Energy Efficiency Capital Requirements for Buildings in the United States

J. Michael MacDonald, Oak Ridge National Laboratory

Estimates of energy savings for any national energy efficiency or environmental improvement program should be based on a reasonable understanding of how much of the market can be served by such a program and what is the total value of investment required (capital requirements) to accomplish the savings claimed by the program. Current information on the energy savings performance and capital requirements of large-scale energy efficiency programs is used to develop a simple framework for analysis of capital requirements and the size of markets (dollar value of the markets) to compare with proposed new initiatives or programs. The comparison provides a reality check on the energy savings claimed. Based on this analysis framework, current energy efficiency efforts and estimates of savings for proposed initiatives are examined. The examination shows that, in the United States, investment requirements for achieving claimed national energy savings goals should be estimated more consistently and that constraints related to the dollar volume of markets do not appear to be considered adequately. The analysis framework is used to show that major growth in existing energy efficiency markets is needed, and that simple reliance on existing approaches such as current utility DSM programs will not be adequate to reach proposed goals. Any nation serious about achieving needed energy use reductions in buildings should have reliable information about the costs of and increase in market size needed for achieving reduction goals. The analysis framework presented here will help improve that reliability.

Introduction

Analyses of building energy savings potential for proposed new programs or initiatives at a national level in the United States are usually stated in terms of quads/yr (quad = quadrillion Btu), based on estimates of future changes to building stock. Checking the reasonableness of these estimates has typically been difficult when the savings are obtained from a computer model that incorporates economic, engineering, and other factors to estimate changes over time. Planning efforts for the U.S. Department of Energy (DOE) for the *Existing Buildings Research Program* and for a new initiative titled *Rebuild America*[1] included an examination of the capital requirements for energy efficiency retrofits or modifications to existing buildings and of the capital requirements for achieving one quad/yr savings for various programs. This examination indicated the importance of this type of information for planning and policy development, as a simple reasonableness check on expected savings can be obtained through comparison with historical results. The results presented here are intended to help those involved with energy efficiency policy and planning to include capital requirements data in analyses where appropriate.

Recent estimates of national energy savings for specific initiatives are examined using a capital requirements analysis framework. The examination shows that some savings estimates may be flawed, as the claimed changes in energy use fail to match the total capital investment indicated by the analysis framework (capital requirements) needed to effect the change, and the claimed changes sometimes imply large (and unlikely) changes in overall market size (amount of dollars invested by consumers to make the changes). For example, enormous benefits have been estimated from new standards related to increased efficiency of heating and cooling appliances for buildings in the near future, without considering market size and total capital costs involved. However, the potential savings from such standards are constrained by the size of the market (total dollars invested each year). Standards by themselves will not lead to a larger market size. The need for improved understanding of what can be accomplished through proposed initiatives is highlighted by this examination.

The analysis results are presented from the perspective of energy use, which is also a reasonable analog for air emissions, as air emissions and energy use are fairly well related. Achieving energy use savings and reductions in air emissions are current national priorities in the United States. Reducing energy consumption by one generic quad/yr in buildings will lead to a reduction in air emissions of about 16 million metric tons of carbon equivalent.

The analysis and comparisons are based on total costs (total investment required to achieve specific energy savings), as opposed to marginal or incremental costs. This distinction is important, as it means this type of analysis is typically not an estimate of cost effectiveness. The total costs are necessary to calculate total capital requirements and market size. The data are specifically focused on buildings already in existence and do not examine impacts for new buildings.

The data presented are highly aggregated, which is appropriate for some types of examination of national-level goals. However, a word of caution should be given that this type of information may not be appropriate for comparison with smaller-scale initiatives. Some care must be used in making comparisons of highly aggregated data with more localized results.

Some Historical Data on Capital Requirements

Examples of available data on capital required for achieving one quad/yr are presented in Table 1. The data in Table 1 are based on specific values for the Weatherization Assistance Program of DOE and for the Texas LoanSTAR Program. The values presented for utility DSM programs are approximate estimates based on examination of impact evaluations and on a "best guess" as to what the "average" utility DSM program is achieving. The key point of the data is to understand the ranges of capital requirements. The appropriate use of data such as these is to "estimate" capital requirements for achieving energy savings from current or planned large-scale energy efficiency programs.

All discussion of energy savings in this paper refers to primary energy, where the conversion factor for electricity is over 10,000 Btu/kWh (typically 11,600). Results are presented in terms of billions of dollars to achieve a quad/yr of savings. The specific values are also equivalent to the cost in dollars for a million Btu (dividing billions of dollars by a billion and dividing a quad by a billion to have millions).

The data from the National Weatherization Evaluation (Brown et al. 1993), which examined Program Year 1989 for the Weatherization Assistance Program, show that the total investment required to achieve 1 quad/yr of *net savings* (in comparison to a control group) is about $88 billion. This value includes all overhead and administrative costs (what the evaluation terms the Program Perspective). The total cost per dwelling weatherized is about $1550, and this investment saved about 15.7 MBtu/yr. If only installation costs are considered, the cost is $1050 per dwelling, and the investment cost would drop to $60 billion for 1 quad/yr savings.

As an example of the variations in estimated costs that can occur if other factors are introduced, a second column is shown to indicate the cost for achieving 1 quad/yr savings if nonenergy benefits are subtracted from total costs. The evaluation estimated these nonenergy benefits (enhanced property value, indirect employment income, environmental externalities, etc.) to be $976 per dwelling. If total costs of $1550 have the $976 subtracted as offsetting benefits, the net cost is $574 per dwelling. Based on this value, the net investment cost for achieving 1 quad/yr savings is $33 billion. Whenever the concept of net costs is introduced, the picture changes. Although the nonenergy benefits are important, the total capital requirements for the Program to achieve 1 quad/yr savings are still $88 billion. However, additional benefits must be considered at some point in determining national priorities.

The Texas LoanSTAR program is a major effort to increase the energy efficiency of state and local government buildings in the State of Texas (Turner 1990). Under this program energy and dollar savings are calculated based on measured energy use in buildings, usually with submetering of steam, chilled water, and electricity for heating/cooling systems. Data were obtained on the first years of the program, where adequate historical data on retrofit savings covering 4.6 million sq ft of commercial floor space (24 buildings) exist. These data show that the 24 buildings are saving about 0.0006 quads/yr, with a total investment cost of $12.9 million, which translates to $21.5 billion invested to save 1 quad/yr.

Other data we have on commercial projects shows that this value is about typical for projects where high energy savings are expected in the buildings (McLain et al. 1994). A field demonstration project conducted for the *Existing Buildings Research Program* in a small bank building had a smart thermostat installed (Sharp 1990). The results for this small project translate to a cost of $6 billion to save a quad/yr, but if overhead and management costs were added, this would probably increase to the range of $10-20 billion. However, not all commercial buildings have possible high savings for low investment cost. Thus, the value $20 billion per quad/yr is presented as a lower range of expected investment costs for commercial retrofit programs.

Table 1. Initial Retrofit Investment Cost for Energy Savings, by Sector

($1987 billions per quad/yr)

	DOE Weatherization Program retrofits Program Year 1989		Texas LoanSTAR or Exemplary Project	Utility DSM retrofits Electric only
Sector	Average	Adjusted for nonenergy benefits	1993	1990
Residential	88	33	NA	75
Commercial	NA	NA	20	45
Source:	From Brown (1993)		Texas LoanSTAR and ORNL data	For both sectors, estimated from Hirst (1993)
			Energy benefits only for these data -- no electric demand or other benefits	

The third major column in Table 1 shows estimates of capital investment costs for electric utility demand side management (DSM) programs. Total utility DSM retrofit costs are available directly from Hirst (1993). The total investment cost for 439 electric utilities in the year 1990 was $1.18 billion, and their cumulative energy savings from all past DSM investments was an estimated 18.7 TWh/yr. At 11,600 Btu/kWh, this translates to a savings of 0.22 quads/yr total. Estimating the total investment to achieve this savings over time is difficult. A value of $45 billion to save 1 quad/yr in the commercial sector is one estimate presented in Table 1.

The value of $45 billion is obtained as follows. A rough estimate of total DSM investments over time would be that DSM ramped up on a straight line that can be approximated as extending from the year 1980 to the year 1990 (note that programs run by the Tennessee Valley Authority in the 1970's and early 1980's which account for almost 20% of the total savings are included). The area under a right triangle of 10 years length and $1.18 billion/yr in height is 5 x 1.18 = $5.9 billion. This $5.9 billion to save 0.22 quads/yr would imply capital requirements of $27 billion per quad/yr. However, the estimated savings from DSM programs are probably higher than actual. Actual evaluations (examine the Proceedings of the Energy Program Evaluation Conference 1993, Ettinger 1993) indicate that, at best, the actual savings achieved is 70% of estimated. Dividing $27 billion by 70% leads to a value of $38 billion. This overall value includes residential, commercial, and industrial sector results, and an examination of sectoral results (Ettinger 1993) indicates that the most cost effective DSM is achieved for the industrial sector. Also, an evaluation of a major commercial lighting program in Massachusetts shows the cost of net savings to be about $55 billion per quad/yr (MacDonald 1993a). Overall, the evidence suggests that commercial sector DSM is likely to be at least $40-50 billion per quad/yr, so a value of $45 billion is used in the table. However, we must remember also that utilities make these investments to save electric demand in most cases, and assigning all capital requirements to energy savings does not accurately reflect what they are trying to accomplish. Conversely, from the energy savings and air emissions reduction perspective, this estimated cost represents the capital requirements for reducing energy use and emissions under such programs.

A value for residential DSM is not specifically known at this time, but extrapolation of available data beyond benefit/cost type results suggests that costs for residential DSM are about $75 billion per quad/yr. An exact value would be useful to know but not critical to the ideas presented here.

Capital Requirements by Measure Type

The information presented in this section is not meant to be precise but is meant to indicate reasonable estimates. The purpose of these data again is to allow "estimates" of capital requirements for achieving energy savings from current or planned large-scale energy efficiency programs.

The results presented above for the national evaluation of the Weatherization Assistance Program indicate that $60 billion is spent for installation of a comprehensive set of retrofits in low-income residences to achieve 1 quad/yr savings ($88 billion per quad/yr includes all overhead and administrative costs also). Data from field tests conducted by Oak Ridge National Laboratory (ORNL, MacDonald 1993b) in residences show an investment cost for achieving one quad/yr savings for low-income weatherization that has declined over time. Results in 1983 showed that one quad/yr was costing almost $200 billion. Improvements to the methods used in 1983 led to an investment cost of about $60 billion per quad/yr in a 1985 field test, and a field test in 1990 showed an investment cost of about $55 billion per quad/yr. The field test data, combined with the national evaluation results, suggest that a reasonably comprehensive program of residential retrofits aimed at, primarily, saving heating energy has capital requirements for installation of the measures of $55-60 billion per quad/yr.

The commercial sector results presented above indicate that energy savings of one quad/yr can be achieved for an investment of $20-45 billion (Table 1) in typical cases, where the lower value is typically achieved for a mix of measures in a building with high initial energy use per sq ft of floor area.

Data for specific end uses of energy are useful, but the potential variations lead to an incredible possible range of values, since energy savings can be negative in some cases. Thus, these values are difficult to specify with precision and are approximate. The purpose of presenting the values is to stimulate thought and consideration of measurement and reporting of such values in the future. Because of the wide variation and inexact nature, the numbers will be presented within the text to assure that the reader understands the context in which the data must be viewed.

The capital requirements presented below are based on total cost and NOT INCREMENTAL COST. Thus, replacement of a refrigerator depends on the total cost of the refrigerator and not the incremental cost between an energy efficient unit and a standard unit. The purpose of this is to understand the TOTAL capital requirements. The capital requirements values are based on ENERGY SAVINGS ONLY, so benefits related to demand and other factors are not included.

For the residential sector insulation is a common measure. The capital requirements for installation of ceiling insulation for one quad/yr savings are estimated to be $40-130 billion; for wall insulation, $90-170 billion. The requirements for lighting retrofits are estimated to be $60-300 billion, and for refrigerators, $100-200 billion. The requirements for high-efficiency heating/cooling equipment are estimated to be $90-200 billion.

For the commercial sector lighting retrofits are estimated to cost $30-70 billion, while variable air volume retrofit is estimated to cost $80-150 billion. Energy management is accomplished in many ways, often through enhanced control systems for heating/cooling systems, but also possibly through informed action of building occupants or operators. However, many energy management systems are installed that do not function properly. Thus, the capital requirements for energy management are estimated to be $10 billion to infinity (no savings for some cost, or division by zero). Payoff in this area can be extremely good but is also often negative.

Capital Volume of Building Alteration Markets

Understanding the capital volume (total dollars spent per year) of building alteration markets is important, because the volume of the markets indicates how much activity is currently conducted. This volume is a reference that indicates how much the market will have to grow to meet increased capital requirements for higher efficiency.

Data on the capital volume of alterations in buildings for different markets by residential and commercial sector are shown in Table 2. The total value of the alteration, replacement, and repair market is shown in the first column. These data are obtained from Department of Commerce data (DOC 1993) and cover all such modifications in buildings, including all maintenance and repair work, for the years shown.

The commercial data for this first column are estimated by ratio of data contained in DOC Tables 1205 (residential total construction) and 1233 (residential alteration, renovation, ...) multiplied by total commercial construction from Table 1205. Total commercial construction equals total nonresidential minus industrial and farm nonresidential construction.

The value of energy-saving alterations or retrofits shown in the second column are estimated by the author based on examination of limited residential data and ratio estimate for the commercial sector. These values are very rough.

The data from the National Weatherization Evaluation (Power 1992) are used for those data in the third column. The total value of all finds invested in low-income weatherization according to DOE Program Rules are given in Figure III of the Executive Summary of that report for the years 1988 and 1989 (1990 value estimated to be about $0.5 billion based on trend).

The electric utility DSM program data are estimated from Table 1 of Hirst (1993). The total investment by 439

Table 2. Retrofits and Alteration/Repair Market, by sector

($1987 billions per year)

	Total Alteration, Renovation, and Repair Market		Energy-saving Retrofits		DOE Weatherization Program Retrofits		Electric Utility DSM Retrofits	
Sector	1988	1990	1988	1990	1988	1990	1988	1990
Residential	92	100	8	9	0.6	0.5	0.2	0.4
Commercial	41	50	4	5	NA	NA	0.1	0.3
Source: Resid:	Statistical Abstract of U.S. 1992, Table 1233		For both sectors, based on author estimates		From Power (1992), Figure III		For both sectors, estimated from Hirst (1993), Table 1	
Comm'l:	Statistical Abstract of U.S. 1992, Tables 1233, 1205							

electric utilities in DSM programs is almost $1.8 billion in 1991, but only $1.2 billion in 1990. These costs are probably close to 90% of total DSM expenditures by all electric utilities in the country. Given that DSM expenditures include significant efforts to treat INDUSTRIAL facilities improvements and shift demand through rates programs, only a portion of these costs is directed at residential and commercial retrofits. The estimate derived here is that $0.4 billion was spent for residential retrofit and $0.3 billion for commercial retrofit in 1990. These values probably increase dramatically for 1991 and 1992, but future growth is uncertain. Values for 1988 are (roughly) estimated.

Scenarios on Capital Requirements to Meet National Goals

Significant effort has been expended toward defining national energy saving goals. A couple of years ago, DOE developed a goal of holding energy consumption in buildings level through the year 2030. Figure 1 shows an example of the breakdown of the components of energy use developed for this goal, where 15 quads/yr of buildings energy use had to be saved by the year 2030. The *Climate Change Action Plan* (Clinton and Gore 1993) describes goals for reducing air emissions by 16 million metric tons carbon equivalent (MMTCE) in residential buildings and over 10 MMTCE in commercial buildings by the year 2000. (One quad/yr saves about 16 MMTCE.)

Saving 15 Quads/Yr by the Year 2030

The values presented earlier can be used to examine these national goals. The 15 quad/yr savings achieved by the year 2030 could only be achieved through a broad program approach that addresses both existing and new buildings through a wide range of measures. Assuming that 8 quad/yr of these 15 must be achieved through improvements to existing buildings allows capital investment estimates to be made based on the data presented previously.

The broad program approach in both residential and commercial buildings suggests that the cost of achieving the savings will be in the neighborhood of $50-60 billion per quad/yr savings. A total savings of 8 quads/yr leads to a total investment of $400-480 billion. Over a 40-year period from 1990 to 2030, the average yearly investment required is $10-12 billion/yr. From the capital volume of the retrofit markets shown in Table 2 ($14 billion in 1990), we can observe that the energy-saving retrofit market would almost have to double to achieve such a goal, or that the equivalent of 20 or more Weatherization Assistance Programs or utility DSM retrofit programs would have to occur. Imagine having national retrofit activity that is 10 times what current DSM and Weatherization activities combined are for the next 40 years (and all this without considering activities for new buildings). This is a lot of investment to leverage, and probably more than utilities alone can afford.

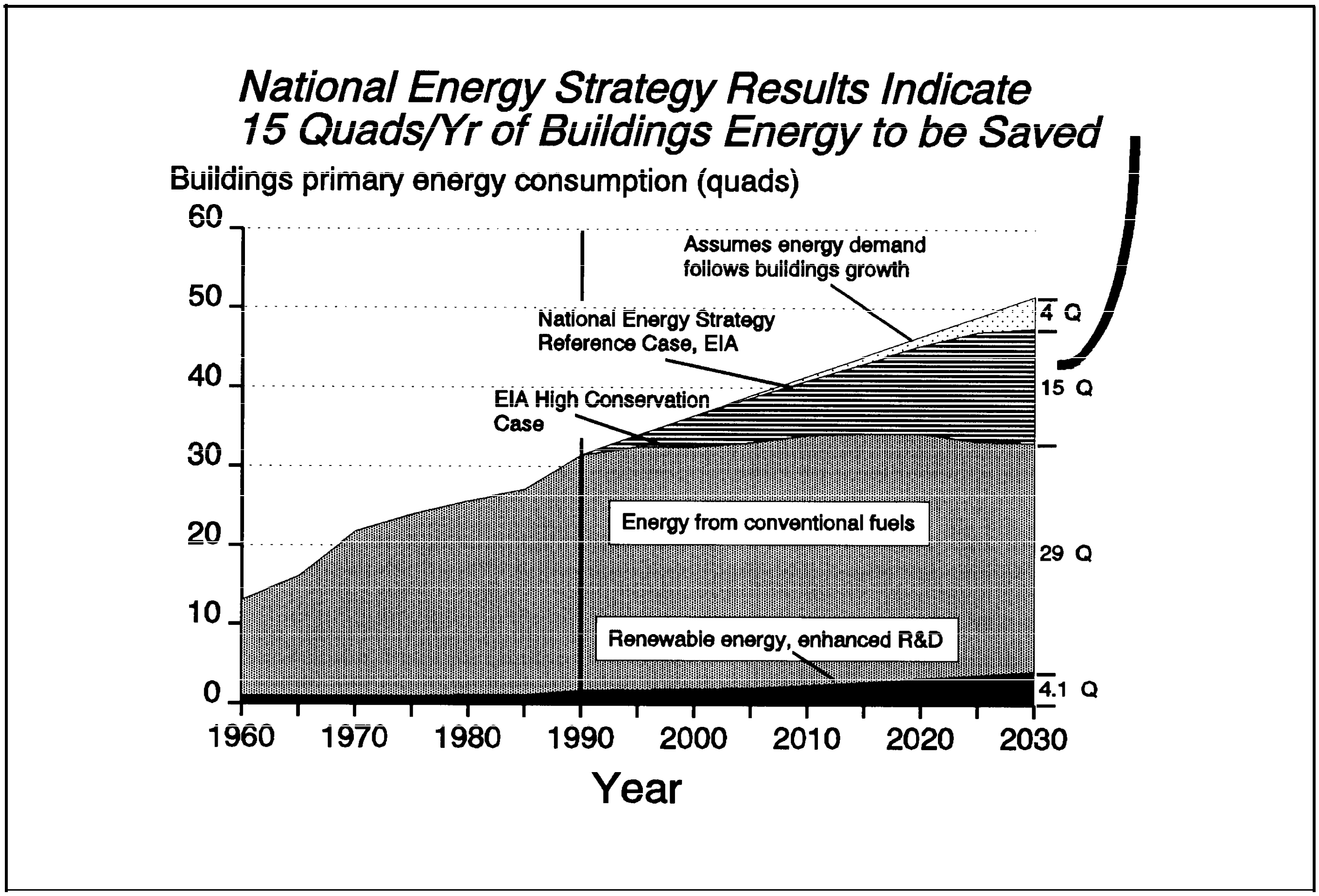

Figure 1. National Building Energy Efficiency Goal Diagram for the United States, cir. 1993

Now consider that we would like to achieve 2 quads/yr of the 8 quads/yr total from heating/cooling system replacements in residential buildings. The total dollar value of ALL replacement heating and cooling systems in residential buildings in 1990 was $3.4 billion (DOC 1993, Table 1233). Saving 2 quads/yr will require an investment of $90-200 billion per quad/yr (see Capital Requirements by Measure Type), and a likely average value may be about $150 billion. The $150 billion average leads to a total investment of $300 billion that would be required for the needed savings, but we are constrained by the size of the replacement market to some degree.

An investment of $300 billion over 40 years is $7.5 billion/yr, while the existing capital volume of this market is $3.4 billion/yr. Thus, investing $7.5 billion/yr implies that all replacements which would have occurred normally over the next 40 years have to be high efficiency and that an additional $4.1 billion would also have to be stimulated to occur each year. Achieving such an immediate increase, in tandem with having ALL replacements be high efficiency is unlikely.

Without early retirement of equipment, the savings that can be achieved through high efficiency heating and cooling systems is probably approximated reasonably by the size of the existing replacement market. Thus, $3.4 billion/yr for 40 years implies a total investment of $130-140 billion. If one quad/yr requires $150 billion to achieve, this calculation implies that a little less than one quad/yr savings is possible over the next 40 years without efforts to promote early retirement of equipment.

Similarly, assume that we want to achieve one quad/yr energy savings from commercial lighting retrofits. The required investment is $30-70 billion, which amounts to $0.75-1.75 billion/yr invested for the next 40 years in lighting retrofits. This value is about 2-6 times the estimated total value of utility DSM efforts in commercial buildings in 1990. An increase in lighting retrofits alone that is this much larger than current DSM activities also appears unlikely.

Saving 26 MMTCE/Yr by the Year 2000

The reduction in greenhouse gas (GHG) emissions needed for the *Climate Change Action Plan* (CCAP) is also substantial. The GHG reductions imply an energy savings of roughly 1 quad/yr for residential and 0.6 quads/yr for commercial buildings. As in the previous section, a broad-based program would be required to achieve these goals. Table 1 indicates capital requirements of about $75-80 billion for 1 quad/yr savings, but the assumption will be made here that residential savings can reobtained for $60-75 billion (to indicate possibly more favorable bounds). Table 1 also indicates capital requirements of $20-45 billion for commercial buildings, and these will be modified slightly to $25-45 billion for this discussion to indicate a more likely lower bound.

The CCAP shows required investment levels in the summary table of actions. The total estimated investment is about $30 billion for residential and $20 billion for commercial. Based on the data presented here, the CCAP residential investment requirements appear to be low by a factor of 2 or more and the commercial requirements are $5-25 billion low. This comparison says nothing about the individual actions proposed within the CCAP.

Examining the capital volume requirements for the CCAP, over the five years inclusive of 1995-1999 (the CCAP time frame), the numbers above indicate a required average yearly investment of $12-15 billion for residential and $5-7 billion for commercial, for a combined capital volume of about $15-20 billion/yr for both sectors combined. This level of investment is slightly larger than the estimated 1990 level of activity for all energy-saving retrofits (Table 2, $14 billion) and implies that the total market would have to double its current size to meet the additional energy savings goals beyond what the existing market would achieve. This capital volume is 10-15 times the size of all current utility DSM efforts in building retrofits and DOE Weatherization Program efforts combined.

Thus, to achieve the emissions reductions goals described in the CCAP, a major effort is needed, essentially doubling all current activity immediately in 1995 and continuing at that rate for the following five years.

Estimated Savings from the Energy Policy Act

A paper on implications of the Energy Policy Act of 1992 (EPACT) for utility DSM efforts was prepared by Geller and Nadel (1992). The electricity savings estimated in this study for energy efficiency provisions of EPACT are 1.24 quads/yr by the year 2000 and 3.2 quads/yr by the year 2010. Using calculations similar to those above and assuming that one quad/yr will cost about $50-60 billion, the total investment required to reach the savings of 1.24 quads/yr is about $60-70 billion. Investing $70 billion over 7 years leads to $10 billion/yr, which is less than the $15-20 billion/yr needed for the CCAP goals but still requiring an approximate doubling of the current energy retrofit market capital volume for a seven-year period. The requirements for the year 2010 goal are approximately the same on an annualized basis over 17 years.

Geller and Nadel indicate that savings from standards for increased equipment efficiency will amount to 0.5 quads/yr by the year 2000 and 0.9 quads/yr by the year 2010. Achieving 0.5 quads/yr savings through equipment standards would require an investment of perhaps $75 billion. If the equipment replacement market for the items covered under the applicable sections of EPACT is $10 billion/yr (and the market is probably smaller than this for the residential and commercial sectors), then the total investment required exceeds the market size. The implication is that standards alone would cause the existing replacement market of these items to totally saturate with the higher efficiency equipment (which may be possible) and lead to new activity that exceeds current market capital volume (which is unlikely). Overall, the savings estimates appear too high, based on these simple capital comparisons.

Conclusion

The data and scenarios presented in this paper highlight important information that should be considered by energy planners and policy developers relative to large initiatives or programs aimed at achieving substantial energy savings. First, the total dollar cost (not expressed as incremental costs, life cycle costs, or levelized costs) for achieving improvements in energy efficiency, energy use reductions, or energy emissions reductions should be considered in any analysis of possible policy options. The capital requirements for energy efficiency must be understood better. However, the highly aggregated approach used here may not be appropriate for examination of more localized initiatives or programs.

The inclusion of total investment values in the *Climate Change Action Plan* (Clinton and Gore 1993) is important for understanding the likely costs for each part of such a program, but the simple analysis presented here suggests that the capital requirements for the CCAP were not estimated consistently for the commercial and residential sectors. In addition, each individual initiative in the CCAP should be examined to compare expected capital requirements, market volume limitations, and sources of capital to satisfy desired goals with what is proposed.

Much energy efficiency planning appears to occur in a framework that considers economic growth but does not check market constraints. The information presented in this paper provides a beginning framework for inclusion of capital requirements in energy efficiency planning.

The analysis presented here suggests that major growth in existing energy efficiency markets is needed if proposed energy savings goals are to be met. The source of capital for this growth is not certain. Examination of the two major energy efficiency retrofit sectors, the DOE Weatherization Assistance Program and utility DSM programs suggests that retrofit efforts 10 to 20 times the current level of those programs are needed to achieve typical stated national energy saving goals. Electric utilities are not likely to have access to all this capital, and indeed, some are turning to the financial sector of our economy for assistance.[2] Overall, energy efficiency policy has to address the issues related to this major growth. If we want to achieve the types of goals often stated, how are we going to accomplish the required growth in market volume and allocate the required capital.

Of major importance, simply treating low-income residences and continuing DSM programs does not appear able to achieve the types of capital investment required. So, when policies are formulated that appear to hand over responsibility to DSM programs or low-income weatherization, without also addressing the major new efforts needed, these policies should be examined using methods such as outlined here to question whether and how the changes will be accomplished. When we are told that new or improved standards will cause us to reach our goals, a reasonable capital analysis should be conducted to determine how much of the goal will be met. All estimates of energy savings for large scale initiatives should be based on a better understanding of what the capital requirements are and what the implications for the capital volume of specific markets are. Analysis of capital requirements and the capital volume of markets appears to be important for developing a better understanding of what proposed initiatives can be expected to actually accomplish.

Overall, the capital requirements analysis for energy efficiency appears to provide a means for corroborating estimates achieved using economic or other models. The capital estimates also indicate the amount of change needed relative to existing markets. If we are serious about achieving needed energy use reductions in buildings, we should have better information about the costs of and market volume increases needed for achieving reduction goals. In turn, tracking capital investment levels can provide an important comparison of what has been achieved, both in terms of actual capital in place and level of capital required to achieve specific savings or reductions.

Endnotes

1. The Rebuild America initiative is included in the *Climate Change Action Plan* (Clinton and Gore 1993).
2. For example, Pacific Gas & Electric in California asked for approval of a pilot program to provide financing from outside lenders to non-residential and multifamily building customers to help them pursue energy efficiency projects (McGraw-Hill 1994).

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