Assessment of Achievable Potential for Energy Efficiency and Demand Response in the U.S. (2010 – 2030)

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ABSTRACT

Utilities and regulators across the U.S. are setting aggressive goals for energy efficiency in the face of increasing customer demand for electricity. A key motivation for these goals is to reduce CO_2 emissions from the electricity sector. This paper presents preliminary results of a nationwide assessment of the potential for electricity savings through energy efficiency (EE) and demand response (DR) programs. The study is sponsored by the Electric Power Research Institute (EPRI) and the Edison Electric Institute (EEI).

The study estimates the realistic achievable potential for energy efficiency that would occur with the implementation and full operation of EE and DR programs and initiatives nationwide. The analysis evaluates the potential for energy efficiency improvement in the major categories of energy end use through the year 2030 for the four U.S. Census regions.

This paper presents preliminary results from the EPRI/EEI study for the U.S. as a whole. Our conference presentation at the August 2008 ACEEE Summer Study will include final savings estimates by Census region, as well as the results of the scenario analysis.

Executive Summary

According to the Energy Information Administration's 2008 Annual Energy Outlook, adjusted for DSM programs embedded as of 2007, electricity use will be 30% higher in 2030 than it is in 2008. This forecast already accounts for market-driven efficiency improvements and the impacts of all Federal appliance standards and building codes that result from legislation which there is legislation (such as the 2007 Energy Information and Security Act) and rulemaking procedures. Our forecast of peak demand, which extrapolates NERC's 2005 Peak Demand and Energy Projection Bandwidths, results in non coincident peak demand that is 55% higher in 2030 than it is expected to be in 2008.

Based on our analysis of energy efficiency and demand response measures, the electric utility industry can realistically expect to offset 37% of the growth in electricity use (in TWh) by 2030. This represents 8.5% of total electricity use in 2030 (413 TWh) and a reduction in the growth rate from 1.2% to 0.8%.

Through demand response and energy efficiency programs, the electricity industry can also realistically expect to offset 40% of the growth in non-coincident summer peak demand (in GW) by the year 2030. This represents 14% of summer peak demand in 2030 (173 GW) and a reduction in the peak-demand growth rate from 2.0% to 1.3%. Half the peak demand savings result from demand response and the other half from energy-efficiency.

Introduction

The Electric Power Research Institute (EPRI) and Edison Electric Institute (EEI) commissioned a joint study to assess the potential for the reducing electricity use and summer peak demand through utility programs for the United States and four Census regions for the time horizon of 2008 to 2030. A key objective of the study is to inform utilities, policymakers, and other industry stakeholders in their efforts to develop actionable savings targets for energy-efficiency and demand-response programs.

The study forecasts U.S. energy-efficiency and demand-response potential with respect to the DOE Energy Information Administration's "Reference Forecast" for electricity consumption as presented in its 2008 Annual Energy Outlook (AEO) and NERC's 2005 Peak Demand and Energy Projection Bandwidths extrapolated to 2030. The first step was to develop baseline forecasts of electricity consumption and peak demand at the region, end-use, and technology levels which are consistent with the AEO 2008 and NERC forecasts. Then we developed annual energy-efficiency and demand-response potentials for the years 2009 through 2030 at the end-use level for the residential, commercial, and industrial sectors at the national level in addition to the four major U.S. census regions. This results in forecasts of electricity use and non-coincident summer peak demand, as well as energy and peak savings estimates for the U.S. and four Census regions for 2008 through 2030. Finally, the project analyzed three scenarios that reflect higher supply side costs and a carbon tax.

Types of Potential

The primary focus of this study is to develop a range of realistically achievable potential for energy efficiency and demand response. The approach for deriving achievable potential is predicated on first establishing the theoretical constructs of technical potential and economic potential and discounting them based on market constraints. All potential estimates represent "phased-in" potential since it is assumed that appliance and equipment replacement takes place at the end of its useful life, rather than instantaneously. We employ the following definitions of potential.

- **Technical potential** represents the savings due to energy-efficiency (EE) and demand-response (DR) measures that would result if all of the most efficient measures and actions were adopted by customers, regardless of cost. It provides the broadest and highest definition of savings potential since it quantifies the savings that would result if all current equipment, processes, and practices in all sectors of the market were replaced by the most efficient. Technical potential does not take into account the cost-effectiveness of the measures.
- **Economic potential** represents the savings due to EE measures that would result if only cost-effective measures are adopted by the utility's customers. It is a subset of the technical potential and is quantified only over those measures that pass an economic screen. For our analysis, we use a variation of the participant test.
- **Maximum achievable potential (MAP)** refines the economic potential by taking into account expected program participation, customer preferences, and budget constraints. Maximum achievable potential establishes a maximum target for the savings that a utility can hope to achieve through its programs. MAP usually involves incentives that represent

100% of the incremental cost of energy efficient measures above baseline measures, combined with high administrative and marketing costs.

- **Realistic Achievable Potential (RAP)**, unlike the other potential estimates, represents a forecast of likely customer behavior and penetration rates of efficient technologies. It takes into account existing market, financial, political, and regulatory barriers that are likely to limit the amount of savings that might be achieved through energy efficiency or demand response programs. For example, utilities have budget limitations that often restrict funding of energy efficiency and demand response programs to less than optimal levels. Political barriers often reflect differences in regional attitudes toward energy efficiency and its value as a resource. The RAP also takes into account recent utility experience and reported savings.

Analysis Approach

The savings potential of an individual energy-efficiency measure is a function of its unit energy savings relative to a baseline technology. This potential is then discounted by a variety of factors that take into account technical applicability, economic feasibility, the turnover rate of installed equipment, and market penetration. This is consistent with the method described in the National Action Plan for Energy Efficiency (NAPEE) "Guide to Conducting Energy Efficiency Potential Studies," published in November 2007.

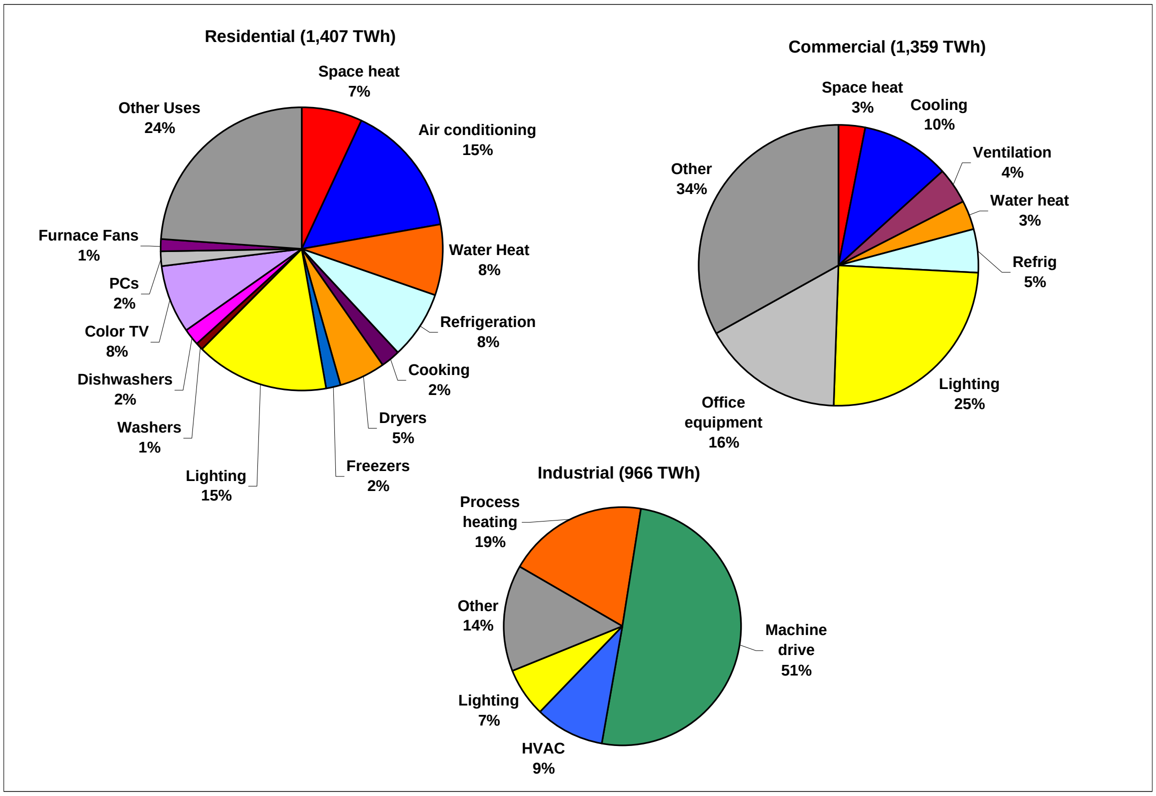
The study utilized Global Energy Partner's Load Management Analysis and Planning (LoadMAP^{TM}) tool for forecasting energy use, peak demand, and estimating savings. LoadMAP is a highly detailed micro-economic model of energy and peak-demand savings at the level of major end uses (i.e., residential lighting, commercial air conditioning, industrial motors, etc.). LoadMAP leverages a comprehensive technology database, as well as a sophisticated building simulation tool based on the DOE-2 engine. Savings potentials are developed using a "bottom-up" approach, aggregating the impact of discrete technology options within end uses across sectors and regions. This approach follows industry best practices and has been applied successfully in numerous utility potential studies.

The Starting Point: Base-Year Electricity Use by Sector and End Use

Before any analysis of energy savings can begin, it is critical to understand, to the best of our ability, how customers use energy today. For this study, we began with the 2008 AEO estimate of 3,732 TWh for electricity use in the U.S. across the residential, commercial, and industrial sectors. Figure 1 shows the AEO breakdown by sector and end use. The largest sector is the residential, with commercial only slightly smaller. In both residential and commercial sectors, lighting and cooling are major end uses. Both sectors also have a substantial "other" category which includes various plug loads not classified among the other end uses. Office equipment is another large use in the commercial sector. Machine drives (motors) are the largest electric end use in the industrial sector.

In addition to quantifying end-use energy use and peak demand in the base-year, it is necessary to understand the fuel mix, specific equipment types, and the efficiency levels of the equipment in place. Information about fuel shares and specific equipment types is relatively easy for utilities to gather, but efficiency levels pose a challenge. For this national study, we utilized the market studies (RECS, CBECS, and MECS) conducted periodically by the Energy Information Administration and other publicly available sources.

Figure 1. 2008 U.S. Electricity Use by Sector and End Use



Source: Energy Information Administration (2008)

The Reference Forecast

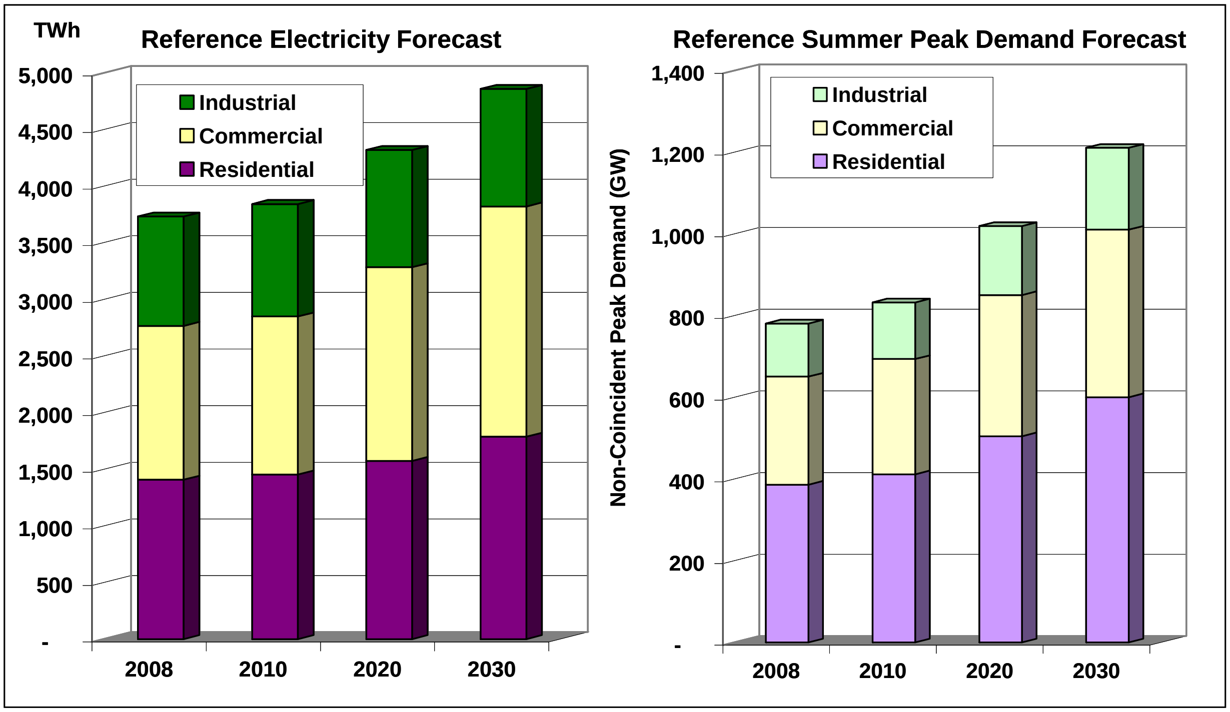
By 2030, electricity use is expected to increase to 4,858 TWh, a 30% increase over 2008. This baseline forecast already includes expected savings from several drivers of efficiency:

- The Energy Information and Security Act of 2007 (particularly the lighting standards)
- Appliance and equipment standards already on the books
- Trends in customer purchases of energy efficient equipment outside of utility programs
- Existing state and local building, appliance and equipment standards
- The impact of energy efficiency programs adopted prior to 2008

This forecast does not include the expected savings from future Federal and State appliance and equipment standards and building codes. Finally, the forecast assumes the AEO 2008 price forecast, which is relatively flat in real terms over the forecast horizon. Figure 2 presents the forecasts by sector.

Summer peak demand is expected to increase from 781 GW in 2008 to 1,211 GW in 2030, an increase of 55%. The high growth reflects the growth in the warmer climates and the increasing saturation of air conditioner across all climates. The forecast does not include any expected impacts from demand response programs beyond what is in place in 2007.

Figure 2. U.S. Electricity and Summer Peak Demand Forecast by Sector



Source: Electric Power Research Institute et al. (2008) – preliminary estimates June 2008

Table 1. Summary of Energy Efficiency Measures

Residential	Commercial
High-efficiency AC (central, room, heat pump)	High-efficiency cooling equipment
High-efficiency space heating (heat pumps)	High-eff. space heating equipment (heat pumps)
High-eff water heat (incl. heat pump water heat & solar)	High-eff. water heating equipment
High-eff appliances (refrig, freez, washers, dryers)	High-eff. refrigeration equipment & controls
Efficient lighting (CFL, LED, linear fluorescent)	Efficient lighting (interior and exterior)
Efficient power supplies for IT and electronics	Lighting controls (occ sensors, daylighting, etc.)
AC maintenance	Efficient power supplies for IT and electronics
Duct repair and insulation	Water temperature reset
Infiltration control	Efficient air handling and pumps
Whole-house and ceiling fans	Economizers and Energy management systems
Reflective roof, storm doors, external shades	Programmable thermostat
Roof, wall and foundation insulation	Duct insulation
High efficiency windows	**Industrial**
Faucet aerators and low-flow showerheads	Process improvements
Pipe insulation	High-efficiency motors
Programmable thermostat	High-efficiency HVAC
In-home energy displays	Efficient lighting

The Potential for Electricity Savings from Utility Programs

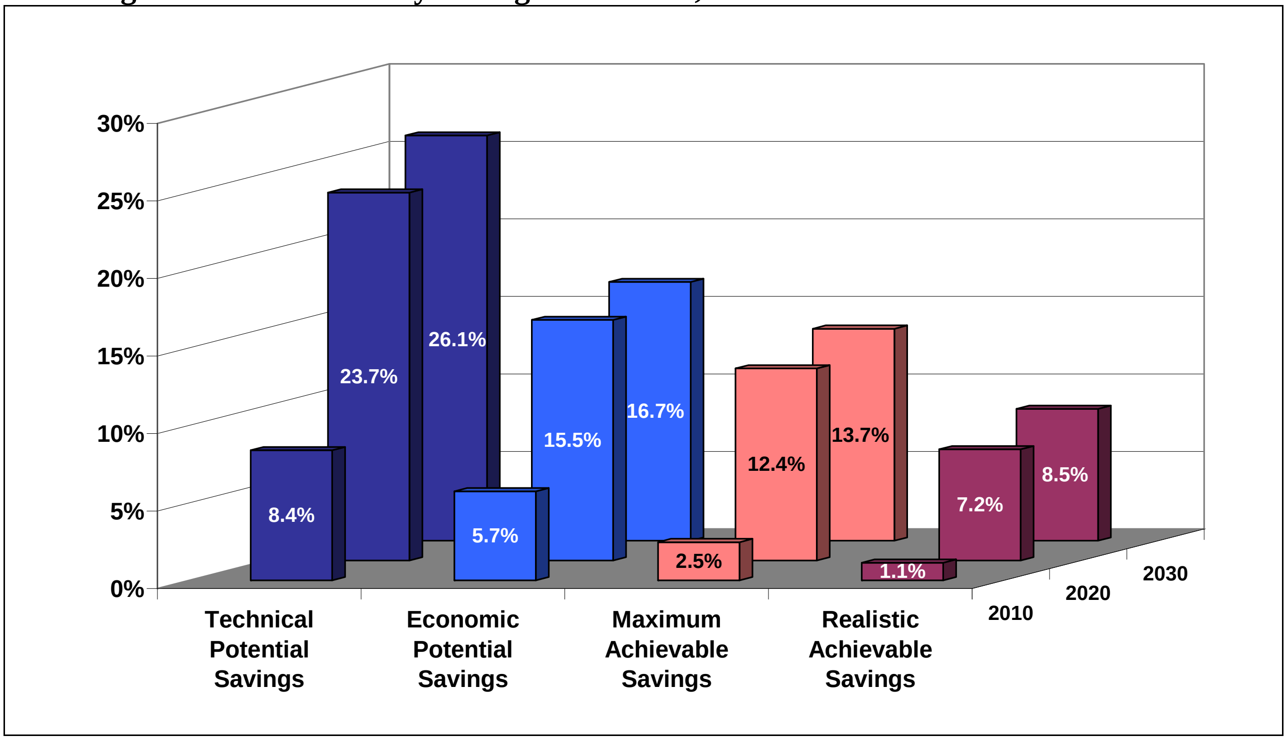
The analysis of potential savings from utility programs begins with a list of energy efficiency measures that includes high-efficiency appliances and equipment for most end uses, many of which have numerous efficiency levels, devices, controls, maintenance actions, and enabling technologies (such as programmable thermostats). Table 1 summarizes the energy-efficiency measures included in the analysis.

As described above, the full set of measures is included in the estimation of technical potential, while only the subset that passes an economic screen is included in economic and achievable potential. Energy-efficiency potential estimates for the U.S. in 2030 are:

- Technical potential is 1,269 TWh, which represents 26% of total load.
- Economic potential is 810 TWh, or 17% of total load.
- Maximum achievable potential is 664 TWh, or 14% of total load.
- The range for realistic achievable potential is 215 to 545 TWh, or 4.4-11.2% of total load. The reference RAP is 8.5% of total load.

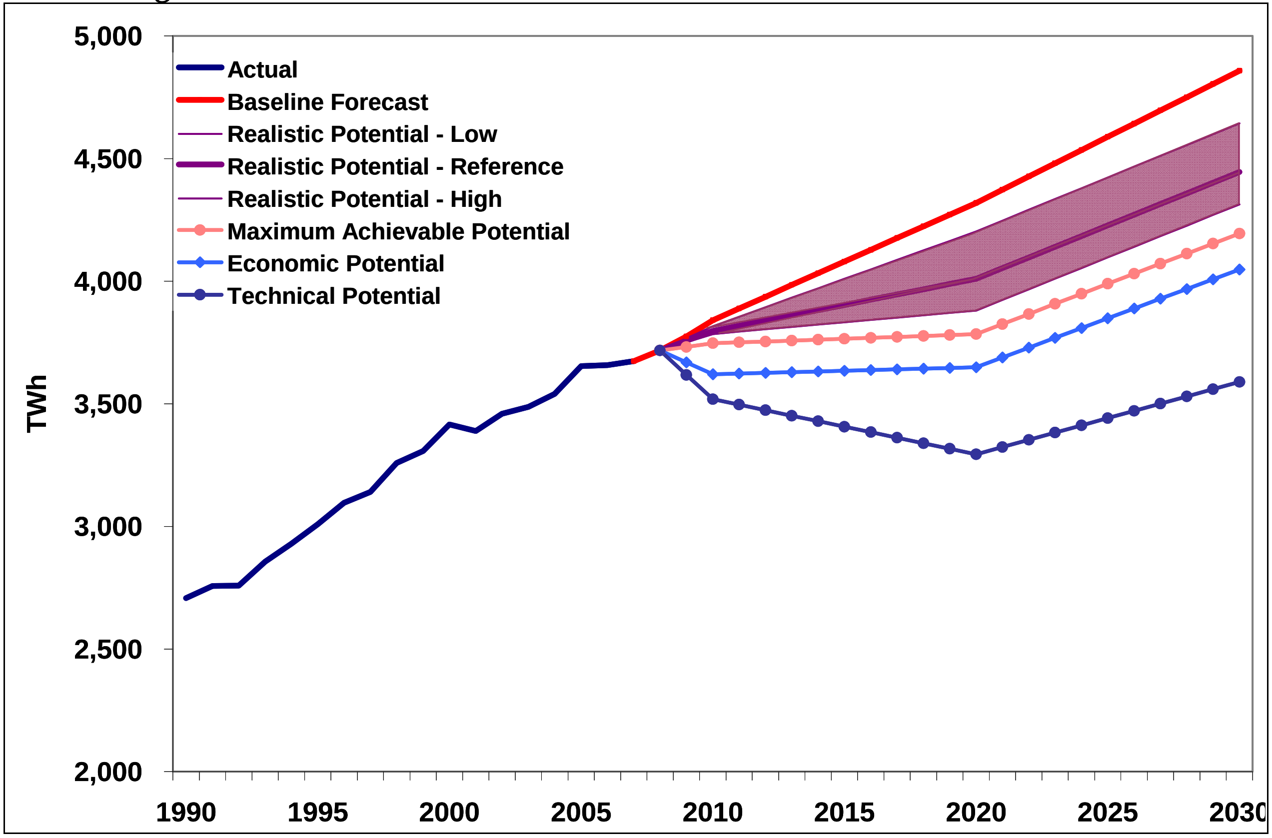
Figure 3 illustrates the savings for technical potential, economic potential, maximum achievable potential, and reference realistic achievable potential in the years 2010, 2020, and 2030. These savings represent the total, cumulative GWh that would be saved by the installation of energy efficiency measures.

Figure 3. U.S. Electricity Savings: Technical, Economic and Achievable Potential



Source: Electric Power Research Institute et al. (2008) – preliminary estimates June 2008

Figure 4. The Potentials Estimates in the Context of the Baseline Forecast



Source: Electric Power Research Institute et al. (2008) – preliminary estimates June 2008

Figure 4 presents the potential savings in the context of the baseline forecast. It also shows the range of realistic achievable potential. RAP is expected to offset between one-fifth and one-half of load growth between 2008 and 2030.

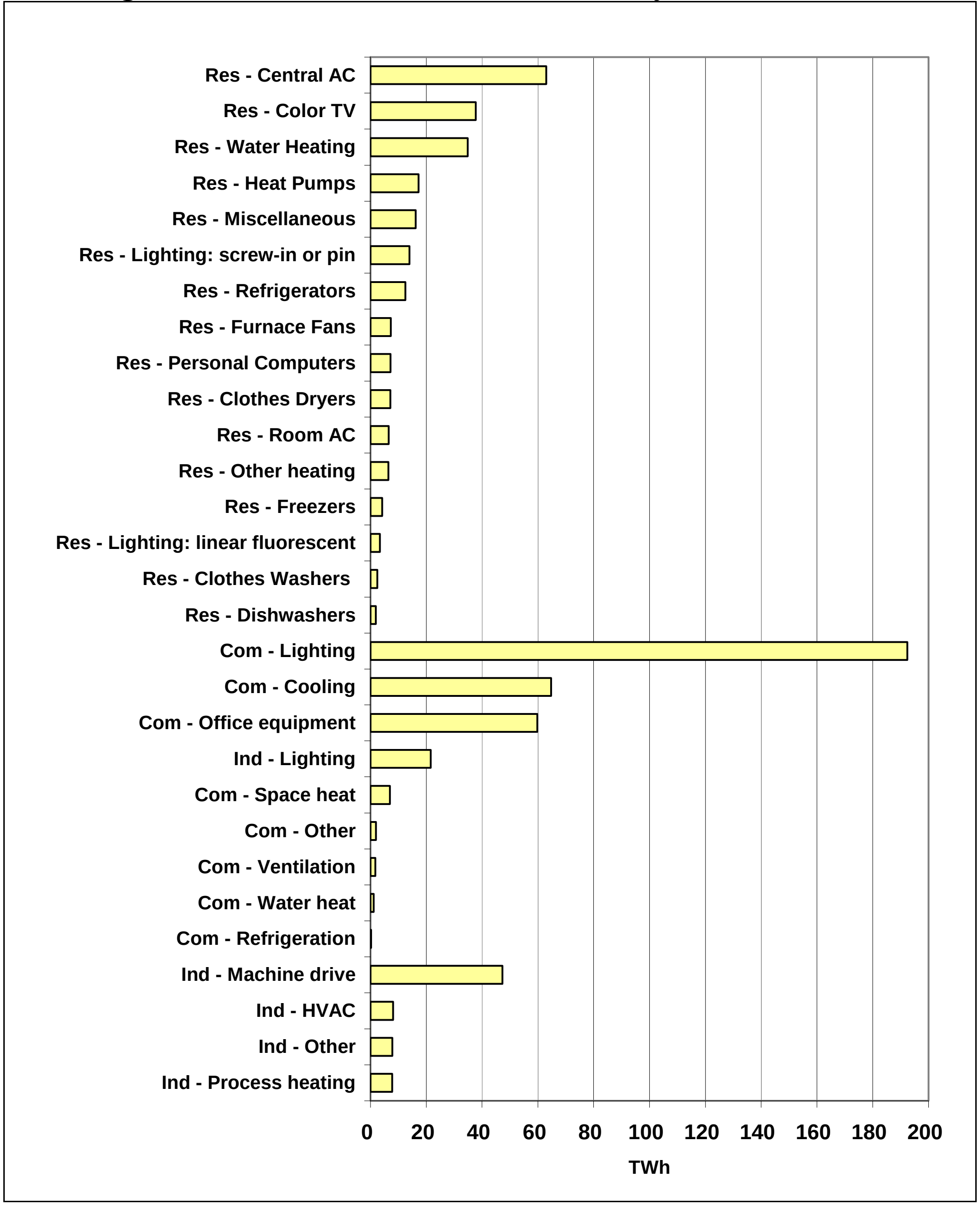
Where do the savings come from? Figure 5 presents the estimates of maximum technical potential for 2030 by sector and end use for existing homes and buildings and new construction combined.

- Upgrading commercial lighting equipment, in addition to daylighting controls, occupancy sensors, and task lighting, account for the largest savings. What's interesting about this result is that it contradicts a widespread belief that the opportunities for reducing commercial-sector lighting use have been exhausted. That is, the "low-hanging fruit" has already been picked. While this may be true in some areas, it is clearly not the case for the U.S. as a whole.
- Cooling in the commercial sector and air conditioning in the residential sector are also major contributors, in spite of appliance and equipment standards.
- Efficiency savings from computers, other office equipment, and electronics are substantial. Utilities can achieve these savings by educating customers and/or providing incentives for the purchase of Energy Star-rated equipment.
- The numerous residential appliances, from water heaters to freezers, also contribute to savings, even in light of past and future Federal appliance standards.

- The opportunity for electricity savings in the industrial sector is dominated by motors, again in spite of long-standing efficiency standards.

In the last six months (since late 2007), the end-use potential has changed. Before the passage of EISA and the revised forecast of economic growth, the second largest impact came from residential lighting. In an earlier set of estimates, residential screw-in or pin lighting contributed almost 90 TWh to the total savings in 2030. Now that figure is less than 20 TWh. On the flip side, new EE measures (such as in-home display devices) are being incorporated into potential studies.

Figure 5: Maximum Achievable Potential by End Use in 2030



Source: Electric Power Research Institute et al. (2008) – preliminary estimates June 2008

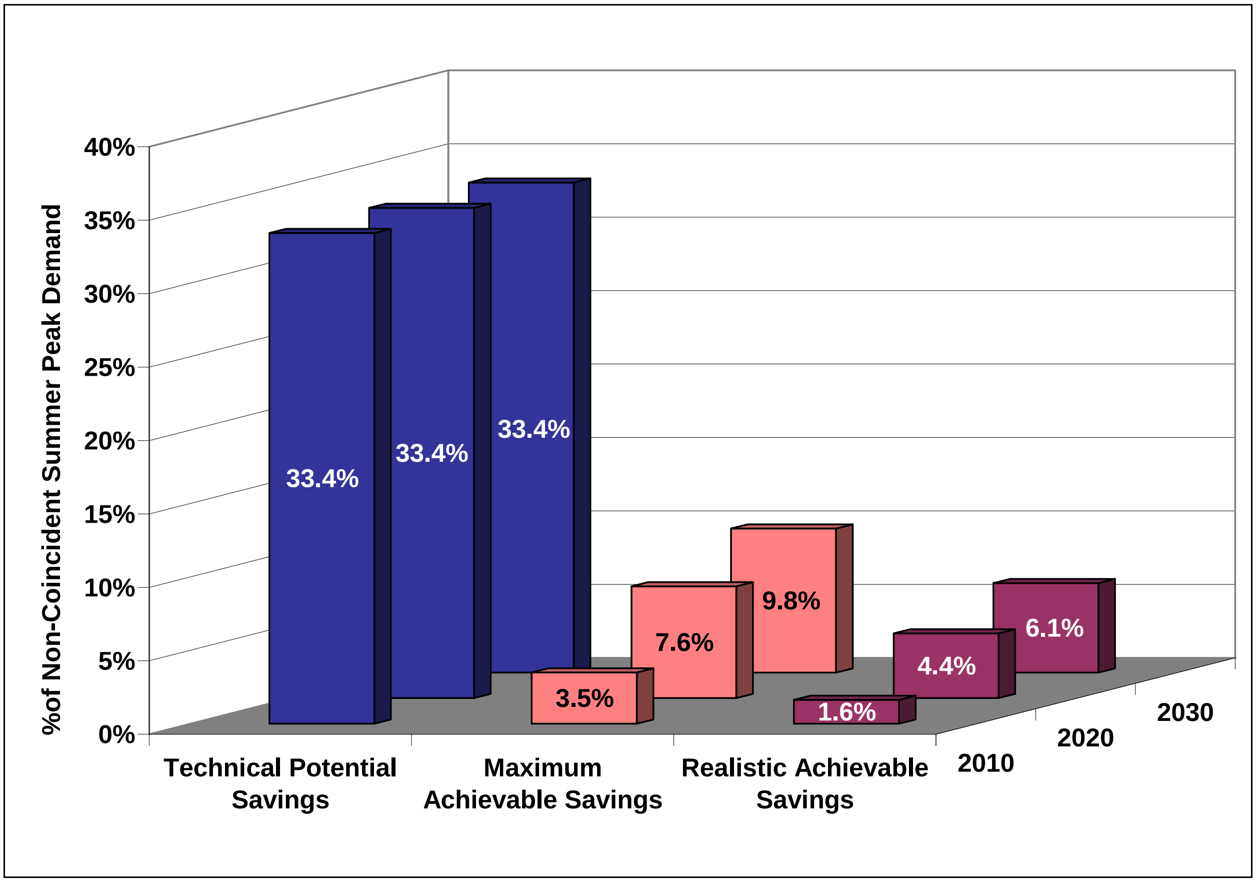
The Potential for Electricity Savings from Utility Programs

Two types of summer peak demand savings are assessed in this study. First, analysis of the measures in Table 1 results in summer peak savings, in addition to energy savings. Second, utility demand response programs result in additional savings. Demand response programs considered in the analysis include the following:

- Residential sector: direct load control for air conditioning, direct load control for water heating, and dynamic pricing programs (time-of-use, critical-peak pricing, real-time pricing, and peak time rebates)
- Commercial sector: direct control load management for cooling, lighting, and other uses; interruptible demand (e.g., interruptible, demand bidding, emergency, ancillary services); and dynamic pricing programs (TOU, CPP, RTP)
- Industrial sector: direct control load management for process; interruptible demand (e.g., interruptible, demand bidding, emergency, ancillary services); and dynamic pricing programs (TOU, CPP, RTP)

Figure 6 shows the results for technical and achievable potential for the U.S. from demand response programs.

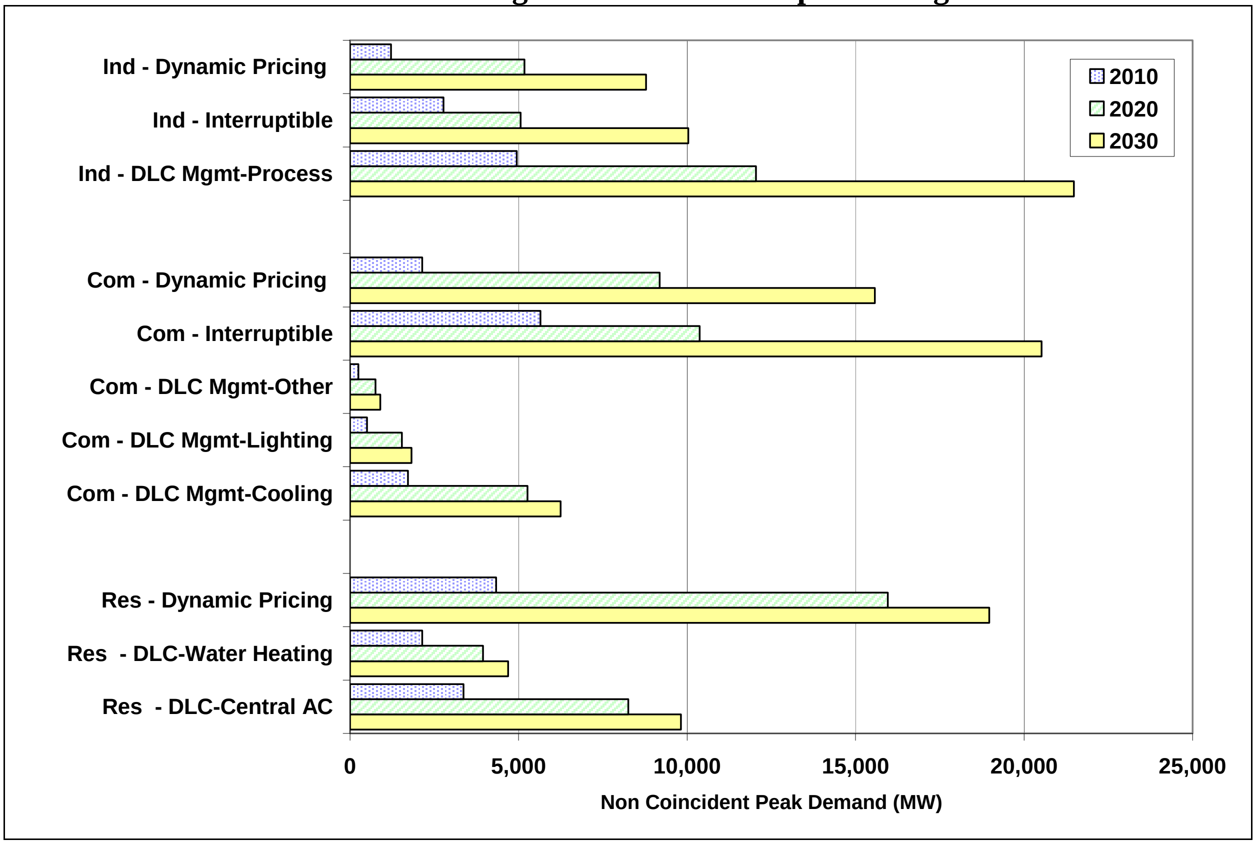
Figure 6. Demand Response: Technical Potential, Economic Potential and Maximum Achievable Potential for the U.S.



Source: Electric Power Research Institute et al. (2008) – preliminary estimates June 2008

The expected savings from demand-response measures are spread roughly equal across the three sectors. The three categories of measures, direct load control, dynamic pricing, and interruptible demand, each deliver roughly the same level of savings. Figure 7 presents realistically achievable potential by sector and program type.

Figure 7. Realistic Achievable Potential for U.S. Summer Peak Demand Savings from Demand Response Programs



Source: Electric Power Research Institute et al. (2008) – preliminary estimates June 2008

Coincidentally, the summer peak demand savings from energy efficiency measures are similar to the savings from demand response, particularly further into the future as cooling equipment turns over. Table 2 presents the range of realistically achievable summer peak demand savings from demand response and energy-efficiency measures individually and combined. Because there is the potential for double counting, we applied the savings from energy-efficiency measures first and then estimated demand response savings. This loading order is consistent with the approach taken in California.

Table 2. Realistic Achievable Peak Demand Savings (GW) from Demand Response and Energy Efficiency Measures

	Energy Efficiency	Demand Response	Total
2010	6.3–8.4 (0.8–1.0%)	12.7–13.9 (1.5–1.7%)	19–22 (2.3–2.7%)
2020	38–80 (3.7–8.0%)	43–47 (4.2–4.6%)	80–128 (7.9–12.6%)
2030	74–124 (6.1–10.2%)	70–77 (5.8–6.3%)	144–201 (11.9–16.6%)

Summary and Conclusions

The potential for electricity and summer peak demand savings from energy efficiency and demand response programs is significant. Across the U.S., the electricity industry can realistically expect to offset 37% of electricity load growth and 40% of summer peak demand growth between 2008 and 2030. Stated differently, the expected savings from energy efficiency programs in 2030 is 8.5% of total electricity load and the expected savings from energy efficiency and demand response programs in 2030 is 14% of non coincident summer peak demand. These savings are in addition to what will be achieved through market-driven efficiency appliance/equipment standards, building codes, and energy legislation.

Comparison with Actual Program Results

How do these estimates compare with recent program results for the nation? To address this question, we analyzed data available in EIA Form 861, which suggests that U.S. utilities have achieved cumulative savings of 74 TWh from 1995 to 2006. More than half these savings come from the West Census region, primarily from California. A comparable time frame from the EPRI/EEI study is 2008 to 2020, which has a RAP estimate of 309 TWh. Clearly, the expected savings exceed what has been reported for 1996 to 2006. However, the electricity industry is dramatically different today and it is reasonable to project higher expected savings. Our forthcoming regional analysis will be helpful to understanding this.

Lessons Learned

Conducting a potential study at the national or regional level is somewhat different from conducting a utility or state-level study. However, there are some elements in common:

- **Base-year energy profiles are critical**. It is very important to develop and maintain the best possible profiles of how customers use energy on an annual basis and during peak days (if not the full 8,760 hours). During restructuring, the industry went away from primary market research and many utilities are now starting over with market surveys and load research. Energy efficiency and demand response are stories best told at the end-use and customer-segment levels and they require underlying data.
- **The baseline forecast by end use and sector is desirable** (perhaps even necessary). The baseline forecast provides the context for possible program savings. It should incorporate, if not explicitly analyze, the impacts of all efficiency drivers, except utility programs.
- **Be ready to deal with change**. The electricity industry is more dynamic than ever right now. That means that the results from a potential study may be obsolete shortly after the final report is completed. For example, during the first eight months of the study, we had to deal with two revisions to the baseline forecast (AEO 2007, Early Release AEO 2008, and Revised Early Release AEO 2008) and the passage of the EISA of 2007. The EISA includes a standard for incandescent lamps that shifted about 70 TWh away from program savings from residential lighting into the baseline forecast. It is imperative that these types of studies produce not only a static snapshot that may become a plan, but that they also result in a process that can address these types of changes in near-real time. Also, the report should carefully document the details of the analysis so that readers

understand the key assumptions about energy prices, market shares, technology profiles, and codes and standards.

Finalizing the EPRI/EEI Study

In June and July 2008, the results from the EPRI/EEI study will be finalized. They will also be reviewed by a distinguished group of 100 reviewers from across the industry representing utilities and various agencies. The final study results will be presented at the August 2008 ACEEE Summer Study conference and they will include estimates for the U.S., four Census regions, and three scenarios.

References

Electric Power Research Institute and Edison Electric Institute. 2008. *U.S. Potential for Energy Efficiency and Demand Response in a Carbon-Constrained Future*. Palo Alto, CA: Electric Power Research Institute. Forthcoming.

Electric Power Research Institute. 2008. *DSM Guidebook*. Palo Alto, CA: Electric Power Research Institute. Forthcoming.

Energy Information Administration. 2008. *2008 Annual Energy Outlook (Revised Early Release)*. Washington, D.C.: Energy Information Administration.

National Action Plan for Energy Efficiency. 2006. *National Action Plan for Energy Efficiency*. Washington, D.C.: U.S. Department of Energy and the U.S. Environmental Protection Agency.

National Action Plan for Energy Efficiency. 2007. *Guide for Conducting Energy Efficiency Potential Studies*. Washington, D.C.: U.S. Department of Energy and the U.S. Environmental Protection Agency.

North American Electric Reliability Corporation, *2005 NERC Peak Demand and Energy Projection Bandwidths — 2005-2014 Regional and National.* Princeton, NJ: North American Electric Reliability Corporation.