PROJECTING ENERGY EFFICIENCY IMPROVEMENT POTENTIAL: A COMPARISON OF METHODOLOGIES USED IN SIX RECENT STUDIES

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Abstract

This paper reviews six recent studies of the potential for energy efficiency improvement in the U.S. It develops a standard by which the methodologies and results of these and other similar studies can be better compared and understood. Emphasis is placed on the quality and comprehensiveness of the technology data sources the studies use as inputs, and on the assumptions made and methodologies used to project the savings which might result from adoption of these technologies. In particular, important modeling assumptions regarding economic and demographic trends are identified, as are the parameters which determine the adoption rate of new energy efficient technologies, and the methodologies used to compare their cost-effectiveness.

An important and often underemphasized aspect of most studies of energy efficiency improvement potential is found to be their assumption of ideal market conditions for the adoption of energy efficient technologies. Authors of these studies commonly assume that social discount rate financing, as well as all necessary information, hardware and installation expertise, is available for the energy efficiency improvements they consider. As a result, the studies identify an upper bound on achievable efficiency improvement potential, which could only be realized through large scale policy initiatives. Future studies of the likely cost and benefit of specific policy alternatives will be necessary to determine what portion of this total potential should ideally be targeted for attainment.

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INTRODUCTION

This paper reviews six major studies of energy efficiency improvement potential in the U.S. The objective of the paper is to develop a basis of comparison that will help elucidate both the methods and the results of the many divergent estimates of energy efficiency improvement potential ("EEI potential") which have been published. We attempt to develop such a basis by comparing study data sources, assumptions, and methodologies, including the methods of cost analysis and adoption rate projection employed. More specifically, this paper attempts to do four things: 1) identify the data sources, assumptions and analytical conventions on which the six studies relied, 2) summarize and compare the results of the six studies, and then, generalizing from these specific analyses, suggest 3) the study data sources, assumptions and methodologies that appear to be the most complete and consistent for studies of EEI potential, and 4) the uses and limitations of EEI projections of this type for purposes such as government and utility incentive program design.

In general, we found that the important inputs and methodological choices of major EEI studies can be identified and compared, and that much understanding of study results can be gained from analysis of these factors. Not surprisingly, natural links exist between the goals and perspectives of study authors and their choices of data sources and assumptions. For instance, optimistic estimates often rely on more inclusive definitions of the range and types of efficiency improvements considered, and more favorable assumptions regarding their rates of adoption. With some work, these differences in assumptions can be followed through the machinery of the study analyses, and their consequences for the results can be estimated. While in the past attempts to reconcile varied EEI projections have been difficult, in part due to perceived "philosophical" differences across studies, a discussion of the differences in assumptions and analytical methods used by the studies should help in understanding some of the major differences in results. Finally, a better understanding of both the methods and results of recent EEI studies should facilitate their use in the policy making process, and suggest places they might most profitably be augmented.

In fact, when their assumptions and methods are analyzed, the six studies demonstrated more consensus than might have been anticipated. It appears that some agreement is beginning to develop among authors of EEI studies regarding the types of scenarios to model and the methods of cost analysis to use. In addition, differences in assumptions about macroeconomic variables and rates of new technology development were surprisingly small. An additional aspect of this developing consensus reflects the choice of a general method of approach to EEI potential analysis, with important implications for the interpretation of the results. This is the choice to calculate EEI potential as the amount of efficiency improvement anticipated to occur under ideal conditions for EEI implementation, relative to presently existing implementation conditions. In particular, when modelling EEI potential, the studies generally assume that low interest rate financing and full information about new technologies are uniformly available. They do not describe the policy actions that may be required to achieve these conditions, and do not include the likely costs of such policies in their calculations of EEI cost. This modelling choice is made because the principal aim of the studies is to estimate the extent to which EEI adoption would increase if substantial efforts were made toward improving present EEI market conditions. Surprisingly, neither this goal nor the approach taken toward it is made clear in most of the studies. The studies fail to provide the sort of direct comparison of the scenarios they use to model improved market conditions with those modeling a continuation of present conditions, focusing on the effects of differences in implementation conditions, that would allow the reader to readily understand the implications of their results. In particular, the studies present the level of efficiency improvements projected given ideal implementation conditions as "cost-effective", without including or even mentioning the likely additional costs of achieving the ideal conditions, an oversight likely to lead to misinterpretation of their results. Therefore, while progress continues to be made in many areas of EEI analysis, such as the development of EEI technology databases, and systems for analyzing and aggregating individual technology level projections, until this "implementation gap" in the studies is more carefully addressed, the studies' "best" estimates of EEI potential should be interpreted and used with caution.

THE STUDIES

In order to develop a basis for understanding and comparing studies of EEI potential, we began with a careful review of six major EEI studies. The studies selected were chosen to represent recent work offering a wide range of projections. The studies were all done by well known organizations, many of which have acknowledged differences in goals and perspective. They are mostly "bottom-up" studies of technical EEI potential, meaning, roughly, that they estimate the aggregate energy savings that would result if the most efficient and/or "cost-effective" technologies available today were widely implemented. The studies all address large sectors of U.S. energy use, and rely on the results of detailed, technology-specific analyses of EEI technologies as inputs.

The authoring organizations and the study titles for the studies considered are:

1) The Energy Information Administration ("EIA"): "Energy Consumption and Conservation Potential: Supporting Analysis for the National Energy Strategy".

2) Oak Ridge National Laboratory ("ORNL"): "Energy Efficiency: How Far Can We Go?"

3) Tellus Institute ("Tellus"): "America's Energy Choices: Investing in a Strong Economy and a Clean Environment". (See Alliance to Save Energy reference).

4) The Electric Policy Research Institute ("EPRI"): "Efficient Electricity Use: Estimates of Maximum Energy Savings".

5) Lawrence Berkeley Laboratory ("LBL"): "Residential End-Use Energy Forecast".

6) Rocky Mountain Institute's Competitek ("RMI"): "Competitek Technical Reports".

Study Goals and Scope

All six of the studies shared the general goal of projecting aggregate EEI potential in major U.S. end-use sectors. As noted above, most studies chose to approach this goal by examining the impact that removal of important barriers to EEI implementation might have on the amount of EEI potential achieved in future years. Across studies, however, the motivation for making the EEI projections, as well as the range of end-use sectors addressed, varied significantly. The EIA and ORNL studies both have a broad scope, reflecting their expressed goals of presenting detailed assessments of the conservation potential across U.S. end-use sectors. They project EEI potential in all major end-uses, which they divide into the four sectors of residential and commercial buildings, industrial use, and transportation. They both make their projections for the year 2010. The Tellus study also has a broad scope, and in addition to the four end-use sectors which the EIA and ORNL studies modeled, it addressed the potential for efficiency improvements in electric utility generation and transmission. In contrast to the goals of the EIA and ORNL studies, however, the Tellus study sought to support an alternative to the administration's National Energy Strategy by projecting possible energy savings within given technological, resource, and market constraints. It also made its projections for the year 2010, but included calculations of the future benefits of those changes through 2030. Not surprisingly, the EPRI study sought to estimate the EEI potential of efficient electrical technologies. It made its projections for the year 2000, and addressed electricity use in the same four end-use sectors as above: residential and commercial buildings, industrial use, and transportation. The LBL study sought to use LBL's extensive residential sector end-use modeling capacity to project the potential for efficiency improvements in electricity use in the residential sector by the year 2010. Finally, and in some contrast, RMI's Competitek Technical Reports sought to serve as a user's guide to efficiency improvement technologies in electricity use. They address only present EEI opportunities, and do not attempt to project future EEI adoption rates, or the potential effects that changes in implementation conditions might have on these rates. Apparently, the reports provide projections of aggregate EEI potential principally to motivate implementation efforts. The four RMI reports address most major electricity end-uses, grouped into the categories of lighting, water heating, appliances and drive power.

Scenarios Modeled

Since the studies all address the potential for energy efficiency improvement relative to present efficiency levels, they naturally chose to construct their scenarios and quote their results based on comparisons of this kind. Therefore, while the range and precise definitions of the scenarios the authors chose vary among the studies, baseline scenarios and scenarios which project substantial levels of efficiency improvement, principally resulting from the removal of implementation barriers, can always be identified. Comparison of the scenarios which serve these purposes across studies immediately leads to interesting insights into the studies' reported results. For instance, the assumptions made for study baseline scenarios, which might be expected to be fairly consistent and therefore innocuous, prove to be quite variable. As an example, the baseline for the Tellus and ORNL studies, both of which address all major energy types and sectors of the economy, were 105.0 and 115.4 QBtu respectively, a difference of over 9%. While not so in this case, large differences in baseline scenarios across studies often result because some studies use a frozen efficiency baseline, in which current efficiency levels are projected into the future, and energy use rises with growth in the economy and the population, and other studies use a business-as-usual baseline, in which efficiency levels are projected to improve at some "natural" rate based on "expectable" government or utility policies, future fuel price paths, sectoral shifts in the economy, and capital stock turnover. While a difference as obvious as use of a frozen efficiency baseline versus a business-as-usual baseline is easy to identify, its impact is often overlooked.

In order to construct scenarios reflecting substantial energy efficiency improvement, many more assumptions about the process and extent of such efficiency improvement must be added to those assumptions necessary for construction of the baseline scenario. These sort of assumptions are more central to the principal task of most EEI studies, which is to model the adoption process of available EEI's over time. Not surprisingly, they are even more likely to vary significantly across studies. Since the individual impacts of all the assumptions which affect the adoption rate combine to determine the final EEI projections made, generally only their aggregate effect, and not their individual effects, can be compared. Most of the efficiency improvement scenarios constructed in this way fall into one of two general types: "cost-effective" scenarios, and "technical potential" scenarios. Cost-effective EEI scenarios project adoption trends for EEI's which, under the assumptions of the study, are calculated to have lifetime costs equal to or less than standard technologies. Two important assumptions the studies generally make when determining which EEI's meet this criteria are that full information about EEI's, as well as EEI financing at social discount rates, are uniformly available. Technical potential scenarios project the energy savings possible if the most efficient available technologies were implemented, regardless of their cost-effectiveness. Generally these scenarios are poorly defined, since rather than considering unrestricted implementation of "ultimate" technologies, they simply increment the potential savings of cost-effective scenarios for savings from situations in which the technology being considered failed to be cost-effective relative to existing technologies.

Relying on the general types of scenarios defined above, or frozen efficiency, business-as-usual, cost-effective, and technical potential, the scenarios modeled in the six studies examined can be put in roughly equivalent classes. Frozen efficiency scenarios were presented under exactly that name in ONRL, EPRI and LBL studies. Business-as-usual scenarios were included in the EIA, Tellus and EPRI study as the "Reference" scenario, and as the "Where We Are Headed" scenario in the ORNL study. Cost-effective scenarios were included under that name in the ORNL, EPRI and LBL studies, and as the "Market" scenario in the Tellus study. Because the EIA study combined cost analysis with other factors affecting the adoption decision, its "High Conservation" scenario can with only limited accuracy be categorized as a cost-effective scenario. Maximum technical potential scenarios were included in the EPRI and LBL studies under that name, as the "Very High Conservation" scenario in the EIA study, and, approximately, as the "Environmental Protection" and "Climate Stabilization" scenarios in the Tellus study.

The RMI study is the only exception to the scenario framework described above. Rather than project the extent of adoption of EEI's over time under various possible implementation conditions, RMI simply projected the amount of energy that would be saved if available EEI technologies were presently in place everywhere they calculated them to be cost-effective relative to existing technologies. This is equivalent to the definition of the cost-effective scenario described above, except that the total current potential of EEI technologies is measured, rather than the amount of EEI potential likely to be realized in some future year. The relative merits of this approach are discussed further below.

METHOD OF COMPARISON

To begin our analysis of the studies, we considered the completeness, consistency and currentness of the data sources used by each study. Because the purpose of bottom-up EEI studies is to project the aggregate energy savings that can be achieved by substituting more efficient for less efficient end-use technologies, the basic energy use technology input assumptions are perhaps the most fundamental aspects of any EEI study. These technology specific assumptions include the performance characteristics, useful life, and purchase, installation, operation and maintenance costs of the technologies. They come from measurements of actual in-use performance for presently available technologies, and from prototype performance or engineering estimates for emerging technologies. Clearly, much greater latitude exists in projecting the in-use performance characteristics, or even the eventual widespread acceptance, of emerging technologies than that of available technologies.

The most important thing to note about different attitudes and choices across studies regarding technology input assumptions of this kind is that where such differences exist, their impact cannot later be resolved, but only confounded, by the subsequent aggregation and projection stages of an EEI study. As the fundamental input assumptions, technology assumptions flow throughout the EEI analysis and drive its results.

After describing their technology inputs, studies of EEI potential attempt to project energy savings achievable from the phase-in of these technologies over time. Therefore, our second step was to examine the assumptions the studies make about the rate of adoption of the technologies they consider. This rate can be expected to depend on many factors, including those which affect the cost-effectiveness of the technology, such as the discount rate and the projected fuel price path, those that affect the growth in energy demand, such as the rate of growth of the population and the economy, and those that affect the adoption decision, such as the availability of information and low cost financing, and utility or government incentive or standards programs.

Finally, since much of the analysis of the expected rate of adoption of an EEI depends on its cost-effectiveness relative to existing technologies, the third study aspect we considered was the method used to calculate and compare EEI costs. Since the primary economic benefits of EEI's are the reduction in future energy use they make possible, the two primary methods of EEI cost analysis have been developed around energy cost comparisons. The first relies on projections of future fuel prices to value future energy savings, while the second attempts to treat future energy savings as equivalent to an alternative energy supply source, and analyzes the relative value of EEI's in that context.

DATA SOURCES

As described above, the EEI technology analyses that serve as the data sources for studies of EEI potential are the fundamental inputs of the studies. EEI studies themselves principally attempt to aggregate these inputs in an intelligent way, taking into consideration their end-use interactions and relative costs, and then project their adoption over time. As a result, the quality of all EEI studies is dependent on the quality and comprehensiveness of the EEI technology analyses available. Ideally, EEI technology studies should compare existing technologies and alternative, more efficient technologies on the basis of up-front cost, operating and maintenance costs, and of course, energy use and quality of end-use need satisfaction. At present, careful and exhaustive studies have been done on a technology by technology basis for only some of the major sectors of the U.S. economy. An excellent example of a comprehensive existing study is the LBL Residential End-Use Model, which includes careful analyses of over 200 of the major residential end-use technologies. In other major sectors, such as industrial energy use, little general, comprehensive work appears to exist.

The authors of each of the six studies seem to be well aware of the importance of good data sources. All the studies reflect attempts by their authors both to search for and make use of existing resources, and to fill remaining gaps on their own. The LBL and RMI studies, in fact, relied almost completely on their own technology analyses. An important aspect of the differences in results across studies is the extent to which they had access to analyses which allowed them to include a broader range of technologies in their forecast, or that they were willing to include technologies based on very limited, or judgmental evaluations of their potential. As an example of the first case, RMI's own work on lighting efficiency improvements allowed them to include lighting in their analysis, while other studies, such as ORNL, were unable to. As an example of the second case, reflecting an apparent desire to include personal transportation in their forecasts of EEI potential in electricity use, EPRI projected widespread adoption of electric vans by the year 2000, based on what appears to be a highly judgmental evaluation.

The primary data sources used in the six studies are listed in Table 1. Well respected sources, such as the LBL Residential study, are made obvious by the frequency of their occurrence in the table.

Table 1: Data Sources

	Residential	**Commercial**	**Industrial**	**Transportation**
EIA	AEO 1990, EIA Residential End-Use	AEO 1990, EIA Building End-Use	ORNL, various	DeLuchi, various
ORNL	LBL Residential Energy Model	PNL[1] Commercial Energy Model	EPA End-Use, Engineering Forecasts	ANL[2], ORNL and DOT
Tellus	LEAPS[3]	LEAPS	LEAPS	LEAPS
EPRI	Residential End-Use Planning System	ACEEE, LBL, various	Various	University of Michigan
LBL	LBL Residential Energy Model	NA	NA	NA
RMI	RMI	RMI	RMI	NA

[1] Pacific Northwest Laboratory
[2] Argonne National Laboratory
[3] Long-Range Energy Alternative Planning System
NA = Not Applicable

ASSUMPTIONS

If we treat the assumptions specific to the technology analyses of the data sources as part of the data sources themselves, the remaining important study assumptions relate to the prediction of trends in energy end-use service demand, and to the prediction of the EEI adoption rate. We term the first category "macroeconomic assumptions", and the second category "assumptions which affect the adoption rate", and discuss each below.

Macroeconomic Assumptions

As discussed in the scenario section above, projections of EEI potential in future years are based on projections of the trend in aggregate energy use and its major components. At a minimum, projections of aggregate energy use require projections of economic and population growth rates. Additional projections of sectoral shift and changes in energy intensity per unit of GNP are often also included in these projections. To project the energy use of any of the four primary sectors of residential and commercial buildings, industrial use, and transportation, additional projections such as trends in the number of households, dwelling type, commercial floor space, and transportation demand and vehicle type are also required. While these projections are important, they are essentially independent of the effects of energy efficiency improvements. Most study authors assumed relatively standard values for them, and in some cases treated them only implicitly. The assumptions made for these parameters in each of the six studies, to the extent acknowledged, are listed in Table 2.

Assumptions Which Affect the Adoption Rate

Since projecting the assumed adoption rate of EEI's is central to all EEI studies which attempt to project the EEI potential that will be achieved in future years, the assumptions which affect the adoption rate have a significant effect on study results. As a result, study authors focused their attention on many of these assumptions, and differences in the choices they made for them appear to be the source of many of the significant differences in their results. Adoption rate assumptions naturally fall into two groups; those that affect the cost-effectiveness of EEI's, such as the assumed discount rate, the projected fuel price path, and, indirectly, the extent of government or utility incentive programs, and those that affect the adoption timing of cost-effective EEI's such as the availability of information about new technology and of the necessary hardware and installation expertise, and the assumed rate of capital stock turnover.

Table 2: Assumptions

	Discount Rate	**GNP**	**Sectoral Shift**	**Fuel Prices**	**Population**	**Households**	**Commercial Space**
EIA	NA	+2.5-1.8% Variable	Yes exogenous	AEO '90, exogenous	+0.7% per year	+0.83% per year to 2030	+1.7% per year to 2030
ORNL	7% real	+2.5%	Yes exogenous	AEO '89 exogenous	+0.7% per year	+1.4% per year	+1.9% per year
Tellus	3% real	+2.5-1.8% variable	Yes exogenous	AEO '90, exogenous	+0.7% per year	+0.83% per year to 2030	+1.7% per year to 2030
EPRI	5% real	+2%	Yes exogenous	NA	+0.7% per year	+1.3% per year	+1.5% per year
LBL	7% real	NA	NA	NA	NA	+1.1% per year	NA
RMI	5% real	NA	NA	NA	NA	NA	NA

NA = Not Applicable

Controversy frequently exists about some of these assumptions. Assumptions made regarding government CAFE and appliance standards programs, and utility demand side management programs ranged from the status quo (in most studies) to aggressive promotion of energy efficiency in scenarios such as the Tellus Environmental Protection and Climate Stabilization scenarios. On the other hand, as noted above, the studies showed strong consensus in their assumptions about implementation conditions. Since the studies principally chose to explore the extent to which EEI adoption rates would be augmented if present implementation conditions were improved, their assumptions for these variables were naturally different from those presently observable. For instance, the studies all assumed that financing for EEI's was uniformly available at "social discount rate" levels of between 5 and 7%. Where justified, this level was described as appropriate for energy efficiency investments for reasons ranging from the societal importance of energy to the level's equivalence to the real rate of return on utility investments, which was argued to represent the cost of supply alternatives to EEI savings. This assumption is significant, since presently observed values for EEI discount rates generally range between 15% and 100%, and even small changes in the discount rate used can have a large effect on a study's results. For instance, the LBL study used a 7% discount rate, but noted that using a 3% rate would have lowered their average EEI cost projection by 29%. In their potential scenarios, the studies also generally assumed that decision makers had full access to costless information about available EEI's, and to necessary hardware and installation expertise. In reality, most of these conditions are far from the case for the majority of existing EEI's. In contrast to the justification the study authors provide for their other assumptions, the types of the government or utility programs necessary to achieve these ideal implementation conditions, together with their estimated costs, are not discussed.

The assumptions made for these parameters in each of the six studies, to the extent acknowledged, are listed in Table 2.

METHODOLOGIES

The two most important methodological issues in these studies are how to compare the cost of new, more energy efficient technologies with the cost of existing technologies, and how (or even whether, in the case of RMI) to project the future adoption rate of available EEI's. Since EEI cost-effectiveness, and therefore a method for EEI cost comparison, is central to all the methods of projecting adoption rates, we discuss cost comparison first.

EEI Cost Analysis

As described above, all studies projecting the adoption level of EEI's require some methodology for comparing the cost of EEI's with the cost of existing in-use technologies. One of two basic approaches to this problem is generally used for this purpose. The first calculates some form of the discounted total cost of an EEI, including up-front costs, energy use costs, and operation and maintenance costs, and compares it with the comparable cost for the technology currently in use. The second uses the cost of conserved energy supply curve methodology. Both of these methods are described below. A brief discussion of the particular techniques used in each of the six studies then follows.

Present Discounted Value of Total EEI Costs:

The discounted cost method compares the present discounted value of all the costs associated with each energy using technology over its useful life. The complete "life-cycle" cost for a technology includes its up-front purchase and installation costs, the discounted value of its projected operation and maintenance costs, and the discounted cost of its energy consumption over time. If the technologies being compared have different projected useful lives, their respective life-cycle costs must be converted into equivalent annual costs to be directly compared. A short-cut version of this method for technologies with the same useful lives is to simply compare the difference in their up-front costs (the efficient new technology usually being more expensive) to the discounted value of the energy costs avoided as a result of the new technology's greater efficiency.

There are obviously many assumptions that must be made to complete the calculations described above. Perhaps foremost of these assumptions are the discount rate used to calculate the present value of future expenditures, and the projected fuel price path required to calculate energy costs in future periods. Fuel price path projections are important because, as noted above, the principal economic benefit of EEI's result from the reduction in future fuel use they allow. Fuel price projections are required to convert these units of energy saved into dollars saved. The discount rate is important because once these future savings are projected, they must be discounted to the present for inclusion in the net present discounted cost of the EEI. The discount rate assumption therefore adds further uncertainty to the projected dollar value of energy saved in future periods. Once combined in this fashion, the effects of the two assumptions cannot later be separated. When an annual equivalent cost is calculated for an EEI in addition to its net present cost, the discount rate also affects the impact of the capital cost since it is used to spread the capital cost over the life of the technology. Since all the studies considered used discount rates in the "social discount rate" range, in contrast to the much higher discount rates commonly observed in actual EEI investment decisions, it is clear that relative to observed behavior, the study calculations place much greater weight on future savings or, equivalently, underweight up-front capital costs.

An ambitious study author could overcome the limitations imposed by the need for specific discount rate and fuel price path assumptions by calculating their results under each of a range of possible discount rate and fuel price path assumptions. It would certainly be instructive to compare the sorts of discount rate and energy price scenarios under which a particular EEI or set of EEI's are cost-effective with those where they are not. However, given the number of potential technologies being considered, their varied useful lives, and their energy use interactions, this sort of analysis is unreasonable if not impossible. As a result, all the studies which employed this methodology modeled only one fuel price path and one discount rate. This greatly weakens the overall analysis, because it provides only one "point" estimate of the value of future energy savings. The impact that making such a specific assumption has on the likelihood of achieving direct comparability of results across studies is also clear. Moreover, it eliminates the possibility of incorporating potential energy supply cost add-ons to reflect environmental or other externalities.

The remaining assumptions required for the life-cycle cost calculation are also often difficult to estimate. They include the actual costs and the realized in-use efficiencies of site-specific installations, projected technology maintenance and repair costs, and actual user operating behavior characteristics. Since very little data exists on average in-use efficiency for most of the technologies considered, nearly all studies ignored the impact of user behavior and the quality of real world implementation on realized in-use efficiency. Unfortunately, the energy use levels of experimental or prototype installations of many EEI technologies have been significantly different, and generally lower, than their average real world energy use levels. Also, since lifetime use data often doesn't exist for new technologies, differences in expected maintenance and repair costs are also commonly ignored.

Cost of Conserved Energy Supply Curves:

A cost of conserved energy supply curve shows the amount of energy savings achievable from a given set of EEI's (along the x-axis) for each energy price level (along the y-axis). As an example, the curve used to present the general results of the LBL study is shown in Appendix A. The curves are comprised of linked horizontal segments, with each segment representing a particular EEI. The length of the segment for a particular EEI (along the x-axis) represents the magnitude of the energy savings which the EEI could provide. The height, or y-axis coordinate, of the line segment represents the projected cost per unit of energy saved by the EEI. As with other supply curves, the curves demonstrate increasing marginal cost for greater levels of energy savings by ordering the EEI's from least to greatest cost.

Each segment of a conserved energy supply curve requires an estimate of the potential energy savings attainable from a particular EEI, as well as an estimate of the cost per unit energy saved. The cost per unit of energy saved is found by first calculating the discounted present value of all the lifetime costs of the EEI, as in the present discounted value methodology described above, except that <u>energy costs are not included</u>. The annual equivalent of this value is then calculated. Finally, the annual equivalent of these lifetime efficiency improvement costs is divided by the <u>annual energy savings</u> of the EEI <u>relative to the alternative conventional technology</u>, to yield the cost per unit of energy saved. In other words,

Cost of Conserved Energy = Annual Equivalent Cost of the EEI/Annual Energy Savings of the EEI

It is important to note that energy cost projections are not required for these calculations. Instead, the effective energy cost, for the amount of energy savings which the EEI being considered makes possible, is the <u>result</u> of the calculation. The cost of conserved energy supply curve method was originally developed for exactly this reason; it provides a cost of conserved energy, or cost of "negative" energy use, which can be directly compared to the cost of new energy supplies. The cost of conserved energy supply curve method therefore not only allows potential EEI's to be analyzed without reference to a specific energy price path scenario, it facilitates direct comparison of the cost of the energy the EEI saves with the production cost of other energy sources.

There is an additional complication in creating cost of conserved energy supply curves. The EEI's represented in a conservation supply curve are ordered from least to greatest cost, and the methodology naturally assumes the lower cost alternatives will be implemented first. However, interactions often exist among EEI's. For instance, implementing low cost insulation first reduces the potential benefits from the subsequent implementation of a more efficient space conditioning device. In order to avoid double counting of savings for sequential improvements, the incremental energy savings of later improvements must be calculated, conditional on the related improvements already in place. In addition to complicating the process, this requirement forces the creator of the curve to assume and represent one particular sequence of improvements. What values, for instance, are actually appropriate for the user who, for whatever reason, put in more costly weather-stripping before the insulation and space conditioning equipment upgrade described above? One positive effect of this requirement, however, is that it forces consideration of the interactions of related, or serial EEI's, and therefore suggests the benefits of whole system planning.

Other than elimination of the need for a fuel price path projection, the assumptions required to construct cost of conserved energy supply curves are very similar to those necessary for calculating the present discounted value of total EEI costs. In particular, a discount rate assumption is again necessary to determine the annual equivalent of the lifetime purchase, operating and maintenance costs of each technology. In addition, the same assumptions necessary to project actual installation costs and in-use efficiency levels, such as site specific installation and maintenance costs and user specific service demands and operating characteristics, are all still required.

Methods of Cost Comparison Used in the Six Studies:

The ORNL, Tellus, EPRI and RMI studies all relied principally on the present discounted value of total EEI costs for their analysis and presentation of results. The LBL study used cost of conserved energy supply curves to calculate and present the amount of energy savings possible from each type of EEI, together with its energy equivalent cost. ORNL and EPRI also presented cost of conserved energy supply curves to summarize portions of their results. The EIA study, as noted above, did not explicitly address the cost comparison of EEI's and conventional technologies. Instead, it combined relative cost criteria with other factors affecting the EEI adoption rate, and projected only the adoption rate trend. (See Table 3 - Summary of Study Cost Analysis Methods).

Once study authors chose a methodology for comparing the costs of energy end-use technologies, an appropriate definition of the cost-effectiveness of an EEI relative to conventional alternatives was usually obvious. For the studies that calculated the present discounted value of total technology costs and then compared technologies on the basis of the annual equivalents of these costs, the technology with the lowest equivalent annual cost was naturally termed the most cost-effective. For studies that calculated cost of conserved energy supply curves, a technology was termed cost-effective, relative to a given energy price, if its cost position on the supply curve was below the assumed energy cost. In the LBL study, an energy cost of 7.6 cents per Kwh was argued to approximate the average cost of electricity generation, and was used as a representative cut-off point.

In some cases, study authors provided additional information about EEI cost-effectiveness to further refine their results. For instance, the RMI study reported the average cost of the energy savings which they projected EEI's could provide, by end-use. Since for many end-uses these costs are much smaller than the cost of new supply resources, and in some cases even negative, the associated technologies are distinguished as more than only marginally cost-effective. Of course, as noted above, for studies which report projected cost of conserved energy supply curves, such as the LBL study, even more complete information of this type is available. Since the curves show the projected cost as well as the magnitude of potential savings for each

Table 3: Summary of Study Cost Analysis Methods

Study	Method of Cost Analysis
EIA	No explicit EEI cost analyses.
ORNL	Present discounted value of total EEI costs. Conserved energy supply curves presented for some sectors.
Tellus	Present discounted value of total EEI costs.
EPRI	Present discounted value of total EEI costs. Conserved energy supply curves presented for some results.
LBL	Conserved energy supply curves, by technology group, and for all technologies in aggregate.
RMI	Present discounted value of total EEI costs, converted into equivalent cost of energy saved.

technology considered, the reader can readily determine which technologies would be cost-effective at any energy price level of interest, together with the total energy savings which technologies with costs at or below that level are projected to be capable of providing. (See Table 3 - Summary of Study Cost Analysis Methods and Appendix A - LBL Cost of Conserved Energy Supply Curve)

Projecting the EEI Adoption Rate

The discussion above describes the criteria by which EEI's are usually determined to be cost-effective relative to an existing technology. While all study authors treated the cost-effectiveness of an EEI as a primary determinant of the likelihood of its adoption, they also assumed that many other factors were relevant as well. In general, for an EEI to be adopted, it seems reasonable that the adopter must be aware of and have access to it, have a need for the end-use service it provides, find it cost-effective, and be able to finance its purchase. In order to project the adoption rate of an EEI, therefore, in addition to analyzing its cost-effectiveness, studies must project the demand for the service it provides, and the extent of the availability of information about it, of the hardware it requires, and of financing for it. Since the primary goal of the studies, as described above, was to examine the impact which ideal implementation conditions, such as the full availability of EEI information, installation expertise, and low cost financing, might have on the level of EEI adoption, in contrast to all other variables, assumptions about implementation conditions were chosen to reflect ideal rather than likely conditions. Therefore, all of the studies which projected future EEI adoption levels assumed full information was available about EEI's, as was social discount rate financing for them. Since the effects of these assumptions on the amount of EEI improvements projected is the basis for the studies' results, they are clearly important. It is also important to note that the studies do not describe the sorts of government and utility programs that might be required to achieve, even partially, such ideal conditions, or what their costs might be. This is consistent with the goal of the studies, which is to estimate the potential for implementation policy action, not to suggest policy choices or to estimate their likely costs and levels of success. However, since the studies assume ideal implementation conditions without including the cost of bringing the conditions about, care must be taken when interpreting their evaluations of cost-effectiveness. While the likely costs of improving EEI implementation conditions are uncertain and subject to much debate, they are clearly significant, and therefore are likely to alter the "cost-effectiveness" ratings of many of the technologies the studies considered.

In contrast, the assumptions the studies made to project the future demand for energy end-use services and the arrival of new EEI technologies were relatively standard. Study projections for the future demand of energy end-use services rely on the "macroeconomic" assumptions the studies made to project future growth trends in the economy and population, including projections of sectoral shift, the rates of capital stock turnover, and housing and commercial floor space trends. Methods used to project the likely future arrival times of new EEI technologies, and the extent to which new EEI hardware was projected to be available, were less formal and more varied. Most authors attempted to ground these assumptions on the past history of the development and diffusion of related technologies, and the extent of existing and projected government or utility R&D and standards programs. Not surprisingly, assumptions of this kind appear to be significantly different across studies, and most studies reported insufficient detail on their technology specific assumptions to provide much insight into their results.

Two of the studies chose alternative methods for projecting the EEI adoption rate. The EIA study assumed that EEI cost-effectiveness and the other adoption rate factors, such as user need, and the availability of information, hardware and financing, are so interrelated that they cannot reasonably be treated separately. Accordingly, the EIA study projected only one overall adoption rate trend, which they assumed to be dependent on the combined effect of all the factors which affect the adoption rate. In greater contrast, the RMI study eliminated the adoption rate problem all together. Rather than project future adoption rates or diffusion levels, RMI simply estimated the amount of savings that could be achieved today if the most cost-effective EEI's available were in place everywhere that RMI calculated them to be less expensive than the technologies currently in use. RMI's definition of EEI potential is therefore somewhat different than the definition implied in the other studies, since it includes all possible cost-effective EEI potential today, while the other studies present only the amount of EEI potential, relative to a baseline energy use level, which might be achieved at a particular later date. RMI's definition is closer to what is generally meant by "potential", while the definitions used in the other studies more nearly mean the portion of that potential which might be realized by a given date, under the assumptions of a particular scenario. By choosing this method, RMI avoids incorporating the additional uncertainties and assumptions associated with making such future projections, but is unable to examine the relative impacts of different policy choices, fuels price paths, and other scenario variables on actual EEI adoption levels. This difference also at least partly explains why the RMI estimates appear particularly optimistic; they reflect the benefit of complete adoption of cost-effective EEI's, rather than only their partial phase-in.

SUMMARY OF STUDY RESULTS

To give a feeling for the range of results commonly reported in major studies of EEI potential, we report summary results for the six studies below. The primary point to note is the lack of direct comparability of the results. Part of this difficulty is of course because three of the studies are restricted to electricity use, and in the cases of the LBL and RMI studies, to a subset of all electricity uses. However, limited comparability exists between the more general and similar EIA, ORNL and Tellus studies. First, they each have measurably different baseline scenarios. This difference in baseline cannot be overcome by comparing percentage improvements from baseline, since baseline differences generally reflect differences in the range of end-uses the studies considered, and in the assumptions they made about growth rates, sectoral shift, and the fuel price paths. Because the interactions of these assumptions are complicated and begin at the micro level of technology specific analyses, they cannot be corrected for at the macro level of a study's reported results. Crude comparisons of this type emphasize the value of analyzing the construction of the EEI studies in question; differences in the range and quality of technology specific inputs flow throughout and are compounded by different assumptions on growth trends, the discount rate and fuel price path, and the numerous other factors which affect adoption rates. Comparisons of final reported results can only be fairly made by qualifying them with a description of the differences among all these factors across the studies being compared. Bearing in mind the differences between the six studies pointed out previously, a brief summary of their reported results follows.

EIA:

The EIA study projected that business as usual baseline primary energy consumption would rise from 84.7 QBtu in 1990 to 113 QBtu by 2010 for the buildings, industrial and transportation sectors. Under their cost-effective equivalent, "High Conservation" scenario, they project a 6% improvement from baseline, to total energy consumption of 105.1 QBtu. Their technical potential, or "Very High Conservation" scenario projected energy use of 95.4 QBtu in 2010, or a 16% improvement from baseline. The High Conservation scenario savings consisted of savings in the commercial, residential, industrial and transportation sectors of 2.2, 1.5, 2.0 and 2.8 QBtu respectively, or 14%, 13%, 7% and 10% reductions from baseline. The Very High Conservation scenario savings, broken down by the same sectors, and relative to baseline, were 1.9, 3.4, 3.0 and 4.5 QBtu respectively, or 22%, 29%, 11% and 16% reductions.

ORNL:

The ORNL study projected that frozen efficiency baseline primary energy consumption would rise from 80.1 QBtu in 1988 to 115.4 QBtu in 2010 for the buildings, transportation and industrial sectors. In their business as usual scenario, which they termed the "Where We Are Headed" scenario, they projected a 12% improvement from frozen efficiency levels, to total energy consumption of 101.7 QBtu. Their cost-effective efficiency scenario projection is energy use of 89.7 QBtu in 2010, or a 14% further improvement from their business as usual scenario. 41% of the cost-effective savings relative to business as usual are from the buildings sector, 26% from transportation, and 33% from industry.

Tellus:

As noted above, Tellus was the most optimistic of the economy-wide studies. They projected that business-as-usual baseline primary energy consumption would rise from 85.3 QBtu in 1988 to 105.0 QBtu in 2010 for the buildings, industrial and transportation sectors. Their cost-effective, or "Market" scenario projection is energy use of 83.4 QBtu in 2010, or a 20% reduction from baseline. Their "Environmental Protection" scenario projects energy use of 72.7 QBtu in 2010, or a 31% reduction from baseline . Finally, they include a "Climate Stabilization" scenario, which projects energy use of 68.9 QBtu in 2010, for a total reduction from baseline of 34%. Tellus also projected the cost savings, in 1990 dollars, that would be achieved through 2030 under each of these scenarios, relative to the baseline. These estimates include the benefits of the more efficient technologies but do not include economic adjustment costs. For the Market, Environmental Protection and Climate Stabilization scenarios, Tellus' projected savings are 1.8, 2.1, and 2.3 trillion dollars respectively.

EPRI:

The EPRI study projected that frozen efficiency baseline electricity consumption would rise from 2451 TWh in 1990 to 3,273 TWh in 2000. They did not report projections for cost-effective potential, and instead reported projections for their "Maximum Technical Potential" scenario, in which they assumed full penetration of the most efficient technologies presently available. This scenario projects electricity use of between 1,837 and 2,473 TWh, or between 24% and 44% reduction from baseline. Savings in the residential sector are projected to be between 9% and 15% of baseline, in the commercial sector to be between 7% and 15% of baseline, and in the industrial sector to be between 8% and 14% of baseline.

LBL:

The LBL study projected that frozen efficiency baseline residential energy consumption would rise from 828 TWh in 1990 to 1008 TWh in 2010. At maximum technical potential, EEI's are projected to be capable of reducing the 2010 level by 48%. EEI's with costs of conserved energy less than 7.6 cents per kWh would allow 41% savings from baseline. Of cost-effective savings, 27% are from water heating, a 60% reduction from baseline, and 25% of savings are from space conditioning, a 31% savings from baseline. Lighting, and refrigerators and freezers each contribute 15% of cost-effective savings, equating to 47% and 39% reductions from baseline levels, respectively.

RMI:

As noted above, the RMI technical reports did not project the phase-in of EEI's over time. Instead, they presented the total amount of energy savings possible, in today's environment, from available EEI technologies which they calculated to be currently cost-effective. Their results were reported as savings relative to current electricity usage in the four sectors of lighting, water heating, appliances and drive power which they considered.

RMI estimated cost-effective efficiency improvements are capable of saving 92% of electricity currently used for lighting. This is relative to their estimate that lighting accounts for between 17 and 27% of present U.S. electricity usage. Cost-effective EEI's are projected to be capable of saving between 28 and 60% of the electricity currently used for drivepower, with drivepower estimated to account for half of all electricity currently used in the U.S. The potential savings in appliance energy use is estimated to be 50% for commercial sector appliances and 80% for residential appliances, with appliances presently accounting for between 21 and 23% of current U.S. electricity use. Finally, nearly complete elimination of electricity use in water heating is projected, with water heating accounting for approximately 6% of current U.S. electricity use.

The average cost of lighting efficiency improvements is projected to be -1.4 cents per kWh. The average cost of drivepower EEI's is projected to be between -.63 and -.34 cents per kWh. For appliances, "most" savings are reported to cost less than 4 cents per kWh. For water heating, the average cost is projected to be between 1.1 and 2.0 cents per kWh.

LIMITATIONS OF THE STUDIES

As the discussions of the study data sources, assumptions and methodologies above suggest, we believe there is reason to view these projections of potential energy savings very cautiously. The reasons for the limited accuracy of study results, as noted, begin with data limitations on the actual cost and performance characteristics of EEI technologies. This limitation was faced by all the study authors, and will remain until available data sources can be significantly expanded. This problem is compounded by the numerous assumptions which must be made to project the adoption of EEI technologies over time. In addition to facing the difficulties of projecting the fuel price path and trends in economic and population growth, the studies were forced to make important simplifying assumptions to estimate the increase in EEI adoption levels likely to result from the implementation barriers. Each of these limitations is discussed below.

Data Limitations

Accurately projecting the aggregate potential for improved energy efficiency in the U.S. economy as a whole, or even in one or more of its major sectors, requires consideration of the multitude of ways energy is presently used, together with the numerous potential methods of improving energy efficiency in each of those uses. Comprehensive, consistent and current studies of each of these end-uses do not presently exist. Those that do exist are not always regularly updated. As a result of these significant data limitations, study authors are forced to either ignore all or certain aspects of some energy end-uses, to extrapolate results from related areas, or to use their own best judgement of potential energy savings in that area. Substantial doubt exists about how comprehensive the list of the technologies considered in the studies is, and about the consistency and accuracy of the analyses of the technologies included. Doubts such as these will remain until sufficiently complete and detailed databases are constructed for the full range of end-use technologies in major energy use sectors, which is to say, probably a long time.

Assumptions Affecting the EEI Adoption Rate

As described above, the EEI adoption rate depends on a wide range of economic and demographic trends, as well as on the EEI implementation environment. The efforts made by the studies to model the important economic and demographic trends have been discussed above, and seem to be successful, given their inherent uncertainties and limitations. The approach the studies chose for analyzing the effects of implementation conditions, however, places significant limitations on the interpretation and use of the study results which were not emphasized in most studies. These limitations result from the assumption of the ideal implementation conditions by the studies, without including projected mechanisms for achieving them, or their associated costs. Because the studies' purpose was to measure the full size of the "implementation gap", their assumption of ideal implementation conditions should not be faulted. Instead, care should be taken not to misinterpret the careful calculations of cost-effectiveness made in the studies, which rely to a large degree on the costless availability of ideal implementation conditions, as inclusive of all relevant costs. Rather than emphasize that their results are for ideal conditions, the studies make only brief initial mention that, for a social optimum, EEI's were considered cost-effective if their return on investment is greater than 5 or 7%, and that information and installation limitations were not considered. From then on, they simply describe the cost-effectiveness of EEI's under these conditions without qualification, including when presenting their results. Of course, as studies of implementation potential, the studies are not directly concerned with alternative methods to encourage implementation and their associated costs. However, for clarity of presentation, the implementation conditions the studies assume, as well as their rationale, should be made more clear. This would not only help prevent misinterpretation of the results presented, but would help focus attention on the real results of the studies - the amount of EEI potential that is lost because present implementation conditions are far from ideal.

SUGGESTIONS FOR FUTURE ASSESSMENTS OF EEI POTENTIAL

The above analysis of the major components of studies of EEI potential, and of the data sources, assumptions and methodologies employed by the authors of the six EEI studies examined, leads naturally to the identification of what appear to be the most complete data sources and the most consistent sets of assumptions and methodologies presently in use. Suggestions for each of these areas, based on the preceding analysis, are summarized below.

Established Data Sources

LBL Residential Energy Model:

For the residential sector, the LBL Residential Energy Model has established itself as a carefully constructed, comprehensive and complete data source. It contains carefully and consistently completed analyses on a technology by technology basis for nearly all end-uses in the residential sector. In addition, LBL provides integration and aggregation of the technology specific results, in the form of summary analyses and cost of conserved energy supply curves.

EPRI Residential End-Use Planning System:

EPRI's Residential End-Use Planning System is a close relative of the LBL Residential Energy Model. It was developed over time by many of the same people, and relies on similar methods and data sources. Accordingly, it is also well respected and commonly used.

RMI Technical Reports:

The RMI technical reports cover electricity end-uses falling into the categories of lighting, drivepower, hot water and appliances. On a technology by technology basis, they provide comprehensive, consistent analyses of electricity use in these areas. In addition, they carefully address the issue of optimal integration of various technologies for related end-uses, and stress the importance of evaluation and design of the complete end-use "delivery system", including all factors relevant to the satisfaction of the needs of the ultimate users.

Assumptions and Methodologies

Calculating EEI Cost-Effectiveness:

As discussed in the methodologies section above, nearly all studies of EEI potential rely on one of two major methods of comparing the cost of EEI's to the cost of conventional alternatives: present discounted cost, or cost of conserved energy supply curves. Both methods employ many of the same techniques and require that many of the same assumptions be made. However, because it allows EEI cost analysis to be decoupled from fuel prices, we believe the cost of conserved energy supply curve methodology is generally superior. In the end, the cost of an EEI reflected in a conserved energy supply curve will still be compared to the cost of conventional end-use technologies. However, because it is quoted as a "fuel equivalent" price, and calculated without fuel price assumptions, it can be directly compared to fuel prices as well, with or without including other costs that may be associated with a particular fuel, such as the externalities. Any of these comparisons can also be made under a variety of economic or political scenarios without requiring recalculation. As a caveat, special attention should be placed on tracking the interactions of related EEI's when calculating the value of sequential improvements using cost of conserved energy supply curves, as the methodology requires.

Modelling the Rate of EEI Adoption:

As discussed above, the factors with the most important impact on the rate of EEI adoption are the assumed fuel price path, the rate of capital stock turnover, the overall growth rate of the economy and the population, the rate of new technology development and diffusion, and the extent of utility or government based incentive and standards programs, reflected in particular by their impact on the availability of EEI information and low cost financing. The extent to which assumed values for these factors are either explicitly projected or implicitly included varies both by the factor considered and by study author. Our view of the most valid and consistent assumptions for each of these factors are summarized below.

- "Macroeconomic" factors: Nearly all the studies adopted fairly standard assumptions about the general energy, economic and demographic factors listed above, such as the fuel price path, the capital stock turnover rate, and growth rates. We believe this is appropriate, since making energy price and growth projections is neither the purpose, nor generally the area of expertise, of the authors. Assumptions of this type were often taken almost directly from established sources such as the Energy Information Administration's Annual Energy Outlook.

- The Rate of New Technology Development: Most studies made conservative assumptions regarding the further development of commercially available energy efficient technologies over the term of their projections. This seems appropriate for two reasons. First, the primary aim of the studies is to identify the EEI potential available at present. Second, projections of future improvements in technology have been notoriously inaccurate, especially if the commercial projections of future improvements in technology have been notoriously inaccurate, especially if the commercial availability or widespread adoption of the technology is included in the projection, as it generally is in this case. To further motivate the primary consideration of presently existing technologies in future studies, it is interesting to note that in the studies reviewed, advances from current technology were most commonly assumed in end-use areas where either 1) reasonably good technology doesn't currently exist or 2) data sources regarding existing technologies are poor or non-existent. It therefore seems that rather than serving as legitimate attempts at greater predictive accuracy, these assumptions fill gaps in data, or represent presently non-existent technology which the authors expect may emerge in the future.

The implications of choosing to principally consider technologies which are currently available in studies projecting EEI potential over a ten, twenty or thirty year period are important to remember when interpreting study results. Rather than being the best possible estimates of the actual efficiency improvements that will be achieved at specific points in the future, such projections are more reasonably interpreted as models of the possible adoption paths of EEI technologies available today.

- The Extent of Utility or Government Incentive Programs: As discussed in the preceding sections, the studies reviewed consistently assumed that present trends in government standards and utility demand side management programs would be maintained, and simultaneously that ideal EEI implementation conditions exist. The first set of assumptions seems fair in any case, and the second seems appropriate to these studies since they address the potential to increase the EEI adoption by improving EEI implementation conditions. We feel, however, that the purpose of the studies would be made more clear, and their results would be more likely to be interpreted correctly, if the nature of their assumptions about implementation conditions was emphasized. In particular, the lack of discussion of the types of implementation policies which might improve implementation conditions, as well as their likely associated costs, gives the misleading impression that these choices are either easy or are already made, and that their costs are either inconsequential or already included in the cost-effectiveness calculations. Of course, this is far from the case on both counts. In the future, as consensus develops on the rough magnitude of the implementation gap, and interest shifts to focus on achieving EEI potential, discussions and analysis will undoubtedly shift more toward consideration of these implementation policy choices and analysis of their costs.

CONCLUSIONS

While the six studies reviewed present a relatively wide range of results, comparison and analysis of their data sources, assumptions and methodologies provides insight into their calculations, and perhaps, some feeling for a reasonable range for the actual magnitude of EEI potential. Of potentially greater importance, careful consideration of these important studies allows identification of the strongest data sources and the most well-justified methodologies for studies of EEI potential. Important assumptions, together with ranges and approximate averages for their values can also be readily identified. The understanding of the EEI studies done to date, which this sort of analysis provides, is valuable both for interpreting and comparing the results of such previous studies, and for developing a basis by which to evaluate present approaches to the estimation of EEI potential and to structure the approaches of future studies. Accordingly, suggestions were made regarding preferable data sources, assumptions, and methodologies for such future studies of EEI potential. In particular, the cost of conserved energy supply curve methodology was suggested as the preferable method of EEI cost analysis, since it eliminates the need to rely on specific fuel price path projections. In addition, the primary role that the assumption of ideal implementation conditions plays in the definition of EEI potential used in the studies was emphasized. While most recent studies of EEI potential assume ideal implementation conditions, they do not address methods of achieving these conditions, nor do they include estimated costs of doing so in their calculations of EEI cost-effectiveness. Thus the EEI potential the studies actually measure is the maximum "implementation gap" potential, which they calculate by assuming the cost of bridging this gap is zero. In the future, studies of EEI potential are likely to refine these estimates of potential by adding consideration of specific policy choices for narrowing the implementation gap, including the estimated costs and levels of effectiveness of such policies.

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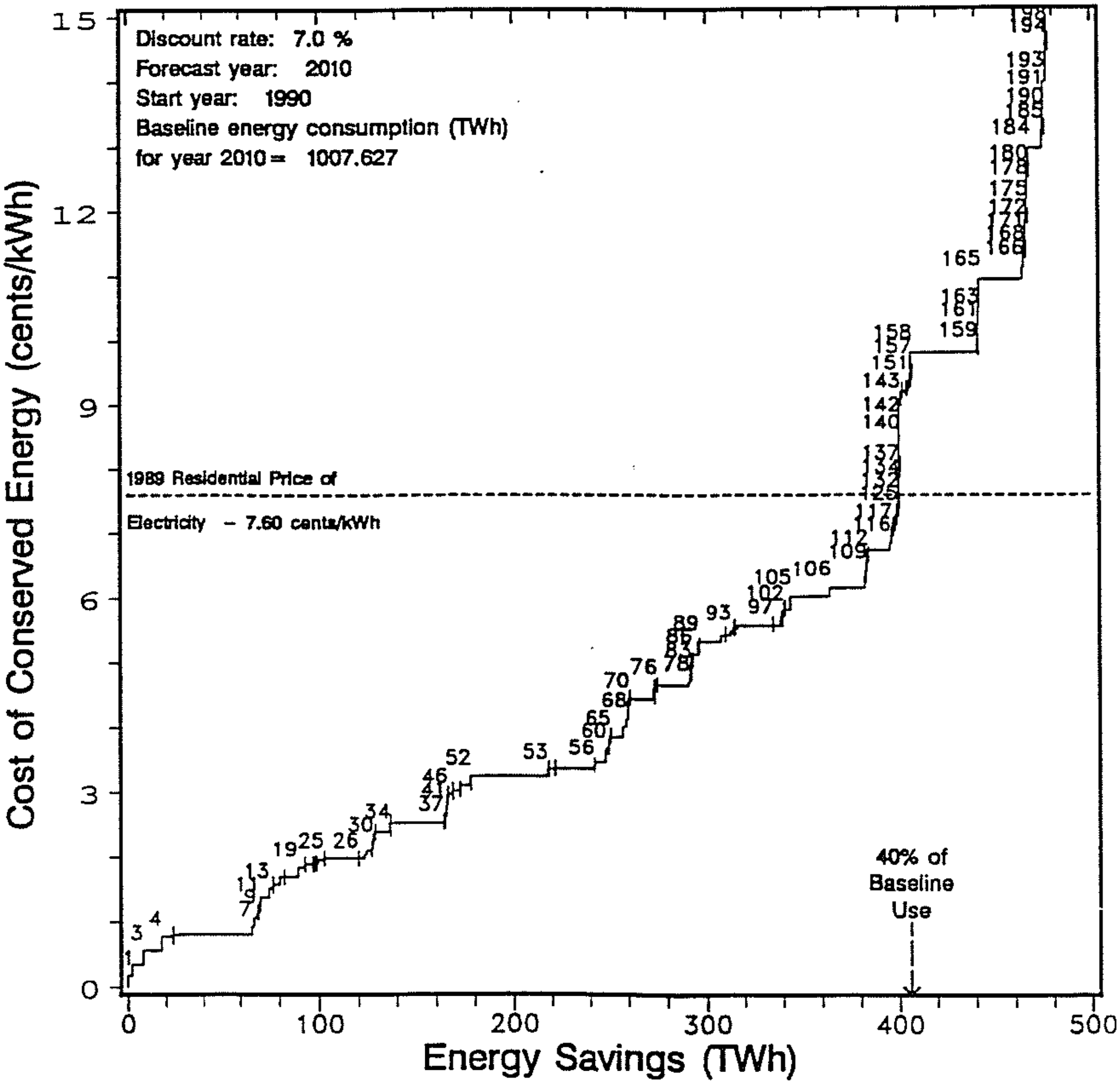
APPENDIX A: LBL Cost of Conserved Energy Supply Curve



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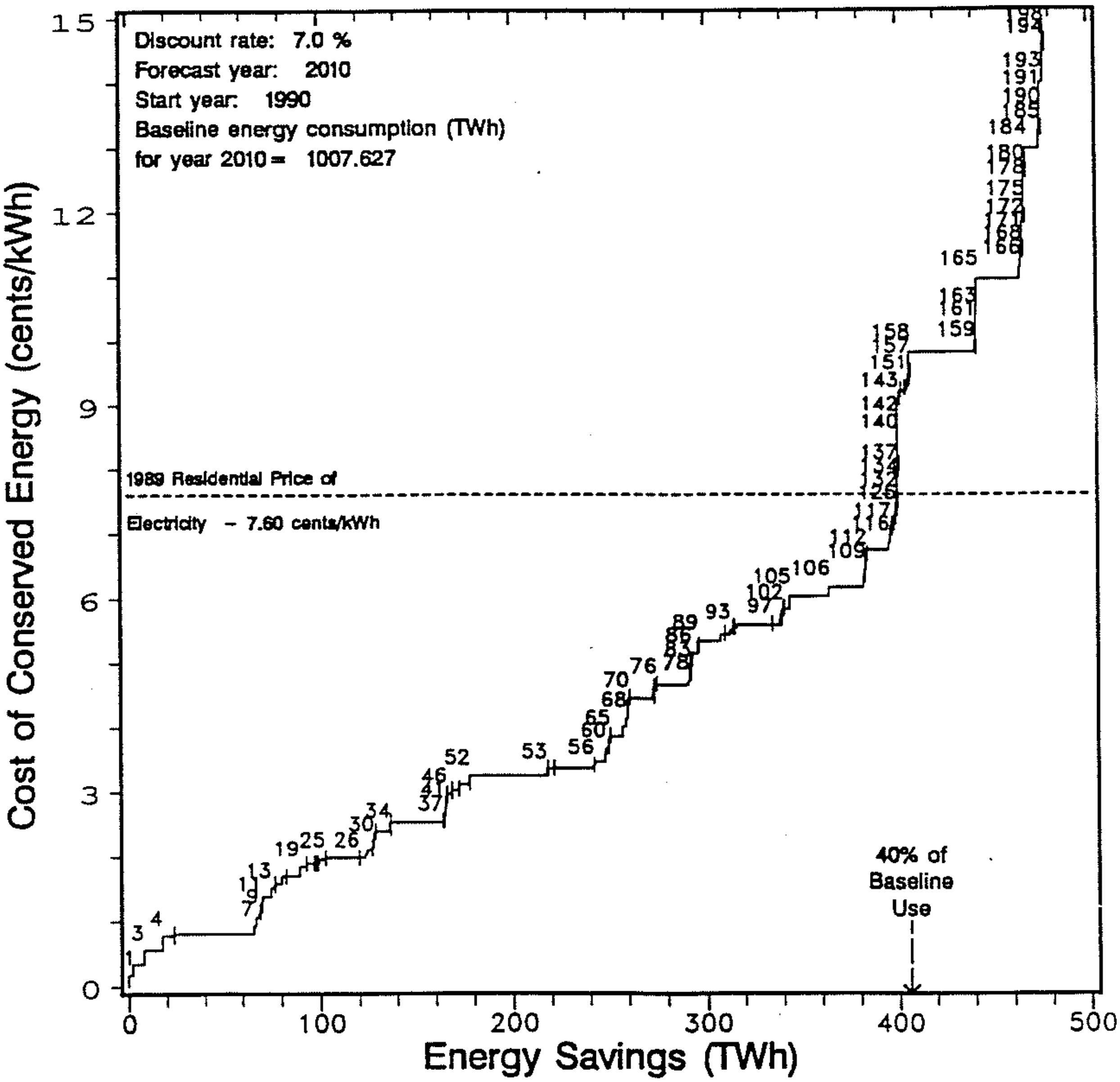

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