

The U.S. Department of Energy's Voluntary Residential Energy Standard—Development and Implementation of an Economics-Based Energy Standard

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ABSTRACT

The U.S. Department of Energy (DOE) has recently developed a voluntary residential energy standard applicable to all locations in the U.S. The standard is designed for voluntary adoption into state or local codes but also is amenable to use in other implementation mechanisms. Developed in response to a congressional mandate, the standard is designed to achieve the maximum level of energy savings justified by consumer economics.

Designing a standard based on optimized consumer economics requires a significant level of effort. The number of variables and processes involved is quite large. The steps include identifying and characterizing available conservation options, estimating conservation option costs, selecting economic parameters appropriate to the task, identifying the optimal combination of conservation measures, selecting the standard's ultimate format, and aggregating the results to fit the constraints of local jurisdictions.

DOE's standard is unique among national voluntary energy standards in the way it approaches these complexities. The standard is embodied in a microcomputer software tool that handles the developmental steps for local jurisdictions. This allows the standard to maintain its cost-effective basis while accommodating new technologies, local climatic characteristics, and local economies.

This paper describes the DOE voluntary energy standard, explains the process by which it was developed, and describes the mechanisms by which it might be implemented. The paper focuses on a description of the process by which most standards move from the developers' notebooks into state and local codes and shows how DOE's standard emulates that process but allows significant reductions in time and effort. It also presents an actual example of how the standard was used by the U.S. Department of Housing and Urban Development (HUD) to update its manufactured housing standards. Finally, some additional mechanisms by which the standard might potentially be used to achieve cost-effective energy conservation are discussed.

INTRODUCTION

The Energy Conservation Standards for New Buildings Act of 1976 (42 USC 6831), as amended, requires the U.S.

Department of Energy (DOE) to issue voluntary performance standards for the design of new residential and commercial buildings. Originally enacted in the wake of the energy crisis, the Act required the U.S. Department of Housing and Urban Development (HUD) to develop, promulgate, implement, and enforce mandatory energy performance standards. Subsequent amendments transferred responsibility for developing and promulgating the standards from HUD to DOE. The Act, as amended, requires DOE to develop energy performance standards that are mandatory for federally procured housing and voluntary for the private sector.

This paper focuses on the voluntary private-sector residential standards. DOE is issuing separate regulations for federally procured housing, noting that purchase volumes, procurement processes, and funding mechanisms differ substantially between the two sectors.

To ensure that the standard is technically sound, economically viable, and politically palatable to the construction industry, DOE involved experts from a number of fields and a variety of institutions in the standard development process. That effort, which involved builders, equipment manufacturers, architects, engineers, educators, researchers, and code officials, is described in detail in Taylor (1988). Here we examine the nature of the product—DOE's voluntary residential energy standard.

We begin with a brief description of the standard. Next, we describe generically the process normally used by standard-setting organizations to establish the provisions of an energy standard. Then, we examine how DOE's standard fits into that context of standard setting. Finally, we present an example of how DOE's standard was used in actual practice and discuss various additional mechanisms by which the DOE standard might be implemented.

DESCRIPTION OF DOE'S STANDARD

Two legislative provisions are particularly important in shaping the design of DOE's standard. First, the standard is required to be established based on economic viability. That is, the standard's provisions should encourage as much energy saving as possible but should ensure that those energy savings exceed the increased cost of construction. In other words, the sum of construction and operating costs should be minimized. Second, the standard's provisions

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must be expressed in terms of equivalency with a target level of energy performance rather than in terms of prescriptive component requirements. A detailed discussion of DOE's response to these mandates may be found in Taylor (1988). A critical result of these mandates is that DOE's standard is packaged in software.

The Automated Residential Energy Standard (ARES) software runs on common desktop computers. It is designed for use by someone responsible for establishing minimum allowable energy construction practices for a particular jurisdiction. Examples of targeted ARES users are a state code official or energy office staff. However, as we will show, many others may find ARES useful as well. The ARES software maintains an extensible data base of energy conservation measure (ECM) costs and contains a procedure for calculating the energy impacts of the various ECMs in various locations. Once an ARES user has entered his/her location and a few current local economic parameters, the software performs an economic optimization to determine the combination of ECMs that results in the minimum overall (construction plus operating) cost of a typical home in that location. The estimated annual energy cost of that optimal house is the primary criterion of the DOE standard. Any house shown by accepted engineering calculations to cost no more to operate than the target house complies with the standard.

Knowing that many builders are not willing or able to perform energy calculations on their houses, DOE provides two alternative compliance mechanisms: (1) a simple prescriptive list of minimum allowable practices (e.g., R-30 ceilings, R-19 walls) and (2) a flexible point system that allows deviation from the simple prescriptive option.

THE TYPICAL STANDARD DEVELOPMENT PROCESS

To fully appreciate the value of DOE's unique standard format, it is helpful to understand the process typically used by organizations that set energy standards. The typical process has three primary features: (1) selection of an energy analysis procedure to evaluate ECMs applied to (usually) one or several hypothetical but typical buildings, (2) definition of a test for the economic viability of ECMs, and (3) selection of appropriate input parameters. For example, the energy analysis procedure could be based on simple degree-day calculations or it could utilize a complex computer simulation. The economic test could be a maximum acceptable payback period, a minimum acceptable rate of return on ECM "investments," or a procedure to identify optimal ECM combinations based on minimizing life-cycle costs. DOE's voluntary residential energy standard is an example of the latter.

The energy standards that typically emerge from the rather involved evaluation procedures described above are rarely used in their resulting forms. More often, a code authority will incorporate a standard's provisions into the

state or local building code. Standards may be adopted merely by reference, but more often they are modified or stripped of provisions not applicable in the local jurisdiction and then incorporated into the local building code. Figure 1 illustrates the process (in an admittedly simplified manner.)

At the top of the figure, the standard's provisions are established by applying an energy and economic evaluation procedure, as discussed above. At this point, the developers of the standard, generally a committee, must collect national average ECM prices, fuel prices, and parameters describing economic conditions. This national average scenario is then used to develop energy conservation criteria for various climates. The evaluation can take years to complete.

At the bottom of the figure, the standard's provisions are incorporated into a state or local building code. At this point, the local official generally uses a common measure of climatic severity (usually degree-days) to select provisions appropriate to the locality. Those provisions are then incorporated, by whatever legislative or rule-making process is relevant, into the local building code. Having converted the standard into a code, compliance procedures and documents must now be developed.

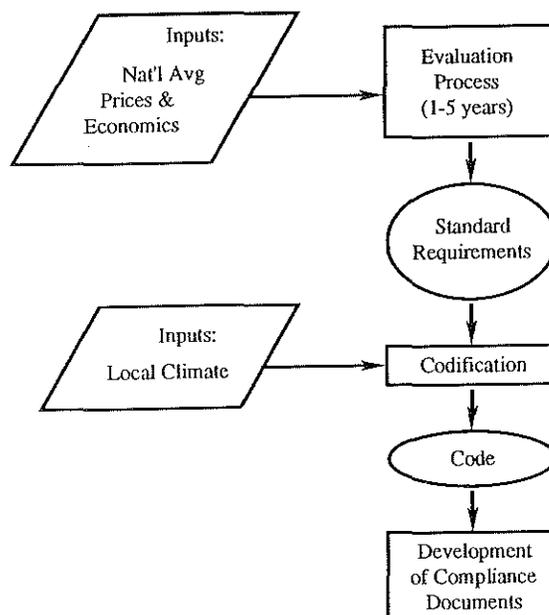


Figure 1 Conventional standard development/implementation process.

Figure 2 illustrates the process as it applies to DOE's standard. Note that the process is almost identical to that just described but has a few notable exceptions. The first and most significant is that the definition and development of the evaluation procedure is done once and encoded in software. Actual application of the evaluation procedure, once current local economic data have been collected, takes hours instead of years. Second, the evaluation procedure is

applied by the local code official, not the standard-setting organization. This allows use of current local prices and economics rather than perhaps outdated national average data. Finally, the software produces compliance documents directly, avoiding, or at least simplifying, the final step of developing compliance procedures and documents.

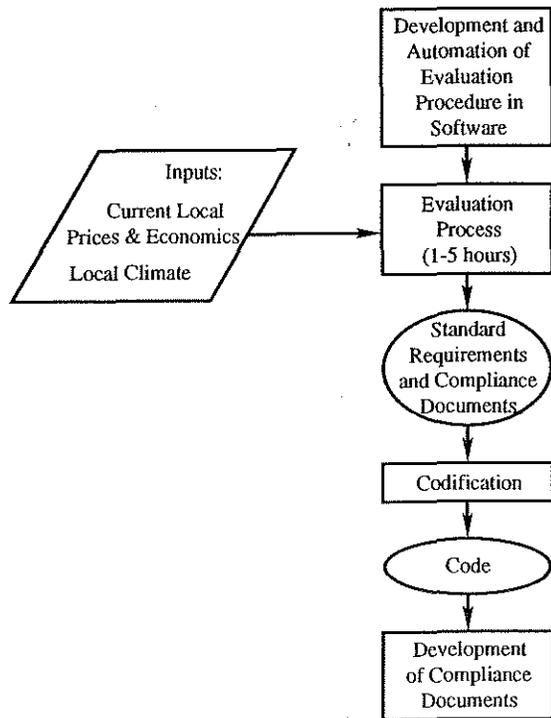


Figure 2 DOE standard development/implementation process.

AN EXAMPLE OF THE DOE STANDARD IN USE

The Housing and Community Development Act of 1987 required HUD to revise energy conservation standards for manufactured housing (HCDA 1987; CRH 1987; CRS 1987). HUD sought to utilize DOE's voluntary standards in developing a revision to the energy conservation requirements in the existing HUD Manufactured Home Construction and Safety Standards (MHCSS) (24 CFR 3280). The development of this standard is documented in more detail in other reports (Conner et al. 1992; Conner and Taylor 1992; Lee and Conner 1992). Here we present the distinctive requirements of that standard-development effort and show how DOE's voluntary residential standard was applied to the problem.

The Housing and Community Development Act of 1987 and the accompanying Congressional Reports (CRH 1987; CRS 1987) defined the type of optimization method that was to be used to set the standard. (The Congressional

reports provided additional clarification of the HCDA and were treated as guidelines.) The optimization methodology was to "ensure the lowest total of construction and operating costs" (HCDA 1987). The methodology was required to "result in the lowest possible total cost taking into consideration down payment, financing, construction, and energy costs" (CRH 1987). The method was specified to be "a life cycle cost analysis" (CRS 1987). The standard was to be developed using "costs to the manufactured home owner" (CRH 1987). The costs and benefits were to be considered for the "home over its estimated useful life" (CRH 1987). This was clarified as "the effective physical life of the structure" (CRS 1987).

ARES satisfied these methodological guidelines and also allowed for the input of the specified parameters (e.g., costs from the consumer's perspective). Its use expedited the development of HUD's new standard. ARES combines a life-cycle cost model, a cost-minimization model, and an energy impact model. Given a set of fuel prices, financial and economic parameters, and ECM costs for a building at a specific location, ARES identifies the set of ECMs such that the homeowner's total life-cycle cost is minimized.

However, not all of HUD's requirements were addressed directly by the DOE standard software. The *Congressional Record* guidelines for the manufactured home standard indicated that HUD should establish "maximum transmission heat loss coefficients (overall U-values, or U_o) in a number of climate zones" (CRH 1987). ARES does not report its results in terms of U-values, nor does it deal with geographic zones. Instead, because it is designed for easy use by a local code official, it specifies component efficiency levels for specific locations represented by one of 881 cities in its data base. Thus, HUD was faced with the dilemma that while ARES could save considerable effort in identifying cost-effective ECMs for a specific location (city), it could not produce efficiency requirements for an aggregated geographical zone.

The approach taken to overcome this divergence was to use ARES to identify cost-effective measures for numerous individual cities, then to convert those results to overall U-value (U_o) units and aggregate to zones outside of ARES. ARES produced separate requirements for each city, five heating fuel/equipment types (natural gas, LPG, oil, electric resistance, and electric heat pump), and two prototypes (single- and double-wide). Financial parameters representing the manufactured home consumer and industry were input. ECM options and costs were identified for manufactured homes. Separate fuel costs were established for each fuel by state. Expected fuel escalation rates were identified for several regions of the country. Given these inputs, ARES identified the optimal set of ECMs for each of the 881 cities in the data base.

The optimum ECMs at various locations were translated into overall U-values (U_o) as the area-weighted average of each building component—ceilings, walls, floors, and windows. These U_o values were then aggregated to

state and zonal averages by a statistical clustering analysis. Because the resulting average U_o values were similar, the requirements for single- and double-wide homes were merged. Similar considerations resulted in consolidating the requirements for different fuel types.

The availability of the DOE standard software allowed HUD to establish a new manufactured housing energy standard, within legislative constraints, with a high degree of confidence that consumer costs would be minimized. The approximate costs and benefits of the proposed standard were estimated (Conner et al. 1992). The average additional cost per current-practice home to meet the proposed standard was estimated to range from \$800 to \$1100. The average present value of the resulting energy savings was estimated to be two to two-and-a-half times the cost of meeting the standard. The aggregate national present value (benefits minus costs) of the proposed standard relative to then-current practice was estimated at \$300 million per year.

OTHER POTENTIAL IMPLEMENTATIONS OF THE DOE STANDARD

As we have pointed out, DOE's voluntary residential energy standard is designed to facilitate its easy adoption by state and/or local code authorities. However, the packaging of the standard in software offers opportunities for many other implementation mechanisms. Indeed, the example of HUD's manufactured housing standard update shows how readily the DOE standard was adapted to meet HUD's specific constraints. We will discuss several additional ways the DOE standard might be utilized to achieve residential energy conservation. Although several of these would require modifications to DOE's standard, particularly changes to the ARES software, they are worth mentioning because of their potential benefits.

Standard-Development Tool

The software packaging of DOE's standard makes it amenable to modification to fit the unique needs of a state or other large geographical jurisdiction. In updating its manufactured housing standards, for example, HUD had a legislative requirement to format its standards in terms of an overall building heat transmission coefficient (U_o). Although DOE's standard is not formatted in that manner, the ARES software made easy the process of identifying optimal building characteristics in a large number of locations. Manual post-processing of the ARES results transformed them to the format required by HUD. Any state or other code authority could follow a similar procedure to accommodate unique local requirements.

Home Energy Rating System

One approach to encouraging residential energy conservation taken by many organizations, particularly electric utilities, is to rate homes according to their relative energy efficiency. A utility may, for example, offer a rebate or reduce electricity prices to customers whose homes meet a specified energy-efficiency rating. An added benefit of these home energy rating systems (HERS) is that a good efficiency rating can increase the market value of the home when it is sold. By giving energy efficiency value in the marketplace, such an implementation of the DOE standards would achieve the goal of reducing residential energy consumption without direct regulation.

DOE's standard is particularly well-suited to a HERS implementation. The point system compliance documents produced by the software offer builders a simple way to calculate the energy impacts of various design trade-offs. The "points" awarded various conservation measures are directly proportional to estimated annual energy costs. With some minor modifications, the DOE standard's point system could produce a rating for a house comparable to the miles-per-gallon sticker found on a new automobile or the yellow appliance efficiency label found on a new refrigerator.

This type of rating is distinct from many existing HERS programs in that it rates homes on a quantitative rather than qualitative scale. In some rating systems, for example, a house may be awarded one, two, or three stars to indicate its relative efficiency. Or, the rating may be simply binary—either the home qualifies as "efficient" or it doesn't. A quantitative HERS, as would be supported by DOE's standard, has the advantage of providing valuable information about the expected cost of operating a home. Such a HERS might possibly facilitate "energy-efficient mortgage" programs, whereby buyers could more easily qualify to purchase a more efficient home. Incorporation of the energy cost information into the loan process would be quite natural, especially if the HERS rating were a direct outcome of demonstrating code compliance.

Design Tool

Use of the DOE standard as a design tool for builders would perhaps require the most modifications to the software, but its potential benefits are significant. The ARES software contains the "engine" necessary to estimate energy and economic impacts of various ECMs. In its current form, ARES operates only on three generic prototype buildings. However, simply changing the program's interface would allow access to ARES' capabilities for a specific house entered by a builder. Such a tool would not only assist builders in identifying the most cost-effective energy features for prospective homes but could potentially simplify the process of demonstrating code compliance later because essentially the same tool would be used for both.

CONCLUSION

We have described DOE's voluntary residential energy standard and shown how its software-based format represents a new concept in energy standards. Compared with the typical process by which energy standards are generated and incorporated into enforceable building codes, the DOE standard offers (1) more flexibility to the local code official, (2) better opportunity to consider current local cost data and economic singularities in establishing cost-effective energy criteria, (3) more rapid and easier periodic code updates to keep up with changing technologies and economics, and (4) a framework that encourages numerous and innovative methods of promoting local adoption of energy-efficient construction practices.

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Stephen J. Turchen of the U.S. Department of Energy is responsible for the issuance and future development of the voluntary residential energy standard. The standard is expected to be published as a draft interim notice in 1992.

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