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ESTIMATING THE IMPACTS OF FEDERAL EFFORTS TO IMPROVE ENERGY EFFICIENCY: THE CASE OF BUILDINGS

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Executive Summary

The U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy [EE] has for more than a decade focused its efforts on research to develop new technologies for improving the efficiency of energy use and increasing the role of renewable energy; success has usually been measured in terms of energy saved or displaced. Estimates of future energy savings remain an important factor in program planning and prioritization.

A variety of internal and external factors are now radically changing the planning process, and in turn the composition and thrust of the EE program. The Energy Policy Act of 1992, the Framework Convention on Climate Change (and the Administration's Climate Change Action Plan), and concerns for the future of the economy (especially employment and international competitiveness) are increasing emphasis on technology deployment and near-term results. The Reinventing Government Initiative, the Government Performance and Results Act, and the Executive Order on Environmental Justice are all forcing Federal programs to demonstrate that they are producing desired results in a cost-effective manner. The application of Total Quality Management principles has increased the scope and importance of producing quantified measures of benefit.

EE has established a process for estimating the benefits of DOE's energy efficiency and renewable energy programs called "Quality Metrics" (QM). The "metrics" are:

- Energy
- Environment
- Employment
- Risk
- Equity
- Economics

This paper describes the approach taken by EE's Office of Building Technologies to prepare estimates of program benefits in terms of these metrics, presents the estimates, discusses their implications, and explores possible improvements to the QM process as it is currently configured.

Background

Over 30 quadrillion Btu of primary energy are used annually to provide energy services to the buildings sector [residential and commercial buildings]; this is 36 percent of total energy use in the United States, includes two-thirds of U.S. electricity consumption. The direct cost of this energy to consumers is about $200 billion per year. Environmental impacts are significant as well; carbon dioxide emissions resulting from U.S. *building* energy use equal *total* combined emissions from Germany and Japan.

Goal and Approach

The Office of Building Technology (OBT), in keeping with guidance provided by the Energy Policy Act of 1992, seeks a 30 percent improvement in the efficiency of energy use in buildings by 2010. This would result in a decline in the total energy used by the sector over a period when significant growth in the buildings stock is expected. The multi-faceted approach to achieving this goal includes

- developing energy-efficient and renewable technologies and advanced materials through *Research and Development*;
- improving the efficiency of appliances, equipment, and buildings through the implementation of *Standards and Guidelines*;
- accelerating the acceptance of efficient and renewable technologies and practices in Federal facilities through the leadership of the *Federal Energy Management Program*; and
- aggressively promoting the adoption of currently available and emerging energy-efficient technologies with *Market Conditioning* actions, especially as provided for in the Climate Change Action Plan (CCAP).

The original requested budget for these activities for FY 1995 was $184 million, more than double the appropriation for FY 1994; the increase was targeted to meet the mandates of the Energy Policy Act and to execute the actions outlined in the Climate Change Action Plan. The QM estimates discussed in this paper are based on this level of funding; however, the actual FY 1995 appropriation remains uncertain, and appears likely to be less than the original request.

History

Federal involvement in improving the efficiency of energy use in buildings dates back prior to the formation of the Energy Research and Development Administration [DOE's predecessor agency] in 1975. Funding for these activities has exhibited considerable variation, depending on the perceived urgency of controlling energy demand and the philosophies of various administrations. Until the passage of the Energy Policy Act of 1992, the central focus of the OBT program was the development of new, energy-efficient technologies through research and development. The program was responsible for several notable successes, including the retention-head oil burner, low-E glazing, and the solid-state fluorescent light ballast. The energy cost savings to consumers resulting from these and other DOE-sponsored technologies have been estimated to total $50 billion. Under the current administration, the thrust of OBT's program has shifted toward promoting the *adoption* of energy-efficient and renewable technologies, and the achievement of objectives beyond energy savings, including the creation of jobs and achieving equity in the distribution of the benefits of government actions across demographic groups. The variety of concerns to be addressed by the program and interest in improving the performance of government programs has led to the implementation of the QM process discussed in this paper.

Quality Metrics

QM is the process of systematically estimating the benefits of EE programs to support budget justification and strategic planning. The process includes

- developing analytical techniques and supporting information to estimate benefits;
- providing information at a level and in a format useful to inform decision-making; and
- reviewing and critiquing to ensure the credibility and defensibility of the benefit estimates.

Although the various offices within EE have prepared estimates of energy savings and other benefits of their programs for purposes of program prioritization in the past (OBT has used a methodology evolved for over a decade), the QM exercise is the first attempt at an ongoing effort to estimate benefits in a consistent fashion across EE.

The QM process is designed to serve a variety of purposes

- to increase the impact of Federal expenditures in accordance with the Government Performance and Results Act of 1993 and the Department of Energy Strategic Plan;
- to provide performance indicators to assist in strategic planning and budget formulation to effectively achieve the Administration's objectives;
- to address questions from Congress and others regarding the benefits of specific programs or actions; and
- to demonstrate the benefits of EE programs to stakeholders and the broader community.

Benefits are estimated on an annual basis for the years 1995, 2000, 2010, and 2020. The benefits estimated in the current QM process use the following units of measure:

- *Energy* - measured as reductions in energy used and oil used [quadrillion Btu];
- *Environment* - measured as reduction in carbon-equivalent emissions associated with energy use [million metric tons of carbon];
- *Economics* - measured as return on investment, benefit/cost ratio, and net economic benefit [$ 1995];
- *Employment* - measured as number of net jobs created;
- *Equity* - measured in terms of program impacts specific to various demographic groups;
- *Risk* - measured as probability of program technical and market success; and
- *Supplemental metrics* - program benefits not accounted for in the above metrics.

Benefit estimates are prepared by the sectors and assembled, reviewed, and disseminated by the Office of Planning and Assessment (OPA), the EE-wide planning office.

The OBT Process

The OBT program is composed of more than 50 discrete activities. For purposes of analysis and comparison, the OBT program has been grouped into nine *Planning Units*:

*Residential Building Systems**	*Building Standards* *
*Residential Building Equipment**	*Appliance and Equipment Standards* *
*Commercial Building Systems**	*Federal Energy Management Program*
*Commercial Building Equipment**	*Implementation and Deployment* *
Building Envelope	

Benefits are first estimated at the program or technology level; these estimates are then aggregated to the Planning Unit level to facilitate cross-sectoral comparisons. Seven of the nine Planning Units (marked with asterisks) contain elements specified in the Climate Change Action Plan (CCAP). The five Planning Units in the left column are essentially *Research and Development* activities devoted to the development of improved technologies, although they do contain significant *Market Development* activities (notably CCAP actions). The Building Standards and Appliance and Equipment Standards Planning Units (*Standards and Guidelines*) have been expanded in scope as specified in the Energy Policy Act and the Climate Change Action Plan. The Federal Energy Management Program and Implementation and Deployment are *Market Conditioning* activities, the former designed to improve Federal energy efficiency (and save tax dollars) per Executive Order 12902, the latter to increase the adoption rates of energy efficient technologies and practices through training and education

The following material provides information on the benefits estimated for these programs and the approaches used in estimation. Many of the estimates are preliminary and subject to revision, especially in areas where OBT has limited recent experience (e.g., market conditioning). The baseline for all energy savings estimates was a frozen efficiency scenario developed from the *Annual Energy Outlook - 1994* for this exercise by the Energy Information Administration. The baseline assumes that technology performance does not improve over early 1990's levels. Energy savings and other benefits were assumed to be entirely the result of DOE actions.

Energy Savings - R&D

The approach used to calculate energy savings for research and development activities was derived from OBT's traditional project prioritization methodology, and involved a technology-by-technology "bottoms up" approach, with savings estimated for individual technologies then aggregated to the planning unit level. Markets for each technology were segmented by building type, vintage, and region; energy savings were then calculated as the product of energy savings per unit, target market size, and estimated market penetration. It was assumed that performance goals for the technologies were achieved, and market penetration rates were based on the expert judgements of program managers, subject to review and revision to increase credibility.

Energy Savings - CCAP Actions

The OBT budget request for FY 1995 included funding for nine CCAP Actions, allocated among seven of the nine planning units; funding for these Actions totaled $72 million of the total request of $184 million. Energy savings estimates were calculated separately for these actions due to their visibility and uncertainty regarding their funding. For consistency with the positions taken by the Administration, these estimates were derived from the carbon reductions published in The CCAP and its technical supplement; because the savings for all actions were originally estimated simultaneously using the IDEAS modeling framework, some judgement was required to disaggregate savings to the individual Actions. Where the Actions involved joint DOE/Environmental Protection Agency endeavors, it was assumed that impacts were proportional to funding requests.

Energy Savings - Appliance and Equipment Standards

Energy savings for appliance standards were developed by Lawrence Berkeley Laboratory [LBL] using the LBL Residential and Electric Power Research Institute COMMEND models (the models used in the analysis of proposed standards]. It was assumed that the standards proposed in the March 1994 *Federal Register* will be adopted; baseline technologies were frozen at 1991 efficiency levels. Minimum efficiency standards apply to all models in a product class (100% market penetration).

Energy Savings - Building Standards

Energy savings for commercial building standards were estimated by Pacific Northwest Laboratory (PNL) based on analysis of likely State adoption of and compliance with ASHRAE/IES Standard 90.1-89. The baseline technology was assumed to be current construction practice, and the baseline scenario assumed independent adoption of 40 percent of the States by 2010. Savings estimates were based on adoption of the standard by 90 percent of the States by 2010.

Energy Savings - Federal Energy Management Program

Executive Order 12902 issued in March of 1994 established the goal of a 30 percent reduction in energy use in Federal facilities over 1985 levels by 2005. LBL estimated energy savings based on attainment of this goal. The target market is Federal buildings and facilities; savings are the sum of energy saved by all Federal agencies.

Energy Savings - Implementation and Deployment

The majority of the funding request in this area was in support of two CCAP Actions; savings estimated for these actions were extrapolated to other Implementation and Deployment activities on the basis of requested funding. (Allocating savings to implementation and deployment activities which are complementary to other actions has always been notoriously difficult.)

Environment

The benefits to the environment of reductions in energy use were measured as reductions in carbon dioxide emissions, calculated directly from reductions in energy use by fuel form. Other measures of benefit (e.g., reductions in sulfur dioxide emissions, improvements in indoor air quality) were not considered in this phase of the QM process.

Economics: Costs/Savings

The costs of implementing programs and actions fell into two categories: Federal investment and private investment. Federal investment costs were based on the budget request, escalated at 2.3 percent/year through 2020, with the exception of CCAP Actions, which are near-term and require no funding after 2000. Total private investment was calculated as the total cost of implementing a new technology or approach; incremental private investment was calculated as the difference between the new technology and the technology replaced. Cost savings were computed as the product of energy savings by fuel form and fuel prices; no other savings were monetized. Together, the investment and savings figures were used to calculate several benefit/cost ratios and to calculate both Federal and private returns on investment.

Risk

Levels of technical and market risk were estimated for individual programmatic activities within each Planning Unit by "consensus Delphi" (expert judgement). Overall levels of risk were estimated for each Planning Unit by weighting the estimates for individual activities according to funding levels. Most Planning Units fell into the low and medium ranges because of the dominance of CCAP and other market-pull (inherently low risk) activities in the FY 1995 budget request.

Employment

The changes in employment within each planning unit were estimated based on energy savings using the AMIGA input-output model. The concept is that consumer expenditures for energy generate less employment than expenditures for non-energy products; energy savings translate into expenditures for goods and services with higher employment multipliers. The increases for OBT are impressive, rising to a total of over half a million jobs created by 2020.

Equity

A qualitative attempt was made to determine if OBT's program had differential impacts on various socioeconomic or geographic fractions of the U.S. population; no significant variations were revealed.

Results

The table below presents a sample of the quantitative results from the Quality Metrics exercise; although estimates were produced for 2000, 2010, and 2020 and at a higher level of disaggregation than presented here, it was not practical (or essential to this discussion) to provide more detail. Energy savings and other estimates are for the year 2010, and include the effects of investments made in earlier years.

OBT Quality Metrics Estimates
(Preliminary)

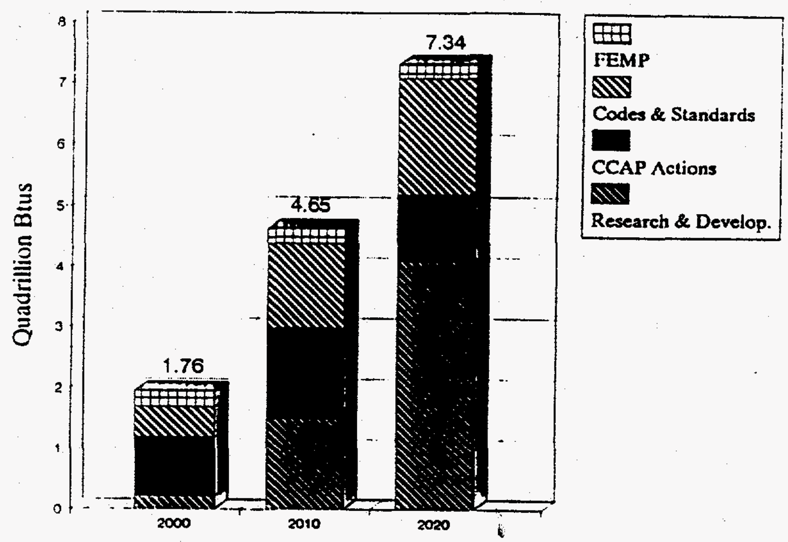
Planning Unit	Budget Request [$ Million, FY 1995)	Private Investment ($ Billion, 2010]	Energy Savings (Quads, 2010)	Energy Cost Savings ($ Billion, 2010)	Carbon Emissions Reductions (MMT, 2010)	Employment Increase (Million jobs, 2010)
Residential Bldg. Systems	15.7	41.0	0.11	1.0	1.6	8
Residential Bldg. Equipment	30.2	9.6	0.52	5.7	8.2	45
Commercial Bldg. Systems	25.2	1.4	0.28	2.0	3.2	17
Commercial Bldg. Equipment	15.6	8.4	0.76	6.0	11.7	47
Bldg. Envelope	9.9	5.6	0.55	5.2	8.4	43
Bldg. Standards	20.1	8.7	0.27	3.1	5.1	24
Appliance and Equip.Standards	11.0	72.2	1.75	17.0	30.1	123
Federal Energy Mngt. Program	37.1	0.2	0.27	2.3	4.2	21
Implementation and Deployment	7.0	0.0	0.14	2.1	3.7	18
Total	*171.8	147.1	4.65	44.4	76.2	346

* Not including Management - The total OBT request for FY 1995 totaled $184.0 million.

As shown on the previous page, the program is projected to produce very substantial benefits at relatively modest cost; for example, energy cost savings of over $40 billion annually by 2010 are shown to result from a relatively small Federal investment in the near term [although the resulting private sector investment is substantial].

The figure to the right illustrates how the major components of the OBT program contribute to energy savings over time. In the near-term [2000], the CCAP Actions provide the most savings. In the mid-term [2010], both Research and Development and Codes and Standards become more important than CCAP. In the long-term, Research and Development provides the largest contribution.

Sources of OBT Energy Savings



Given that the key function of the Quality Metrics process is to assist with program prioritization and budgeting, it is interesting to compare results across the sectors within EE. As shown in the table below, OBT claims the largest near-term energy savings. By 2030, OBT, OTT, and OUT claim nearly equal savings, behind OIT. It should be noted that the figures are preliminary, and in some cases controversial.

Predicted Energy Savings by Sector
[Quadrillion Btu per Year]

Sector [Office]	2000	2010	2020
Building Technologies [OBT]	1.76	4.65	7.34
Industrial Technologies [OIT]	1.05	6.73	11.51
Transportation Technologies [OTT]	0.17	3.79	7.13
Utility Technologies [OUT]	0.62	4.01	6.55
Technical and Financial Assistance [OTFA]	0.73	2.39	3.77

Review/Lessons Learned/Recommendations

Review

Two reviews of the Quality Metrics process have been conducted to date: an Internal Review of estimation methodologies (June 8) and an External Review (June 20 and 21). Both of these reviews were intended to provide insight into the methodologies used to calculate values for the metrics for each Planning Unit and the input assumptions used in their application. While a great deal was learned about the numerous and diverse approaches used by the sectors, specific recommendations were few. Perhaps the most important recommendations from the External Review were to use the QM results only as supplemental information to support budget decisions (not as their sole basis), to highlight limitations to the metrics used in the exercise, and to acknowledge risk and uncertainty more fully. The "lessons learned" below are offered in the spirit of these suggestions.

Lessons Learned/Recommendations

Several problems have emerged from the QM process thus far; several have serious implications for the usefulness of the approach, and deserve attention in the further evolution of the process.

Multicollinear Metrics

In the initial stage of developing proposed metrics for serious program evaluation, attention must be paid to the potential problem of having metrics that are functions of each other - i.e., multicollinearity. If some metrics are simply functional derivations of others, outcomes are essentially determined by the dominant metric, thereby compromising the utility of the derived metrics.

A case in point from our experience with DOE/EE is the relationship of the energy savings metric to those for the environment and economics. The environmental metric of choice, carbon emissions reduction potential, is simply a function of energy savings by fuel form. In turn, the environmental metric partially determines the equity metric, which addresses the effect of DOE programs on, among other things, future generations - and carbon emissions may cause global climate change in the 21st Century. Similarly, one aspect of the economics metric, reduced consumer expenditures on energy, is also derived from energy savings. Planning units with significant potential energy savings will, by definition, also rate highly in terms of reduced carbon and consumer costs, ensuring a high relative ranking. Further, the employment estimates are a function of consumer cost savings, a direct function of energy savings.

To avoid this "double counting," metrics could instead be selected that are more independent of each other. For example, the environment metric might be a combination of three factors: carbon emissions, urban air quality and land and water use implications, with the latter allowing for capture of non-Btu considerations. Thus, electric vehicles that conserve energy might score well for carbon (if the electricity is generated cleanly,) well for urban air but poorly for land use because electric cars demand a road infrastructure and require battery storage facilities. Alternatively, redundant metrics could simply be eliminated and the process simplified.

Lack of Variation in Response

Lack of variation in response within a metric also is problematic, for without enough discriminatory capability the metric will be rendered useless in aiding decision makers who are charged with funding programs based on potential benefits. This may be especially true for qualitatively assessed metrics, such as equity. In the EE QM exercise, a qualitative survey was administered asking for the potential equity impacts in terms of low income populations, geographic regions, and future generations. In all three cases, a significant majority of the respondents indicated that their planning units would provide benefits in all three areas - a delightful outcome certainly, but one that is essentially useless for deciding which programs to fund.

Variation in Degrees of Optimism

In all the concern about how to actually evaluate a multitude of disparate programs using a basket of metrics, a formidably technical exercise, it is essential not to overlook the need to "calibrate" the degree of optimism regarding the future across both planning units and sectors. If this is not done, incomparable results may follow, because the various parties involved may bring wildly different views of the future performance and market penetration of their programs to their analysis. Such calibration is admittedly difficult, but if it is not attempted *ex ante* it will be very difficult to perform after the estimates have been developed.

Simplicity is Beauty

The ultimate goal of EE's Quality Metrics is to inform the decision-making process, allowing intelligent tradeoffs to be made based on a credible assessment of the benefits to the country. Decision-makers are typically very constrained in terms of time, so metrics that require involved explanation to understand and have confidence in may be doomed to non-use. It is therefore better to have a few credibly estimated metrics, which can be elegantly presented to busy managers, than lots of metrics, the estimation of which requires considerable time and thought to explain and understand.

Ranges Are Superior to Point Estimates

For the QM exercise, energy savings and other estimates were provided as point estimates. The omniscience required to provide precise estimates with any confidence (especially for extended time horizons) is unlikely to be found anytime soon. To recognize this, a better approach would be to provide ranges of benefits estimates.

Conclusion

This paper discusses the first phase of a pioneering effort by DOE's Office of Energy Efficiency and Renewable Energy to measure the national benefits associated with implementation of its programs and thereby to enhance the credibility of its planning. This effort, which is in direct response to the Government Performance and Results Act, the Reinventing Government Initiative, and the Executive Order on Environmental Justice, is still evolving, and will likely change in response to lessons learned and suggestions from reviewers, stakeholders and others. The suggestions discussed in this paper, drawn from our experience with Quality Metrics in the Office of Building Technologies, are offered as contributions to this process.

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