Energy Efficiency Capital Requirements for Buildings in the United States

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ABSTRACT

National energy efficiency goals for the United States are examined using data on the total dollar volume of retrofit and replacement markets, together with data on the total investment cost required to achieve an energy savings of one quadrillion Btu/yr for residential and commercial buildings. These goals are analyzed from the perspective of capital investment requirements. The analysis suggests that the investment requirements for achieving the national goals may not be estimated consistently and that constraints related to the dollar volume of markets may not be considered adequately. The analysis also indicates that major growth in existing energy efficiency markets is needed, and that simple reliance on existing approaches such as utility DSM programs may not be adequate to reach the goals. The capital requirements analysis approach 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 our nation is serious about achieving needed energy use reductions in buildings, we need better information about the costs of and market transformation needed for achieving reduction goals.

INTRODUCTION

Analyses of energy efficiency potential at a national level in the United States typically do not examine the implications of capital requirements. Energy savings are usually stated in terms of quads/yr (quad = quadrillion Btu), based on estimates of future changes to building stock. These estimates may be flawed, however, because they account for expected changes and limitations of energy use but fail to account for the dollar volume of markets and the accompanying capital requirements needed to effect the change. For example, enormous benefits have been estimated for 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 efficiency measures are constrained by the dollar volume of the market (since expenditures are only justified if installation would have occurred for another reason) and are typically much smaller than estimated. This paper presents the results of a capital analysis of building efficiency potential, together with capital expenditure data obtained from different programs for achieving one quad/yr savings.

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 size of markets 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 planners and policy development. 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.

The results are presented from the perspective of energy savings only, and savings from other factors are specifically excluded. Energy savings is an analog for air emissions, since air emissions and energy are fairly well related. For example, 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. Reductions in air emissions are important for clean air and possibly for global climate change.

The costs presented are total costs, to foster an understanding of total capital requirements. The data are specifically focused on buildings already in existence and do not examine impacts for new buildings.

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 direct evaluations and on a "best guess" as to what the "average" utility DSM program is probably 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.

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	Including nonenergy benefits	1993	1990
Residential	88	33	NA	75
Commercial	NA	NA	20	50
Source:	From Brown et al 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	

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. The evaluation estimated 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. Thus, the column that includes the nonenergy benefits shows a required investment cost of only $33 billion for 1 quad/yr.

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 on the first years of the program, where enough historical data exist covering 4.6 million sq ft of commercial floor space (24 buildings) where retrofits were installed, were obtained. 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 good 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 and MacDonald 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 indicates a lower range of expected investment costs for high quality commercial retrofit programs.

The third 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). In 1990, the total investment cost for 439 electric utilities 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 rough estimate would be that DSM ramped up on a straight line that can be approximated as extending from the year 1980 to the year 1990. The area under a triangle of 10 years length and $1.18 billion in height is 5 x 1.18 = $5.9 billion. This $5.9 billion to save 0.22 quads/yr would imply an investment cost 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.

An examination of sectoral results (Ettinger 1993) indicates we must consider that the most cost effective DSM is probably 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 et al. 1993). 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 costs to energy savings does not accurately reflect what they are trying to accomplish. Conversely, from the energy savings and environmental mitigation perspective, this is the investment required to reduce 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 Weatherization Assistance Program indicate that $88 billion is spent to achieve 1 quad/yr savings via a comprehensive set of retrofits in low-income residences. Data from field tests conducted at ORNL (MacDonald 1993) in residences show an investment cost for achieving one quad/yr savings that has declined over time. A 1983 study indicated 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 study, and a study in 1990 showed an investment cost of about $55 billion per quad/yr. The data indicate that a reasonably comprehensive package of residential retrofits aimed at, primarily, saving heating energy can cost $50 - 80 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 - 50 billion 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.

Results by appliance type are also 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 and not within a table. This is done to prevent readers from lifting values for reference without reading the text.

The values 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 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 cost of ceiling insulation for one quad/yr savings is estimated to be $50-100 billion; for wall insulation, $100-150 billion. The cost for lighting retrofits is estimated to be $75-200 billion, and the cost for high-efficiency refrigerators $150-350 billion. The cost for high-efficiency heating/cooling equipment is estimated to be $70-2,000 billion.

For the commercial sector lighting retrofits are estimated to cost $50-70 billion, while variable air volume retrofit is estimated to cost $100-150 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. Energy management is estimated to cost $10 billion to infinity. This is the area where the payoff can be extremely good but can also commonly be negative when systems are bypassed or not used.

THE CAPITAL VOLUME OF BUILDING ALTERATION MARKETS

Understanding the capital volume 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.

The replacement rate of heating and cooling equipment constrains how much can be achieved through high-efficiency heating and cooling systems, because the replacement of this equipment must usually be done for other means than increased energy efficiency. Most people will not expend thousands of dollars to replace a functioning system to achieve the relatively small dollar savings from higher efficiency, and most analyses of benefits of such systems use the incremental cost of the systems over a conventional system to justify the high-efficiency capabilities. The higher efficiency is justified based on incremental cost, assuming the system is replaced for other reasons. As a hypothetical example, a high-efficiency residential heating system may save $250/yr in energy costs, but the total cost to install such a system is $2,500. The 10-year simple payback for complete replacement may be too long for some people to justify the replacement based on energy savings alone. However, if the heating system has to be replaced because the old system no longer works, the cost of replacement with a conventional system can be subtracted from the total cost of the high-efficiency system to obtain an incremental cost. If the incremental cost of the system is only $750, then the simple payback period is 3 years and more attractive.

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.

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

	Total Alteration, Renovation, and Repair Market ($1987 billions)		Energy-saving Retrofits ($1987 billions)		DOE Weatherization Program Retrofits ($1987 billions)		Electric Utility DSM Retrofits ($1987 billions)	
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 et al 1992		For both sectors, estimated from Hirst 1993	
Comm'l:	Statistical Abstract of U.S. 1992, Tables 1233, 1205							

The commercial data for this first column are estimated by ratio of data contained in 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 et al. 1992) are used for those data in the third column. The total value of all funds 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 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 FOR 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.

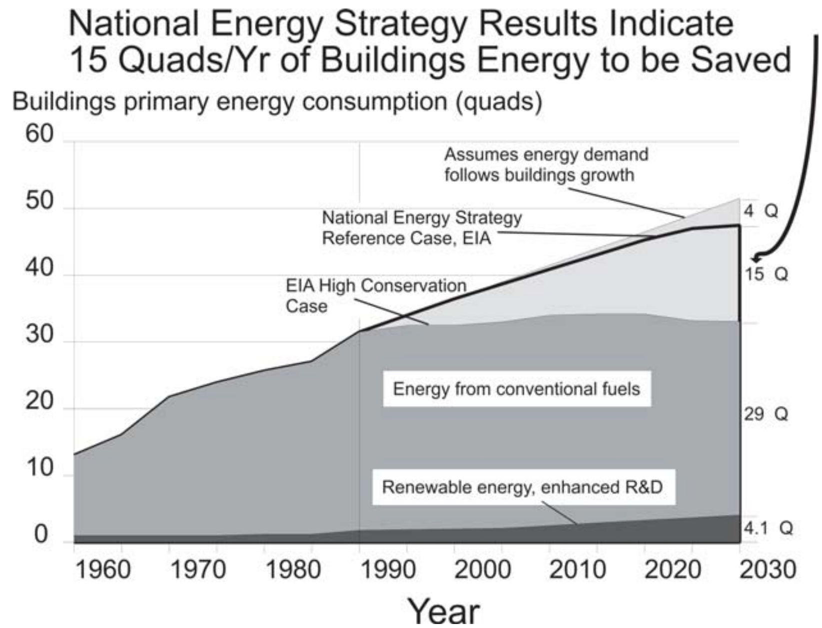

Figure 1 — Diagram of national goals for the United States, circa 1993

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 markets we can observe that the energy-saving retrofit market would almost have to double to achieve such a goal, and 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.

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 $70 - 2,000 billion per quad/yr, but a likely value may be about $200 billion. A total investment of $400 billion would be required for the needed savings, but we are constrained by the size of the replacement market to some degree. An investment of $400 billion over 40 years is $10 billion/yr, which implies that all replacements that would have occurred normally over the next 40 years have to be high efficiency and that an additional $6.6 billion (about twice as much as the existing replacement market) would also have to be stimulated to occur each year. Achieving such an immediate increase, in tandem with having ALL replacements be high efficiency strains the imagination. The maximum 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 these savings require $200 billion to achieve, less than one quad/yr savings is possible through these systems. If the savings can be achieved for a total (not incremental) investment of $130 billion, then likely only one quad/yr total can be saved in the next 40 years in the United States through these residential systems.

Similarly, assume that we want to achieve one quad/yr energy savings from commercial lighting retrofits. The required investment is $50 - 70 billion, which amounts to $1.25 - 1.75 billion/yr invested for the next 40 years in lighting retrofits. This value is 4 - 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 is also hard to imagine but perhaps slightly more possible than the residential heating/cooling system retrofits.

Saving 26 MMTCE/Yr by the Year 2000

The reduction in greenhouse gas GHG emissions needed for the *Climate Change Action Plan* (CCAP) are also substantial. The GHG reductions imply an energy savings of roughly 1 quad/yr for residential and 0.6 quads/yr for commercial buildings. Again examining total investment required for a broad-based program indicates that about $60 - 75 billion is required for residential buildings and $25 - 35 billion for commercial buildings. Over the five years inclusive of 1995 - 1999, the average yearly investment is $12 - 15 billion for residential and $5 - 7 billion for commercial.

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 appear to be low by 20 - 40%. This comparison says nothing about the individual actions proposed within the CCAP.

The proposed level of activity estimated using the capital requirements analysis for the CCAP is about $15 - 20 billion/yr for both sectors combined. This level of investment is about equivalent to the estimated current level of activity for all energy-saving retrofits and implies that the total market would have to double its current size. This required investment is 10 - 15 times the size of all current utility DSM efforts in building retrofits and DOE Weatherization Program efforts combined. Thus, a major effort is needed to achieve the emissions reductions goals described in the CCAP, essentially doubling all current activity immediately in 1995 and continuing at that rate for the following five years. This is a major task that will require an incredible effort.

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 $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 equipment efficiency standards 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 probably require an investment of perhaps $100 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 seems 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. 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.

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 investment requirements 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. 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 major changes needed.

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 put on the firing line to ask 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 equipment replacement should be based on a better understanding of how much of the market can be served by the new equipment and how reasonable the presumed equipment replacement rates are over the specified time frames. Analysis of capital requirements and the dollar volume of markets appears to be important for developing a better understanding of what proposed initiatives can be expected to 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 transformation needed for achieving reduction goals. In turn, the 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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