-Family Dwellings," U.S. Department of Housing and Urban Development, Federal Housing Administration, Washington, D.C., 1979.

Petersen, S.R., The Role of Economic Analysis in the Development of Energy Standards for New Buildings, NBSIR 78-1471, U.S. Department of Commerce, National Bureau of Standards, Washington, D.C., July 1978.

Solmet User's Manual (Volume 1), TD-9724, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Washington, D.C., August 1974.

Stamper, E., "Weather Data," ASHRAE Journal, 19, 2:47, February 1977.

Weber, Stephen F., The Effects of "Resource Impact Factors" on Energy Conservation Standards for Buildings, BSS 114, U.S. Department of Commerce, National Bureau of Standards, Washington, D.C., 1978.

APPENDIX A

RESEARCH AND ANALYSIS NEEDED TO SUPPORT DEVELOPMENT OF OPERATIONAL PROFILES FOR RESIDENTIAL BUILDINGS

The following detailed research is needed to support the establishment of consensus operational profiles for life-cycle-cost analyses, building energy calculations, and functional performance requirements for the service systems:[1]

Thermal Environment

- Acceptability of substantial dead band between heating and cooling thermostat settings.
- Use of dry bulb, operative and mean radiant temperatures in insulated houses.
- Simplification of ASHRAE comfort standard to facilitate computer modeling.
- Guidelines for thermostat setback in winter and advance in summer in relation to occupancy periods.

Air Quality

- Performance requirements and an analytical model for ventilation of housing that embraces combustion, respiration, dilution of contaminants, moisture control, leakage control and temperature control.
- Guidelines for winter and summer attic ventilation.

Lighting

- Technically-based performance criteria for the quality and quantity of lighting related to visual tasks.
- Conduct field studies of natural and artificial illumination usage patterns in residences.

---

[1] P.R. Achenbach, Functional Performance Requirements for the Environmental and Service Systems in Detached Housing and Their Impact on Building Energy Use, Contract Report, August 22, 1980 (In editorial review).

Service Hot Water Systems

- Conduct a statistically planned field study of domestic hot water usage of the scope required to determine water usage in relation to family size, composition, and age, working habits, number of bathrooms and to determine water use temperature, water supply temperature, and equipment room temperature.

Other Major Appliances

- Determine amount of excess storage space in refrigerators.

- Determine degree of active usage of freezers by owners.

- Obtain better data for the various usage factors that determine the energy requirements for clothes washing, such as loads washed per year, water-fill level, load size or weight, water removed from clothing, re-use of wash water, temperature selection, and energy metering.

- Conduct a statistically planned field test of clothes dryers to obtain valid data on loads per year, load size or weight, field use factor, energy use, and water removed to better evaluate appliance performance.

- Conduct a field research program to improve correlation of the energy used for cooking on stove tops and ovens as measured in the field with measurements made during standardized laboratory test procedures, including microwave ovens.

APPENDIX B

RESEARCH AND ANALYSIS NEEDED FOR BUILDING ENERGY CALCULATIONS AND RELATED CONSTRUCTION METHODS

The following research is needed to support the energy calculations required to develop realistic design energy budgets for residences:

- Improved computer modeling of various floor/basement constructions and attic heat transfer.
- Validated energy calculation methods for passive solar design options.
- Construction guidelines to control air leakage.
- Relative air leakage of indoor and outdoor surfaces of walls and ceilings.
- Vision research to support an acceptable basis for quantity and quality of illumination and procedures for prediction and field measurement of illumination system performance.
- Develop and verify analytical models for evaluating the daylight illumination levels in housing.
- Determine basic water requirements for various household functions such as hand washing, shower bath, tub bath, dishwashing, laundry, etc., as a basis for performance criteria.

NBS-114A (REV. 9-78)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBSIR 80-2161	2. Gov't. Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE

A "Reference Building" Approach to Building Energy Performance Standards for Single-Family Residences

5. Publication Date

October 1980

6. Performing Organization Code

7. AUTHOR(S)

Stephen R. Petersen, Jim L. Heldenbrand

8. Performing Organ. Report No.

9. PERFORMING ORGANIZATION NAME AND ADDRESS

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, DC 20234

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS *(Street, City, State, ZIP)*

Department of Energy
Washington, D.C. 20461

13. Type of Report & Period Covered

Final

14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

The Department of Energy is currently developing building energy performance standards (BEPS) that are intended to significantly reduce the design energy requirements of new buildings. This report provides a modified approach to the DoE BEPS development program for residential buildings. The modified BEPS are not meant to replace component performance standards for new buildings but rather to augment them so that design tradeoffs can be made at the whole building level if they can be shown not to increase design energy requirements.

In the modified approach, equivalence must be demonstrated between the thermal performance of a proposed building design and a reference building design of the same type and size and in the same geographic location. A number of approved calculation methods could be used to demonstrate such equivalence. This modified approach to BEPS development is directly linked to reference component performance specifications for both shell and equipment through a reference building envelope configuration. This reference basis for the BEPS provides a great deal of information to the user about acceptable building designs, making the modified BEPS approach both more manageable and more flexible than the current DoE approach.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Building design, building energy performance standards, building standards, component performance standards, energy conservation, housing.

18. AVAILABILITY ☒ Unlimited

☐ For Official Distribution. Do Not Release to NTIS

☐ Order From Sup. of Doc., U.S. Government Printing Office, Washington, DC 20402, SD Stock No. SN003-003-

☐ Order From National Technical Information Service (NTIS), Springfield, VA. 22161

19. SECURITY CLASS (THIS REPORT)	21. NO. OF PRINTED PAGES
UNCLASSIFIED	
20. SECURITY CLASS (THIS PAGE)	**22. Price**
UNCLASSIFIED	

USCOMM-DC