The Federal Buildings Research and Development Program: A Sharp Tool for Climate Policy

Bruce R. Kinzey and Sonny Kim, Pacific Northwest National Laboratory
John D. Ryan, U.S. Department of Energy

ABSTRACT

The U.S. Department of Energy's Office of Building Technology, State and Community Programs (DOE/BTS) has funded approximately $2 billion worth of residential and commercial buildings efficiency research, development and deployment between 1978 and 2000. The empirical record shows that this public investment has brought significant returns in the form of carbon emissions reductions. These reductions have come as side benefits of consumer investments that were justified solely on the basis of reduced energy expenditures. In 2001, starting with technical input supplied from DOE, the National Research Council (NRC) performed an independent evaluation of the results of applied research programs of DOE's energy efficiency and fossil energy offices and published findings that strongly support these results. The NRC report is used in this paper as an independent, conservative, third-party perspective on the savings estimates.

The NRC findings conclusively demonstrate a very high carbon impact as well as return on investment for buildings research and development - 80 million metric tons of avoided carbon emissions achieved while simultaneously providing $30 billion in national net cost savings from *just three BTS case studies.* We show that the federal role was crucial to achieving these savings, then point out that significant opportunities for future carbon emissions reductions through efficiency improvement in the residential and commercial building sector remain.

Introduction

U.S. positions on climate change and the Kyoto Agreement continue to be controversial as proponents and opponents of actions to mitigate carbon emissions debate the issues. Alternatives for atmospheric carbon mitigation range from avoiding emissions entirely (e.g., through reduced carbon-intensive fuel usage) to scrubbing carbon from the fuel or from exhaust emissions, to absorbing carbon from the atmosphere post-emission (e.g., by planting trees or seeding ocean plankton with iron). Some of the controversy over which approaches should be pursued (if any) stems from the fact that these actions can be quite costly, to the point of rendering some forms of fuel usage and associated economic activity untenable. A subset of so-called "no-regrets" actions promise significant reductions to carbon emissions, being defined as highly effective actions that are economically justified on their own merits. Cost-effective energy efficiency investment constitutes one example of a no-regrets action.

In this paper we argue the case one step further removed, that federal support of residential and commercial buildings energy efficiency research, development and deployment (RD&D) provides a tremendous "no-regrets" opportunity. We support this argument with an independent review of federal historical results in buildings RD&D

recently conducted by the National Research Council, National Academy of Sciences. We believe that support of federal buildings RD&D constitutes a "win-win" approach to mitigating future atmospheric emissions of carbon dioxide, and should be considered an important and cost effective instrument in the climate change policy toolbox.

Why Buildings Are a Good Target for Carbon Reduction Efforts

The buildings sector is currently responsible for an estimated 35% of carbon emissions in the United States, and 9% of global anthropogenic emissions (U.S. buildings are responsible for more carbon emissions than the total anthropogenic emissions of any single country in the world except China). Furthermore, the Energy Information Administration projects that carbon emissions from the U.S. buildings sector will grow from 531 million metric tons of carbon equivalent (mmtce) in 1999 to 726 mmtce in 2020 (EIA 2000 and EIA 2001)[1]. These emissions arise primarily from various forms of fossil energy used either directly at the building site or offsite at electric utility power plants.[2]

Given the level of high performance technologies already available in the marketplace, much of the buildings energy consumed is used inefficiently. For example, the typical efficacy of incandescent lighting widely used in the residential sector[3] is between 10-18 lumens/watt. Currently available compact fluorescent lamps commonly offer efficacies of 60-70 lumens/watt or higher. Replacement of incandescent bulbs with compact fluorescent lamps offers instantaneous reductions in energy use of two-thirds or more.[4] Moreover, to the extent that such lighting can be replaced by natural sources in new construction (i.e., through increased used of windows and daylighting), some portion of the demand for conventional energy resources can be avoided entirely. Numerous other building energy uses offer less dramatic but nonetheless significant opportunities for improvement, with correspondingly significant carbon emissions reductions. The Intergovernmental Panel on Climate Change recently concluded as much, "Hundreds of technologies and measures exist that can improve the energy efficiency of appliances and equipment as well as building structures in all regions of the world," (IPCC 2001).

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[1] Values reported from EIA represent sum totals of various emissions including carbon monoxide, methane, and a variety of volatile organic compounds in addition to carbon dioxide, that have been normalized into "metric tons of carbon equivalent." Other sources, such as the NRC report and the MiniCAM model cited elsewhere in this paper, report values in units of "metric tonnes of carbon." Although these different units are not strictly comparable, in order to maintain consistency with the source documents we retain their original conventions for any reported values.

[2] Due to inefficiencies in energy conversion and transmission, electrical energy used at the building site typically requires the consumption of more than three times the corresponding amount of fossil energy at the utility generation plant. In this paper, emissions reported include both "site" and "off-site" emissions.

[3] One recent study estimated that 92% of residential lamp demand in 1998 was for incandescent lamps. Source: Freedonia, 1999.

[4] CFLs generally produce light that is more diffuse than light from incandescent bulbs, and thereby "lose" some of the light in fixtures that were designed for incandescent lighting. A higher lumen output CFL may be required in such cases to provide the same lighting levels on a given surface. Although the lamps themselves emit four to fives times as many lumens per watt as incandescent bulbs, a typical power savings ratio is 3:1, e.g., a 90-watt incandescent bulb might typically be replaced with a 30-watt CFL.

Why a Federal Role Is So Important in Increasing Buildings Energy Efficiency

Energy efficiency is clearly in the benefit of the national interest. In addition to favorable environmental and economic benefits, energy efficiency leads to less reliance on external (to both the building and the nation) energy supplies, and reduced energy expenditures for citizens of all income levels. Unfortunately, progress in improving the energy efficiency of buildings technologies (and implementing them) has been slow when left solely to the devices of the private sector. Several reasons underlie this history.

A defining characteristic of the buildings sector is its fragmentation. The top five builders of residential properties in 2000, for example, only accounted for 7% of the total U.S. market while the top100 only claimed 20% (Guido 2001). These builders install various components from hundreds of manufacturers using thousands of contractors with little or no communication among them. In such a disjointed process, many opportunities for capturing energy efficiency are missed.

In fact, the conflicting objectives of the many players that may be involved in a given buildings transaction often run counter to increased efficiency. A builder speculatively constructing a commercial building is primarily interested in selling or leasing the building as quickly as possible. The subsequent purchaser of the building wants to fill it as soon as possible, at as little cost as possible. Because those people are not typically paying subsequent energy bills, they have little or no incentive to spend extra money on high-efficiency equipment; simultaneously, HVAC contractors, knowing their customers, tend to offer equipment meeting the primary criterion, i.e., low first cost.

Each individual involved in the decision process, attempting to optimize his own profit, may not migrate to the ultimate choice that is optimal for either the end-user or the society at large, particularly when societal impacts like carbon emissions are not yet monetized and incorporated into the relevant decision criteria. The end result becomes a chicken-and-egg problem: manufacturers do not focus on efficiency because consumers do not buy it; but because manufacturers have not achieved economies of scale and other means of cost reduction, high-performing, efficient technologies frequently carry a price premium that those making the purchase decisions are not willing to bear.

Another contributing characteristic to this problem is that the level of R&D carried out by building sector manufacturers is considerably below the national average for U.S. industry.[5] Moreover, a good part of the R&D that is conducted focuses on consumer preference issues (e.g., color, amenities) rather than energy usage, particularly in smaller appliances and equipment that have relatively small annual energy use.

Unfortunately, faulty decisions made in the buildings sector tend to cast long shadows into the future that can continue influencing national energy and environmental situations for years, decades or even centuries. This fact alone underscores the importance of a federal role in encouraging energy efficiency, both in the development of new technologies and in facilitating their implementation.

[5] Less than 0.5% of sales vs. 3.5% industry average (Business Week 1995).

The History of Federal Buildings Efficiency Efforts Has Been a Marked Success

The federal government, primarily through the efforts of the Office of Building Technologies, State and Community Programs (BTS), has had a notably successful record in its efforts to improve energy efficiency in the buildings sector. Certainly, not all activities supported have been successful from a purely economic return perspective, but on balance the results ledger is considerably in the black. The nature of high-risk research and development is such that many activities may be pursued with only a few progressing beyond the laboratory stage.[6] In BTS' case, just a few technologies commercialized to date have repaid all of the BTS investment several times over (in terms of national return on tax dollars spent). A recent study performed by the National Research Council, National Academy of Sciences (NAS) found that the national savings from just three BTS-sponsored technologies (briefly detailed in the following section) have netted $30 billion in reduced consumer energy expenditures to date (NRC 2001, see Table 1 below). This result was derived despite the particularly conservative assumption by NAS that the BTS funding only advanced the state-of-the-art by five years. In other words, only life-cycle savings from the technologies installed during the first five years of commercialization are included in this estimate.[7] The 5-year assumption was made to put the various programs under examination on similar footing despite actual evidence to the contrary, where some technologies have lain dormant for long periods or were even hindered after their technical feasibility was demonstrated (see following section).

A second factor increasing the conservatism of this estimate is the number of other BTS successes which were not included in the NAS analysis. One such example is the Flame Retention Head Oil Burner, which has captured 100% of the residential oil heat market since its introduction and had saved an estimated $5.3 billion as of 1993 (GAO, 1996).[8] A third important factor is that the $30 billion estimate only includes consumer energy cost savings. NRC also attempted to value other accompanying benefits such as avoided environmental damage. In the three BTS cases examined, this was estimated to be in the range of $3-15 billion (see Table 1).

As the focus of this paper is not to document the precise return on the BTS investment (as was neither NRC's focus), but rather to make the case that the R&D is a superior no-regrets approach to achieving future carbon emission reductions, our purpose is satisfied once the total investment has been shown to be cost-effective. Thus, even considering only the consumer cost savings conservatively estimated by NRC resulting from these three technologies (i.e., $30 billion), our argument can proceed for the BTS portfolio as a whole.

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[6] Furthermore, "…any program of research in which everything succeeds is not exploring the frontiers." (PCAST 1997)

[7] "Adopting a 5-year limit…on future installations but allowing the full useful life of the installations to be considered provides a reasonable but conservative estimate of the contributions of the technology without introducing speculative projections of its longer-range impact." (NRC 2001)

[8] Other notable BTS successes were likewise ignored because it was not necessary to examine every program success in order to answer the NRC fundamental question of whether the research was "worth it." The three successes examined sufficiently answered this question all by themselves. To preserve consistency with the NAS report, we also ignore savings from these other programs in this paper.

The technologies submitted for NAS analysis included Low-E Glass, Advanced Refrigerators, DOE-2 Energy Analysis Program, Compact Fluorescent Lamp and the Electronic Ballast. Because of various issues with the methodologies used for estimating savings, NAS focused their savings estimates on just three of these: Low-E Glass, Advanced Refrigerators, and the Electronic Ballast.[9] Brief descriptions of these programs and the federal influence in their development follow.

Table 1. Benefits Estimates of BTS Technologies Reported by NRC[a]

	Economic Benefits (Cum Net Energy Savings and Consumer Cost Savings)				Environmental Benefits (Cumulative Pollution Reduction)			
	Cost of DOE and Private RD&D ($1999 billion)	Cum Site Fuel Savings (quad)	Cum Electricity Savings (quad of primary energy)	Net Cost Savings ($1999 billion)[b]	SO_2 (millions of metric tonnes)	NO_x (millions of metric tonnes)	Carbon (millions of metric tonnes)	Damage Reduction ($1999 billion)[c]
Technology								
Advanced Refrigerator/ freezer Compressor	~0.002		1.0	7	0.4	0.2	20	1-5
Electronic ballast for fluorescent lamps	>0.006		2.5	15	0.7	0.4	40	1-10
Low-e glass	>0.004	0.7	0.5	8	0.3	0.2	20	0.5
Total	~0.012	0.7	4.0	30	1.4	0.8	80	3-15

[a] Excerpted from NRC 2001, Table 3-4.
[b] Cumulative energy cost savings net of R&D costs, extra capital, and labor costs compared to the next-best alternative all in 1999 dollars. The DOE investment is assumed to have led to the innovation coming on the market 5 years earlier than it otherwise would have.
[c] Avoided emissions of SO_2 and NO_x are assumed to be valued in the ranges of $100 to $7,500 and $2,300 to $11,000 per metric tonne, respectively, in avoided damages, and avoided carbon emissions are assumed to be worth $6 to $11 per metric tonne. These ranges are for the lower end of damage values estimated in the literature. See NRC 2001 for related citations.

Low-E Glass

In 1976 DOE initiated a research program to develop new energy-efficient window technologies. After a review of various potential window research projects, low-emissivity (low-E) coatings were selected as the major DOE program emphasis. At that time, the principle behind low-E coatings was understood, but no low-E windows were commercially available in the United States. Industry was not conducting research in this area, being more concerned with rising fuel costs and with responding to building codes limiting window areas than in pursuing a speculative new technology.

After several years of DOE research support (totaling about $2 million), a small firm created the first production facility for applying low-E coatings to thin plastic films. By 1980, this firm was working closely with several window manufacturers to develop and refine a fabrication technology that incorporated a low-E coating. The early success of this

[9] NAS chose to ignore the savings in DOE-2's case because they felt that, although the savings were anticipated to be quite large, they were indeterminate given the lack of "hard" data available for their estimation. In the case of Compact Fluorescent Lamps, NRC felt that DOE's contribution mainly fell in the area of options and knowledge for future development, rather than in realized consumer cost savings.

approach to incorporating low-E coatings stimulated other much larger private sector investment to pursue this technology.

Relative to conventional double-glazed windows, low-E coatings reduce heat losses from the insulating glass unit by 35%. Spectrally selective low-E coatings are now widely utilized throughout the United States.

Advanced Refrigeration

From 1978 through 1981, DOE supported the development, evaluation and market introduction of improved refrigerator compressors at the Columbus Products Company (CPC). The total Federal investment was $1.56 million ($1999). By making changes to several components, CPC achieved a 44% improvement over standard compressor technology (EER 5.0 vs. 3.5). These DOE-developed advancements were subsequently incorporated into a compressor product line manufactured by Greenville Products Company (Kelvinator) and later as Americold Compressor Company. Through the late ‘80s and ‘90s, Americold led the industry in high-efficiency compressor development for refrigerator/freezers, manufacturing over 4 million per year.

According to the vice president of Americold, the DOE program caused his firm to establish a robust in-house compressor R&D capability (people and facilities) that produced continuing improvements in refrigerator compressors long after the DOE project. The fact that Americold’s compressors were so much more efficient than its competitors for so long demonstrates that the other manufacturers were not motivated either by market demand or by efficiency standards to produce equivalent technology. It was not until the very late 1980s that appliance efficiency standards provided a significant impetus for widespread R&D on improved compressors.

Electronic Ballasts

From 1977 through 1981, DOE provided about $2.7 million ($1999) to support the development, evaluation and market introduction of the electronic ballast. This technology offered potential improvement in lighting energy efficiency of about 25% compared to conventional magnetic ballasts. DOE established contracts with three small businesses to develop and test prototypes, after receiving no responses from the major ballast manufacturers in a competitive solicitation. DOE also funded Lawrence Berkeley National Laboratory to establish demonstrations, conduct laboratory performance tests, and develop specifications for electronic ballasts.

All of the major firms in the ballast industry had considered and rejected introducing a solid-state (electronic) ballast. A strong disincentive to production of solid-state ballasts was present in that significant capital investment would be required and the existing infrastructure for manufacturing magnetic ballasts would have to be replaced. The market for magnetic ballasts was also highly concentrated with nearly 90% of sales in the hands of two firms, Universal Manufacturing and Advance Transformer Company. One of these firms actively sought to prevent the introduction of the electronic ballast by acquiring the technology from one of the small R&D firms DOE had supported and then mothballing the technology. After 6 years of litigation resulting in a $26 million damage award, control over the technology was partially reacquired by the small business in 1990 (WSJ 1990). Electronic ballasts now (1999) account for 40% of all ballast shipments (DOC 2000).

The Carbon Emissions Avoided from Federally-Supported Buildings Efficiency RD&D to Date Are Substantial

As noted, the energy expenditure savings to date from the above three technologies supported by BTS efforts were conservatively estimated by NAS at $30 billion. This figure is net of incremental consumer costs for purchasing products using these technologies. The estimate of gross energy savings amounts to 4 quadrillion Btu cumulatively since 1980 (NAS 2001).[10]

Not frequently highlighted, but no less significant, are the carbon emissions that have been avoided as a result of these technologies, or, by extension, from the BTS investments in R&D. The estimated carbon emissions reductions stemming from these investments to date amount to a cumulative 80 mmtc.[11] To put this into perspective, the U.S. buildings sector is responsible for a total annual emission of about 531 mmtce (1999). To achieve an equivalent reduction would require keeping 80 million passenger vehicles off the road for about one year.[12]

What is even more significant is that these carbon reductions have come as a side benefit; BTS pursued these technologies for their energy savings potential. Now commercialized, the technologies compete on their own economic merits and consumers choose them because they make economic sense. It is tempting to claim that the 80 mmtc of avoided carbon emissions were obtained for the extremely small sum of $12 million, the cost of the research. However, these impacts should be evaluated against the funding of the overall BTS RD&D portfolio since winners . Total BTS RD&D funding from 1978 through 2000 reported in the NAS analysis amounts to $2.015 billion ($1999). From the standpoint of ignoring consumer costs and benefits, the avoided 80 mmtc from this portfolio investment results in a carbon cost of about $25/mtc.[13,14]

The Future Holds Similar Buildings Sector Opportunities for Carbon Reductions

Despite the fact that buildings efficiency and corresponding levels of carbon emissions have improved markedly over the last few decades, numerous opportunities for

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[10] Again, reiterating that this NAS estimate includes only savings from units sold in the first five years.

[11] As reported in Table 3-4: "Net Realized Benefits Estimated for Selected Technologies Related to Energy Efficiency RD&D Case Studies," page 29 in NRC 2001, reproduced in Table 1 above.

[12] One million metric tons of carbon equivalent is emitted by one million new vehicles driven 11,700 miles. Source: BTS 2001.

[13] We have chosen to ignore consumer expenditures and their resulting returns in this analysis as they are separate from the federal expenditure, and would furthermore only improve our argument. The same can be said for additional development costs incurred by the private sector in commercializing these technologies; companies pursue these investments on their own initiative, and it is assumed that their behavior is based on sound economic criteria. Their investments and subsequent returns are independent of this particular analysis.

[14] An important benefit neglected in this estimate is that it does not include total global reductions in CO_2 from these technologies. All three have certainly been widely adopted outside the U.S. but international impacts were not included in the NAS analysis.

gains remain. A recent study conducted by Arthur D. Little (Barbour 1998) quantified the potential carbon reductions from a wide range of existing and advanced technologies, covering all building end uses (space heating and cooling, lighting, appliances, etc.) using relatively modest market penetration assumptions. The study found that currently available, but underutilized, technology could reduce carbon emissions from the buildings sector by another 40 mmtce *per year*. Aggressive research, development and deployment of advanced technology could save an additional 53 mmtce per year.

The advanced equipment technologies promising the largest payoff in the ADL study included improved light sources to replace incandescent lamps, low-cost heat pump water heaters, gas heat pumps and efficient thermal distribution systems.[15]

ADL further compared technologies using a BTS-developed "Carbon Figure of Merit" that normalizes the carbon savings based on the added capital cost for the technology. This metric relates to the effectiveness of a particular incremental investment in reducing carbon and should be a key focus in policy discussions of carbon reduction alternatives. In addition to examining a full range of buildings technologies using the carbon figure of merit, the analysis also compared buildings technologies with two of the most prominent automotive and solar technologies in DOE's overall portfolio. This analysis showed that building technologies, at least in the near term, were from 2 to 5 times more cost-effective in reducing carbon, in terms of carbon savings per dollar of added capital investment.

The Potential Carbon Value of Continued Improvements in Buildings Energy Efficiency Is High

To illustrate the potential future value of carbon emissions reductions offered by buildings efficiency (and hence buildings efficiency RD&D), we investigated their magnitude with PNNL's MiniCAM model (Edmonds and Reilly 1985; Edmonds et al 1997).[16] Here, the MiniCAM model is intended to demonstrate that continued improvements to buildings energy efficiency has an important and cost effective role to play in reducing significant amounts of future carbon emissions.

While no model can predict the actual future, models are useful in illustrating differences between various scenarios incorporating different assumptions and thereby the impact of changes in those assumptions. Implicit in the "reference scenarios" of energy and carbon emissions projections from the MiniCAM and other models are significant improvements to energy efficiency in the end-use sectors. We ran two scenarios to determine the amount of carbon emissions reduction attributed specifically to the implied end-use energy efficiency improvement in the MiniCAM's buildings sector. Figure 1 shows two scenarios of projected total CO_2 emissions for the U.S., the Reference Scenario (RS) and a Frozen Buildings Energy Efficiency Scenario (FBEES).

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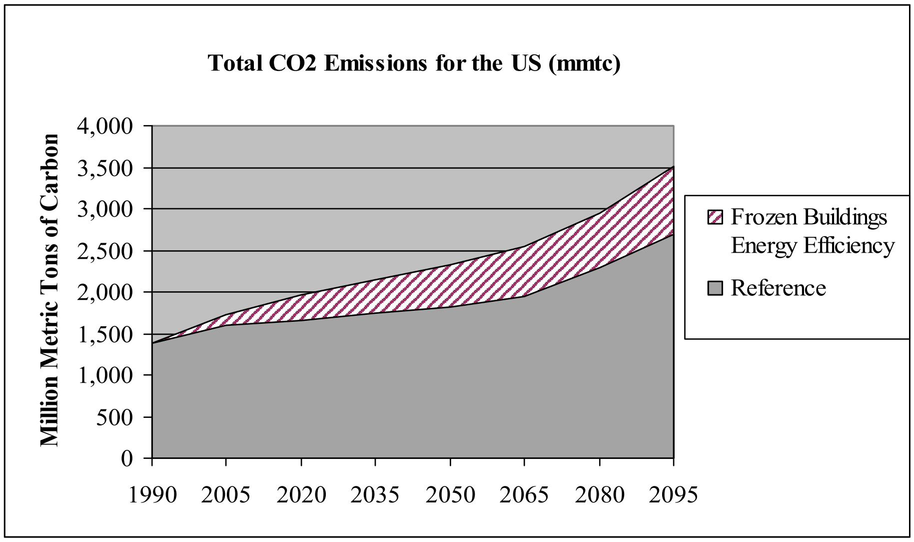
[15] In addition to the equipment technologies studied by ADL, several technologies for building envelopes and whole buildings also have considerable potential for reducing carbon. Among these are advanced windows, building controls and design methods.

[16] The MiniCAM model is a partial equilibrium model of the world with 14 regions that is primarily used to project energy consumption and greenhouse gas emissions from fossil fuel use and land-use change. The MiniCAM is focused on the energy sectors and includes multiple energy supply sectors and technologies. Additionally, there are three energy demand sectors in the model consisting of Buildings, Industrial, and Transportation sectors.

Figure 1. Total CO_2 Emissions for the U.S.



The RS is based on the B2 scenario of the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES) (Nakicenovic and Swart 2000). The B2 scenario is intended to describe a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with moderate population growth, intermediate levels of economic development, and less rapid and more diverse technological change than the other SRES scenarios. Relative to the others, energy consumption and carbon emissions of the B2 scenario fall in the middle of the projected range. Implicit in the MiniCAM's B2 RS are end-use energy efficiency improvements, typically referred to as the Autonomous Energy Efficiency Improvement (AEEI) parameter, for the buildings sector that range from 0.5 to 1.5 % per year (see Table 2).

Table 2. MiniCAM's Buildings Sector AEEI for the US (%/yr)

1990	2005	2020	2035	2050	2065	2080	2095
--	1.3%	1.5%	0.8%	0.6%	0.5%	0.5%	0.5%

The second scenario, FBEES, is the same scenario as RS with the projected AEEI for the U.S. buildings sector set to zero. This effectively freezes buildings energy efficiency to 1990 levels. Comparison of the CO_2 emissions from the two scenarios as modeled indicate that approximately 45 billion metric tons of carbon are avoided due to the improvements to buildings sector energy efficiency shown in Table 2.

To estimate the relative value of the above carbon savings due to buildings efficiency improvements, we forced the total CO_2 emissions for the FBEES to match that of the RS shown above by applying carbon taxes on fossil fuels. In other words, the economy was forced to find alternative means of achieving a similar trajectory of carbon emissions as in the reference scenario, but without the help of increased buildings efficiency. Table 3 shows the level of carbon taxes necessary for the frozen efficiency scenario to match the reference case emissions trajectory.

Table 3. Carbon Taxes Necessary to Meet SRES B2 CO_2 Emissions (99$/tc)

1990	2005	2020	2035	2050	2065	2080	2095
--	18	53	84	112	117	82	71

Utilizing the stream of carbon taxes from the model, we calculated the total cost of achieving the reference emissions trajectory from a time period of 1990 to 2095 by approximating the area under the marginal cost curve for carbon and discounting the cost at a rate of 5%. The resulting present value of the cost of the carbon emission reductions expected from buildings efficiency in the reference case amounts to $164 Billion ($1999). This value represents the benefit of anticipated improvements in the AEEI for the buildings sector, and thus implies a significant and conservative potential return for RD&D investments in buildings energy efficiency. Note that the result reflects only the dollar value of anticipated carbon emissions reductions and does not take into account potential returns from reduced energy expenditures (the primary reason consumers would purchase these technologies). Also note that this result does not comprise the "technical potential" of an aggressive buildings efficiency RD&D program, but rather is only an illustration of what buildings carbon emissions reductions are estimated to be worth between now (1990) and 2095 in this *reference case*.

It is not our intent in this paper to claim that future investments by the federal government are the exclusive determinant of future changes in buildings energy efficiency. Furthermore, even estimating the magnitude of influence federal research will have on the overall rate of efficiency change cannot be done with any degree of certainty.[17] However, we strongly believe that RD&D and related activities sponsored by the federal government have an overwhelmingly positive impact on the rate of efficiency improvement in the buildings sector. If one accepts this presumption, then comparing the anticipated national benefits of improved efficiency against the current federal resources devoted to them provides a useful point of reference on the relative justification of the current portfolio.

The current (FY2001) federal buildings efficiency RD&D portfolio (ignoring funds devoted to Weatherization and State Energy Programs but including deployment activities like Codes and Standards) amounts to about $100 million per year. Assuming that this funding level must remain flat to maintain buildings energy efficiency improvements at the rate indicated in the RS, the total 105 year investment (1990 to 2095) would amount to about $11 billion (inflation adjusted), or less than 10% of what the model estimates the carbon reductions are actually worth to the nation in this scenario. This comparison is not meant to suggest that a carbon savings worth $164 billion is achieved at a cost of $11 billion, as clearly we have ignored both the private sector's contribution and return on the cost of future buildings energy efficiency improvements. However, if the federal government's expenditure seeds even a fraction of the anticipated carbon savings through development of technologies that consumers can cost-effectively purchase based on their fuel savings, then, as a carbon emissions reduction strategy, the federal RD&D program will have achieved unambiguous success.

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[17] "…Predicting the leverage of energy R&D against the challenges described…requires making assumptions not only about what innovations a given R&D program is likely to produce but also about the nature and effectiveness of the enabling policies that are implemented to accelerate the penetration of the worthwhile results into the marketplace." (PCAST 1997)

Summary and Conclusions

Federal R&D investments in future advanced building technologies comprise a "no regrets" strategy for reducing carbon because they can be justified on purely economic grounds. While efficiency improvements alone cannot solve the climate change problem, the federal cost to research and develop these technologies in collaboration with the private sector is relatively modest, and is an extremely cost effective strategy in contributing to the portfolio of technologies necessary to address the climate change issue. The value of federally-supported buildings efficiency RD&D is empirically supported by the historical record, even when only a small subset of successful efforts are examined from a very conservative perspective. The future appears to hold similar opportunities and a heightened interest in climate change mitigation may warrant increased levels of federal support in this area.

Federal support of buildings energy efficiency R&D is a cost effective and important tool in the climate change policy toolbox. Policymakers should consider much greater use of it.

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