Scenario-Based R&D Portfolio Analysis: Informing the Tough Decisions

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ABSTRACT

Previous studies have forecasted the future benefits associated with the Department of Energy's (DOE's) Office of Energy Efficiency and Renewable Energy (EERE) programs. These studies have focused on the impacts of programmatic activities given expected economic and budget situations, and an assumption of complete success. These benefits have invariably been represented as a point estimate, or series of point estimates through time.

As the government climate evolves to one with a greater emphasis on portfolio management, it is anticipated that traditional benefits analysis will evolve to a more ex ante decisional activity that will integrate portfolio analysis and program planning with impact analysis and Government Performance and Results Act (GPRA) compliance. A consideration of the uncertainty associated with point estimates of program impacts will almost certainly alter the representation and consideration of this portfolio. Further, R&D decision makers need to be able to look at alternative assumptions of future markets and performance of future technologies in order to gain a better understanding of the range of potential impacts of the R&D portfolio.

Comparisons with past benefits analyses have illustrated that changes in assumptions such as proposed technology cost, performance, and size of potential market can significantly affect the benefits forecast. This study proposes a new framework for incorporating alternative scenarios into a portfolio tool that provides resulting energy savings estimates given changes from reference-case conditions.

The framework can be changed by altering factors such as the R&D budget response functions, alternative macro assumptions (fuel prices, GDP growth, etc.), programmatic interaction scenarios (leveraging efforts, etc), alternative market outlooks (floorspace growth, etc), and alternative program objectives.

Introduction

The Government Performance and Results Act (GPRA) of 1993 requires Federal agencies to establish goals and objectives (including outcome-related goals and objectives) that are consistent with the mission of an organization. The goals and objectives must be measurable, with annual performance targets, linked to overall long-term goals, presented in budget requests to Congress.

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More recently, the President's Management Agenda (PMA) has been instituted to more closely link budgets to program performance, among other management initiatives. The government-wide initiative on Budget and Performance Integration is consistent with GPRA. The objective of the performance-based budgeting thrust of the PMA is to establish a performance hierarchy for all programs that links specific annual outputs (performance measures) to budget requests. Additionally, the hierarchy should make clear the connections to higher order, longer term program objectives. Ideally, portfolio analysis is used to identify a range of potential outcomes resulting from successful execution of a stated set of goals, objectives and annual targets for the selected technology research and development areas.

Developing a Program Design

The performance hierarchy. The PMA assumes that all programs address important public policy issues, reflected in distinct program missions. Each program is expected to establish long-term goals that are supported by intermediate-term objectives, which include annual performance targets. Note that several levels of goals and objectives may be needed to make the link from public policy issues to specific funded activities that produce directly measurable results.

Within the performance hierarchy, each goal should have multiple objectives, and each objective should have a sequence of annual performance targets. In principle, each objective must be distinct from all other objectives, and in turn, each target must be distinct from all other targets. This distinctiveness allows assessment of the relative contribution (and cost) of the activities producing results that ultimately lead to mission achievement. Note that multiple, yet still distinctive, pathways can lead to successfully meeting performance targets and intermediate objectives. For example, several promising technologies for addressing energy use in lighting might be developed along parallel paths until cost and performance information is sufficient to enable elimination of one or more technologies from the research agenda.

A fully completed performance hierarchy should be able to demonstrate relevance of targets to objectives, and objectives to goals. It should also be able to demonstrate the relative importance and relationship among targets, and among objectives, for a specific goal. Two principal relationship structures can exist in the performance hierarchy: single critical path structure, and multiple critical path structure. In the single critical path structure, all targets must be met in order to achieve an objective, as each target is necessary to achieve the objective. In the multiple critical path structure, only one of the critical paths must be completely successful in order to meet the objective, as the critical paths are in competition; the critical paths may be pursued in parallel or in serial fashion. Understanding program performance hierarchy and structure is essential for portfolio analysis.

Establishing the target market and baseline. For technology research, development, demonstration, and deployment programs, goals need to clearly identify a target market and baseline technology. An explicit identification of the target market (demographics, geography) and baseline technology (cost, performance, services provided) is needed. As R&D efforts are more long-term and new technologies will take time to develop and penetrate the market, the baseline target market and technology may, and probably will evolve. To the extent that these changes can be assessed and incorporated into the analysis, the overall program design will be more robust. In addition, the target market should be segmented as the varying cost and performance of emerging technologies will impact technology adoption differentially in specific market segments.

For instance, if the goal is to reduce energy consumption for lighting by developing an energy efficient light source, the target market could be residential or commercial lighting or some subset of these markets based on application (general illumination, task lighting, or "niche" applications). The performance of the baseline technology (e.g. incandescent, compact fluorescent, halogen) with which this technology is meant to compete, as well as potential improvements to that baseline technology, need to be clearly understood and articulated so that tradeoffs in cost and performance of the new technology can be considered.

Developing alternative strategies. There is most likely more than one strategy to accomplish the objectives and achieve the goal. During program planning, these alternative strategies are explored and the relative costs and chances of success are weighed. Limited resources, including time, necessitates choice among these strategies to adopt the path (or paths) most likely to achieve the objectives and hence, the goal.

For instance, rather than target a niche market (signage or traffic lights) for early success, an R&D effort targeted at solid state (light-emitting diode or LED) lighting could pursue a (perhaps "higher risk") strategy to try to displace an application in the general illumination market (say, desk lamps or other task lighting). Rather than incrementally chipping away at pieces of the market, the program allocates more resources for a longer term, to pursue perhaps more complex, costly, and higher risk effort in general illumination.

Given sufficient resources, multiple strategies would be pursued simultaneously to increase the overall probability of success. Lacking such resources, these strategies might be sequenced (first niche markets, then general illumination), stretching out the time required to achieve the goal. Generally speaking, the further distant the goal, the higher the risk, as assumptions regarding the market, baseline, competing technologies, and other factors are less likely to hold.

Dealing with Uncertainties

Uncertainty can be considered at the objective, strategy, and milestone level. Uncertainty can come in the form of the degree of technical or market success, or the inability to secure resources to fully implement planned strategies. Uncertainty can appear in the underlying assumptions regarding the target market and competing baseline technologies.

Uncertainty can be incorporated directly into the decision-making process. For instance, the prioritization method that was used to develop the original plan could be employed to increase or decrease the budgets for each strategy. This would make it possible to add or subtract research activities as well as overall strategies to accomplish each objective. The second step would be to assign probabilities to those budget scenarios (resource risk). While stretching out the milestone dates for objectives is certainly one response to reduced budgets, this adds additional uncertainty to the underlying assumptions about the target market and baseline technology.

For technical or market risk, consideration could be given to how performance shortfalls (e.g., first cost or technical performance) might affect program success in terms of both future per-unit energy reduction and market share. These alternative performance scenarios could result in either falling short of or exceeding the goal.

While the absolute uncertainty in the underlying assumptions, milestones, and objectives may not be understood, the relative importance can be demonstrated. Most critical to program planning and scenario analysis is the identification of "showstoppers." There may be threshold values for which the forecasted impacts (energy savings) of the technology drop precipitously or fall to zero. The relative effect of these unknowns can be understood and can inform the planning process in order to assess the relative effect of changes to the overall conduct of the program. For instance, if a certain performance level is required to achieve significant market penetration, then it may not be of interest to vary this within narrow bands if this band of uncertainty does not include this threshold value. Likewise, if market success depends on early introduction of the technology, simply pushing out the benefits five or ten years will not represent a true picture of the potential impact.

By incorporating market, resource (budget), and technological uncertainty, program managers begin to get a truer picture of the impact of the R&D portfolio. Point estimates of the future benefits of distant technological developments appear within bands or clouds of uncertainty. Perhaps most importantly, resources can be focused on reducing uncertainty either through better information and analysis or through targeted R&D, thereby increasing the likelihood of successful R&D efforts.

Benefits Analysis

An analysis of potential benefits is usually based on an evaluation of the project, considering project goals, technology characteristics (including performance and cost), the target market, and project milestones.

Performance Analysis

A critical aspect in the estimation of benefits is the transformation of project goals and milestones into expected characteristics for a given technology or practice. Goals can take the form of either an increase in performance, or in changes in other parameters designed to increase the potential market penetration of a product or service (e.g., developing practices or materials that reduce the cost of a currently available product). While initial benefits estimates might be derived by pre-determined cost and performance parameters, it is also possible to analyze potential performance characteristics through various modeling efforts to answer the question, "what performance level (or cost) would this product need to achieve in order to capture at least x% of the market?" Whether the ultimate characteristics are determined by project goals and milestones, or by analysis to determine what those goals should be, the performance and cost characteristics are key to the potential benefits analysis.

Impacts due to changes in a project's objectives may sometimes be calculated by changing the performance or cost parameters of the base assumptions, although recognize that changes in performance and cost will most likely impact the ultimate penetration that the product realizes.

Market Segmentation

In estimating the benefits of a potential project or activity, market segmentation is useful because it helps to realistically define the target market. For example, the commercial market can be broken down by building type, climate zone or region, size, and whether the target is new or existing buildings. Additionally, it can be broken down by end-use or equipment type; for example, lighting can be segmented by use (task, general) and by type (fluorescent, halogen). Potential sales are in part determined by the definition of the target market.

Market segmentation can be employed as one method to estimate the impacts of changes to a project's objectives due to changes in available resources, market conditions, or research issues. By thoroughly defining the market and market segments, segments can be added or subtracted as needed.

Market Penetration

Once the target market has been identified through market segmentation, assumptions may be made regarding the rate of technology/practice adoption by each segment. While some models rely on cost and performance data to endogenously determine market penetration, others rely on exogenous methods. Along with the market segment, the market penetration rate determines the ultimate estimate of the fraction of sales or fraction of installed base that are expected to adopt the new technology or practice.

Market penetration rates present another way in which changes in project objectives can be measured and translated into benefits (or costs). The market introduction date can be moved, the assumed maximum rate can be increased or decreased, or a combination of the two can occur. Through the understanding of the target market and the technology adoption process for similar products, market penetration can be adjusted accordingly to reflect the changes in objectives.

Scenario Analysis

The methods available for benefits analysis of a single project can be applied to a set of scenarios to develop potential outcomes. Within this paper, we explore two possible sets of scenarios: resource impacts (through budget impacts) and research impacts (through efficiency improvement impacts). Scenarios can be developed by following a logic chain, exploring each of the possible outcomes that result from the potential responses. These logic chains form the basis for the impact analysis.

Budget Scenarios

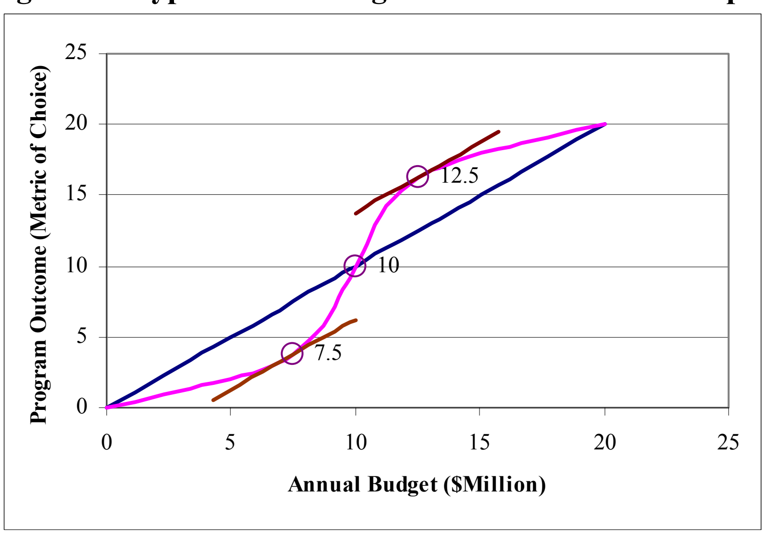
There are numerous possible responses to a large budget reduction (arbitrarily defined as 25% or greater). Assuming that the budget was appropriate before the budget reduction (i.e., there was not a lot of excess funds that could be cut with no effect) the impact could be substantial. The optimal response would be the one that results in the minimum impact; however, as we will demonstrate, the response is seldom optimal.

When faced with an unexpected budget increase of significant magnitude, experience has shown that the most common response is to add a new element/task to the project; whereas, when faced with an unexpected budget decrease of significant magnitude, the most common response is to cut all elements/tasks across the board. This suggests several things:

- All existing tasks are at the same slope on the marginal benefit curve—i.e., a $1 reduction in budget will have the same impact in every task. (Note that this is exactly where you would be if your portfolio was optimal.)
- The slope of the marginal benefit curve is the same for all tasks over the range of the decrease. (This is highly unlikely.)
- Portfolio managers either do not understand portfolio management or their portfolios, they are not in fact attempting to maximize the benefit from the investment, they do not believe that the budget reduction is permanent, or there are other costs that portfolio managers consider that are not apparent (e.g., restart costs).

Figure 1 presents two of many different possible marginal benefit curves for hypothetical R&D projects. The linear or 45-degree line implies a one-to-one relationship between budget and marginal benefit for a discrete project. Each additional dollar of investment yields an equivalent return as the previous dollar invested; hence, the marginal benefit is the same for all possible budget levels. This, for example, would represent a project like home weatherization; the greater the budget the greater the number of houses weatherized with the benefit per house unchanged. However, the nonlinear curve implies that as the budget changes the marginal benefit changes; thus, the marginal benefit varies as a function of the budget. There are just two points on the nonlinear curve where the slope of the curve is the same as the slope of the 45-degree line. The non-linear curve is more representative of a research project. At low budget levels much of the budget is consumed in administration, management, and project justification. As the budget increases more resources are actually devoted to performing research. However, at some point the budget gets so large that additional increases in the annual budget offer decreasing benefits for each dollar invested. This occurs for a number of reasons, for example the "best" ideas/tasks are funded first, the most capable researchers are funded first, or the project becomes too large to be managed effectively by one individual.

Figure 1. Hypothetical Marginal Benefit Curve Examples



Referring to Figure 1, assume that we have a portfolio with three R&D programs, all of which are funded at line item levels in the budget. Congress has funded the three programs such that the marginal benefit is identical for each. Program 1 has a budget of $7.5 million, Program

2 has a budget of $10.0 million, and Program 3 has a budget of $12.5 million. If the total budget were cut by $7.5 million (25% of the $30 million total) then what is the optimal decision regarding task funding? If, for a moment, we ignore the market effects and influences and assume there is no task interaction and no ability to move money between programs, then it is clear that the optimal decision is to eliminate funding for Program 1 because this will result in the least overall reduction in total benefit.

Note that the portfolio before the budget cut is locally optimal as funded from Congress (i.e., the first derivative of the marginal benefit curve is the same for all programs). However, also note that the portfolio is not globally optimal because the second derivative of the marginal benefit curve is not the same for all the programs. This means that a shifting of significant amount of funds between programs (not allowed in the example above because the program funding levels were Congressional line items) could increase the total program benefit. Shifting small amounts of funds does not affect total program benefit because the first derivatives of the marginal benefit curves for each program are the same. Hence, shifting a significant amount of funding from Programs 2 or 3 to Program 1 would increase the total program benefit.

Note further that if we continue to assume no program interaction and if reshuffling of funds was allowed under the budget cut, then the optimal result would not be the elimination of Program 1 but would rather be to eliminate Program 2 and move enough funds from Program 3 to Program 1 ($1.25 Million) such that the investment in Program 1 and Program 3 was identical. Then the first and second derivatives of the marginal cost curves for the two remaining programs would be identical and total program outcome would be maximized. Under this scenario the total program output is not significantly less than the total program output was before the budget cut.

However, there most certainly will be market effects and task interactions. Therefore, some attempt to understand the actual shape of the marginal benefit curve should be made. To inform that analysis there are several questions the R&D manager must ask to determine the optimal allocation.

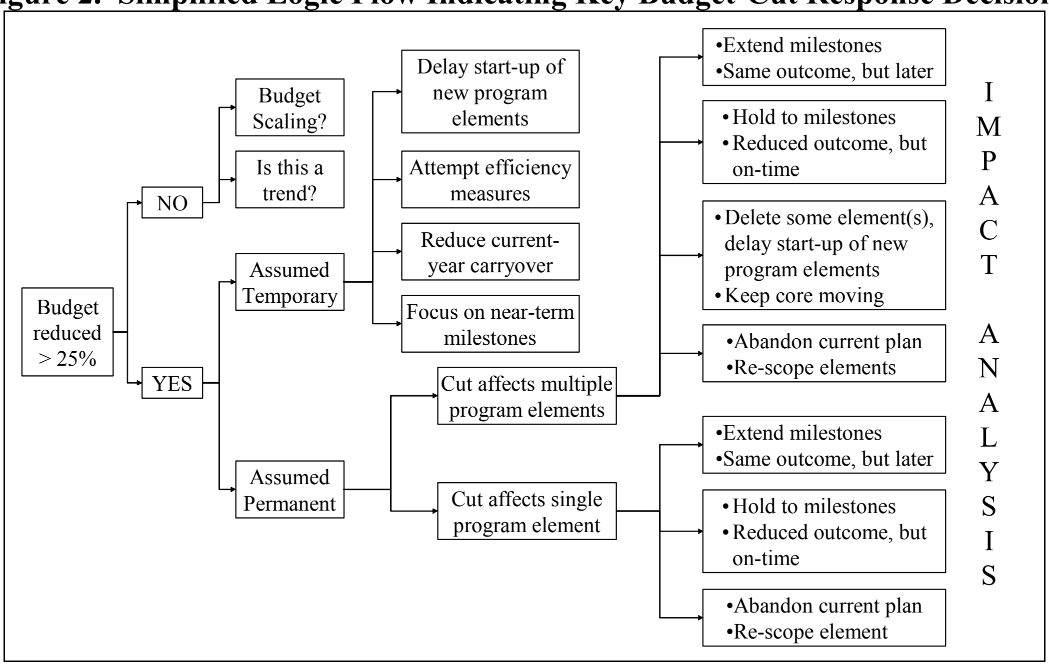
Some questions that might be asked include:

- Is the budget reduction temporary or permanent?
    - Temporary
        - Are there significant shutdown/start-up costs?
        - Will we permanently lose needed inputs (researchers, labs, capability, etc.) if we ramp down and then ramp back up?
        - What will a short delay do to the market we hope to compete in? How long will the delay be? (i.e., How far out will the milestone be pushed?)
    - Permanent
        - Are there less costly (from an R&D standpoint) technologies that should be pursued?
        - What will a delay do to the market we hope to compete in?
- What is the market like that this product will ultimately compete in and how do the performance, date of market introduction, quality, and cost of the technology affect its performance in the market?
    - Technology performance—efficiency/efficacy and secondary measures (e.g., delivery temperature of a heating system or CRI/color temperature of a light source)

- o Date of market introduction—commercial introduction at useable quantities and cost (is this a niche market or the general market)
- o Quality—is the product of the same durability and lifetime as current products in the market
- o Cost—first cost and life cycle cost

Figure 2 presents a simplified treatment of the decisions faced by R&D managers in response to reduced budgets developed from the questions above. For brevity, we focus on cases that assume a budget reduction of some form. We would expect that the decisions in the wake of large budget increases to be somewhat different – not symmetrical to decreases. Note that we do not explicitly treat cases of budget reductions that are less than 25 percent, but we do recognize several issues at play with such smaller cuts. Consecutive years of cuts less than 25 percent can force an R&D program into the same path as would be followed for the single large reduction illustrated. Taken as isolated events, smaller cuts are assumed to be analyzed by a simple scaling of the impact based on a proportional response to the reduction.

Figure 2. Simplified Logic Flow Indicating Key Budget-Cut Response Decisions



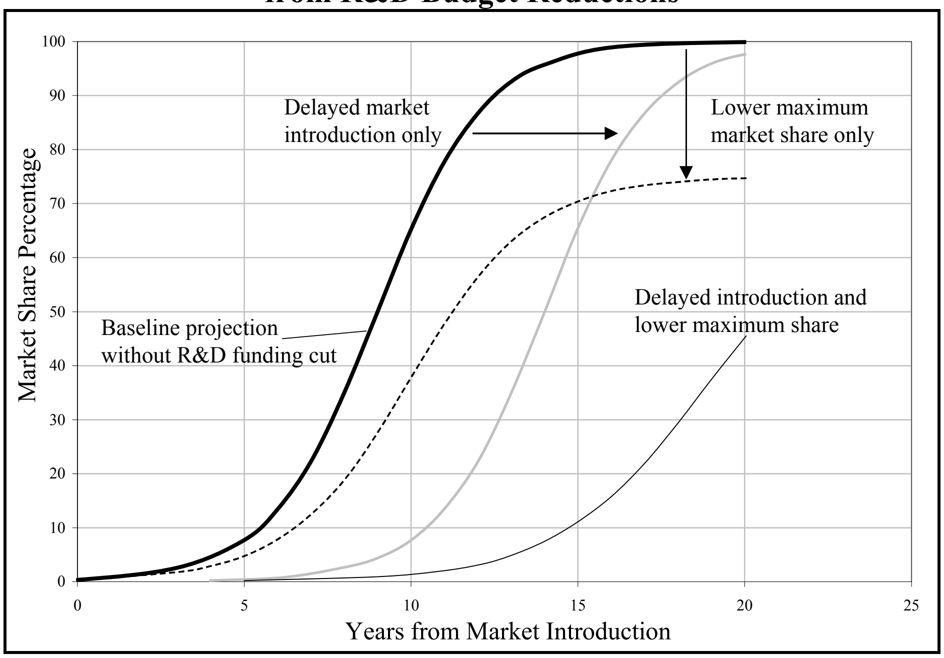
The steps illustrated thus far are necessary to set up the impact analysis. Program R&D managers should be interested in knowing the potential effects on outcomes from several alternative potential responses to the large budget reduction example scenario. Projected impacts of R&D programs are typically a function of the expected market penetration of the products resulting from the research effort. While entertaining the nuances of market penetration forecasting is beyond the scope of this paper, the authors realize the challenges of projecting market penetration for products expected to result from research in the buildings sector. Anderson et al. (2003) describe some of these efforts. Given that market penetration estimates can be developed for expected products from research and development activities, we can also hypothesize expected impacts to such penetration functions resulting from funding reductions.

Examples of the expected effects are shown in Figure 3. We illustrate three potential effects that R&D funding reductions might have on the penetration of some future product.

Large funding reductions can result in delaying the entry of new products – resulting from the impacted research program – as originally anticipated. If project milestones slip due to the funding reduction, the R&D manager may decide to continue pursuing the originally-envisioned product, but at a slower pace. The impact would be the difference between the effect of the product under the original penetration function and the effect of the product as the function moves out along the time axis (the solid grey curve in the figure).

If the reductions do not affect the market entry date, they might affect the ultimate share of the market originally forecasted to be reached by the product. This reduced maximum market share could be caused by entering the market on time, but with a product with less of a technical performance advantage over the rest of the market. As a result, the rest of the market is positioned not as far behind the new product and can cut into the gains offered by the product of the R&D program. This penetration function is illustrated by the dotted curve in the figure.

Figure 3. Potential Impacts on Future Product Market Penetration from R&D Budget Reductions



We also envision the case in which both the delaying effect and the loss of maximum share impact the outcomes of the R&D program. This means that the budget reduction resulted in delaying the product entrance to the market and the product entered the market not as technically superior to other products as originally planned. This function is illustrated by the outermost curve in the figure.

The case of abandoning or re-scoping an R&D program in response to a large budget cut also requires some attention. If funding constraints are severe enough, R&D managers might decide to "go another direction" entirely. One might envision that an R&D program might refocus to address a completely different market or outcome that would be more in line with the current funding situation. This presents somewhat of a wildcard to analysts hoping to reliably forecast the R&D portfolio benefits, because the result of closing out one opportunity may result in an unforeseen success in another.

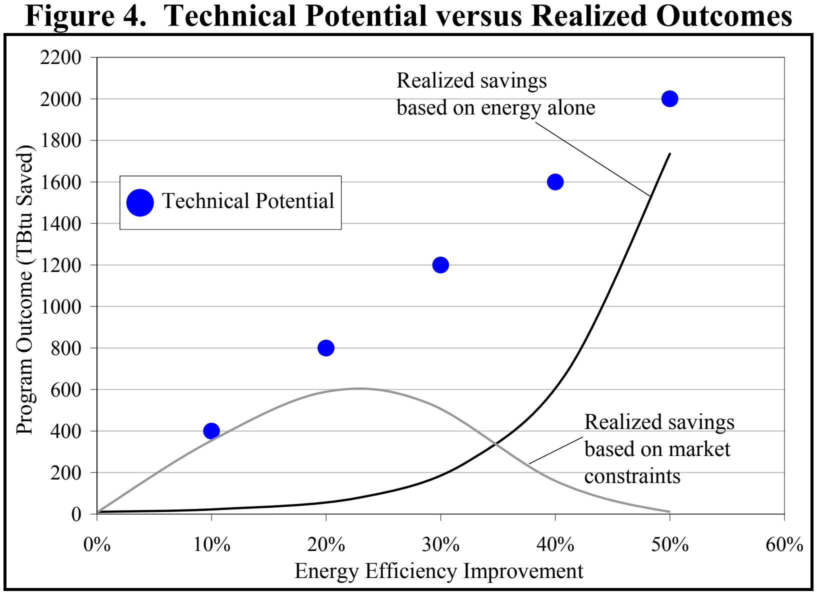
Efficiency Improvement Scenario

Energy-efficiency R&D activities addressing building equipment attempt to develop technologies that provide some efficiency gain above current offerings in the market. Efficiency gains can be expressed as percent improvements (percent reduction in energy use for the same service) over the base technology. Research may proceed with the goal of achieving some target level of efficiency gain in certain equipment, but may result in developing equipment that falls below that goal or surpasses it.

There is a technical energy saving potential associated with whatever advance results from R&D activities. This equates to the total energy consumption of the specific market segment of interest. For example, a research advance in solid-state lighting may lead to development of general illumination products for commercial buildings that are more efficient and have more favorable color rendition than existing fluorescent lamps. A research program in solid state lighting would set goals to develop products that would offer some target improvement in efficiency. As the research and development activities progress, some barriers to achieving efficiency improvement are likely to be removed, while other new barriers might emerge. As a result, products may be developed that fall anywhere along a range of efficiency improvement.

Figure 4 illustrates a hypothetical range of technical potential energy savings that might be expected for energy efficiency improvements of 10, 20, 30 40, and 50 percent above the baseline technology. For this example, the figure would indicate that if a product could be developed that would result in a 50 percent efficiency improvement above the baseline technology, the technical potential of that advance would be 2000 TBtu of primary energy savings. The dots on the figure represent technical potential for varying levels of efficiency improvement.

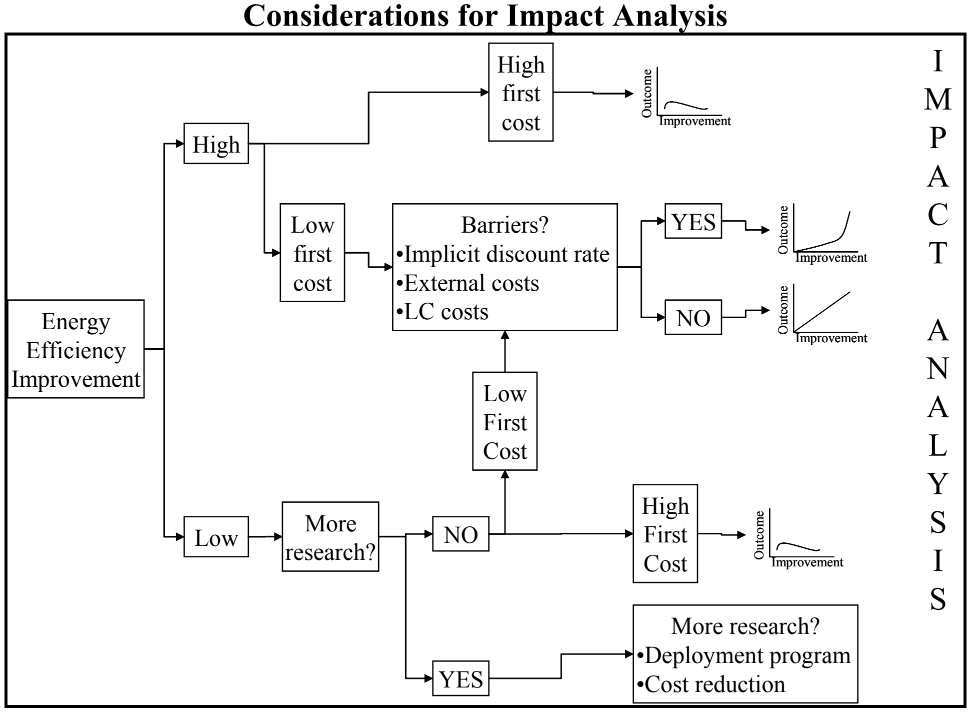
Figure 4. Technical Potential versus Realized Outcomes



Technical potential is a useful concept for sizing an opportunity; however, it is calculated absent any consideration of barriers such as product price, life-cycle costs, or other constraints that hinder any product from reaching it. For example, there are at least two theories that apply in addressing realized versus technical potential. Jaffe and Stavins (1994), among others, describe the slowness of diffusion of energy-conserving technology and the notion of implicit discount rates. One example comes from the notion that if the efficiency gain results in higher service levels for little or no incremental cost (e.g., an efficiency gain in heating equipment allows a user to set the thermostat two degrees higher), there is still some implicit discount rate or "hurdle rate" at play that prevents wide adoption of the new product until the efficiency gain appears to "leap frog" over established products in the same market segment. We illustrate this with the black curve in the figure. The realized benefits (energy savings) don't really take place until a large incremental increase in efficiency becomes available. The other case incorporates cost barriers such that the higher efficiency gains are available, but at an increasing cost (first cost). Therefore, the market goes for the most affordable offering of an efficiency improvement, but does not adopt the higher improvement level because of higher first costs (even if life-cycle costs are lower). We illustrate this case with the gray curve in the figure. The benefits accrue while the improved technology is perceived as a bargain by the market, and then fall off with declining adoption.

Figure 5 presents a simplified treatment of the decisions faced by R&D managers as they might evaluate potential efficiency improvements resulting from research programs. The choice to call an improvement high or low depends on the technology being researched, the market conditions, and historical experience. The figure provides some initial guidance for choosing the appropriate benefit function to apply to the efficiency improvement.

Figure 5. Simplified Logic Flow Indicating Key Efficiency Improvement Considerations for Impact Analysis



The logical process outlined in Figure 5 should help the R&D manager understand the implications of alternative efficiency improvements that may result from research activities. Within the class of improvements judged to be high, there are further considerations that may limit the outcome of the research activity that must be addressed in R&D portfolio analysis.

Analysis

From the approach developed to this point, we can begin to analyze the cases to bound the estimated outcome for a given R&D program. Doing this requires application of probabilities to the potential outcomes. Rarely if ever have sufficient data been collected that might inform the assignment of probabilities to the potential outcomes from EERE's buildings R&D programs. Deployment programs such as Weatherization Assistance have tracked the implementation of their programs and might afford the data necessary to assign probabilities, but the same is much more difficult for research programs. Compounding the issue, research sponsored by EERE attempts to uncover new materials or technologies that increase energy efficiency or better harness renewable energy. Only later are specific products developed to employ the research gains. This lack of specific products makes developing data on outcome probabilities very difficult.

In the absence of objective data on outcome probabilities, analysts must fall back to subjective approaches to derive the basis for a probability assignment to an outcome. These approaches include expert opinion based on experience conducting buildings research, general building engineering expertise, and research program management experience. For example purposes, we have assigned probabilities to the potential outcomes from the budget and technical potential examples developed above and illustrated in Figures 3 and 4. These have been grouped into budget cases, efficiency improvement cases where implicit discount rate is the primary barrier, and efficiency improvement cases where high first cost is the primary barrier. Table 1 identifies these cases with hypothetical year-20 outcomes expressed in terms of primary energy saved. Probabilities shown are subjective assumptions contrived to illustrate the application of the approach.

The information from Table 1 has been arranged graphically in Figure 6. The cases for each of the three scenarios form the theoretical bounds for realizing outcomes under the constraints imposed in Table 1. The figure indicates potential outcomes taken in isolation from each other. There are some implicit linkages or dependencies that are important to keep in mind as we develop the framework. We would expect some correlation or linkage of outcomes from the efficiency cases to depend on the R&D budget afforded the program. As more budget is allocated to research, the implied result is that outcomes will be higher, or that the probability of higher outcomes will increase. Therefore we cannot assume that R&D scenarios are mutually exclusive as the figure might suggest.

To consider developing a bounded estimate of a potential outcome in terms of primary energy savings that would incorporate all of the scenarios developed thus far, we developed a second-stage probability that we applied independently to the scenario means shown above. This means that each case was judged as to the likelihood of whether or not that specific result would be the outcome in year 20 of the analysis. The scenarios are analyzed somewhat independently of each other. This means that they would not be mutually exclusive and the associated probabilities would not need to sum to 1.

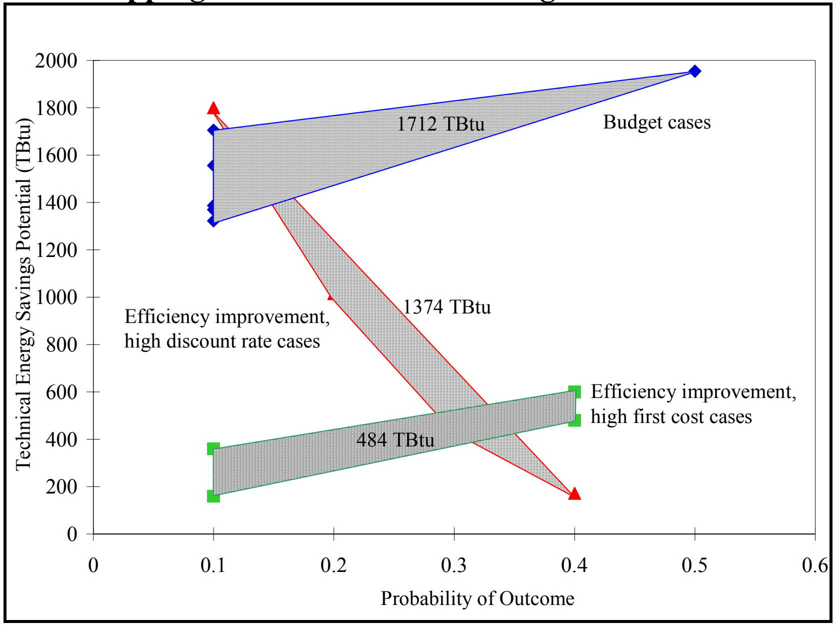
Table 1. Assignment of Probabilities to Potential Outcomes (Trillion Btu Primary Savings)

Case	Outcome	Realized Savings (TBtu - Yr 20)	Probability	Year 20 Normalized Outcomes
B_1	Budget request funded at requested level	1,955	0.50	977
B_2	25% Cut (slower penetration, same max)	1,706	0.10	171
B_3	25% Cut (product delayed 4 years)	1,557	0.10	156
B_4	25% Cut (max share falls by 25%)	1,387	0.10	139
B_6	25% Cut (delayed 4 years, but max falls by 12.5%)	1,370	0.10	137
B_5	25% Cut (max share falls by 25%, but slower)	1,323	0.10	132
Deterministic/Probabilistic Realized Outcome		1,549	1.00	1,712
C_1	10% Efficiency Improvement @ proportional cost	360	0.10	36
C_2	20% Efficiency Improvement @ proportional cost	600	0.40	240
C_3	30% Efficiency Improvement @ proportional cost	480	0.40	192
C_4	40% Efficiency Improvement @ proportional cost	160	0.10	16
C_5	50% Efficiency Improvement @ proportional cost	0	0.00	0
Deterministic/Probabilistic Realized Outcome		320	1.00	484
T_1	10% Efficiency Improvement @ high discount rate	65	0.00	0
T_2	20% Efficiency Improvement @ high discount rate	172	0.40	69
T_3	30% Efficiency Improvement @ high discount rate	448	0.30	134
T_4	40% Efficiency Improvement @ high discount rate	1,015	0.20	203
T_5	50% Efficiency Improvement @ high discount rate	1,800	0.10	180
Deterministic/Probabilistic Realized Outcome		700	1.00	1,374

The results appear in Figure 7. The mean outcome from the budget case was arbitrarily assigned a probability of 0.7. The efficiency improvement case featuring the low-cost, high-discount-rate barrier was assigned a probability of 0.4. The other efficiency improvement case was assigned a probability of 0.5. These arbitrary values were chosen to contrive an example for display purposes.

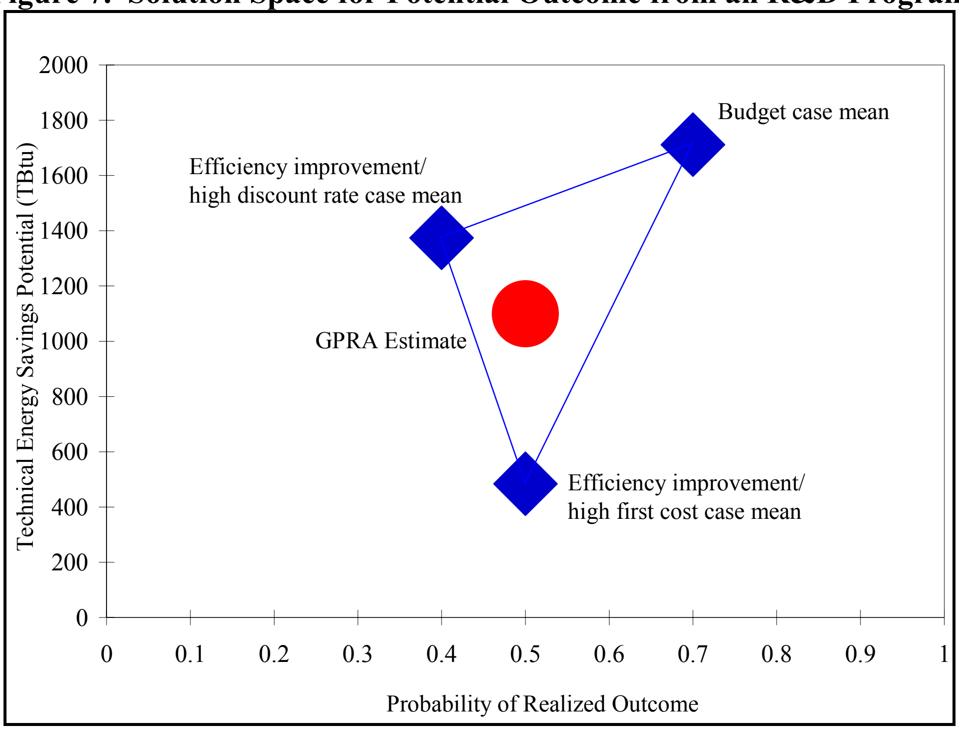
DOE research activities are analyzed each year to determine the expected benefits from the requested federal budget. These estimates are developed using a deterministic approach that results in point estimates. Depending on the rigor of the methods used to develop such point estimates, we would expect that the solution space in the approach we have developed would surround the point estimate for the program of interest. Hence, for example purposes we have plotted a hypothetical estimate by assigning it a probability of 0.5.

Figure 6. Mapping of Potential Outcomes against Technical Potential



Many other dimensions of scenarios can be envisioned. These might include the effects of alternative baseline conditions such as floorspace forecasts or lighting end-use demand forecasts, alternative macroeconomic conditions such as long-term higher world oil prices, fundamental technological changes, or other major influences on buildings R&D.

Figure 7. Solution Space for Potential Outcome from an R&D Program



Discussion

Portfolio analysis of the alternative R&D options cannot be conducted in earnest without consideration of the uncertainty of underlying assumptions (market, competing technologies) and the range of technological outcomes (cost, performance). Simple point estimates of future benefits (energy savings) of R&D programs can present a misleading picture of the relative impact of the R&D portfolio. For instance, on average, the benefits of longer-term, "higher risk" R&D will be less certain than more near-term efforts focused on technology development.

Quantification of this uncertainty requires a strong underlying planning process that yields basic information regarding these assumptions and potential outcomes. While sophisticated processes and approaches can be developed to demonstrate the impact of uncertainty, these methods are strongly dependent on solid data. An awareness of the "softness" of benefits estimates requires good understanding of the current and future market for the technology and its competitors as well as the range of potential technological outcomes.

While it may not be possible to describe the absolute range of uncertainty caused by these factors, the relative importance of these key assumptions can be demonstrated. Some factors (e.g., energy costs, baseline technology assumptions, and target markets) may be relatively more important than others in terms of the range of uncertainty. It is conceivable that the uncertainties caused by some of these factors are much more (orders of magnitude) significant than others. For example, an R&D program may have a target of a certain cost and performance of a technology. The range of uncertainty around this target, in terms of the calculation of benefits might swamp the impact caused by the potential variation in the price of natural gas or some other market factor.

Finally, a better understanding of uncertainty can help guide the program. To the extent that increased knowledge through better information or analysis can help reduce the impacts of uncertainty, overall program planning (and investments) is enhanced. Understanding the relative impacts of underlying factors can guide programmatic investments to reduce this uncertainty.

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