

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

## Executive Summary





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# Citations

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# Executive Summary

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This document highlights the results of EPRI technical report (*Assessment of Achievable Potential from Energy Efficiency and Demand Response Programs in the U.S.: 2010 – 2030*. 1016987) that assesses the achievable potential for energy efficiency and demand response programs to reduce the growth rate in electricity consumption and peak demand through 2030. This “achievable potential” represents an estimated range of savings attainable through programs that encourage the adoption of energy-efficient technologies, taking into consideration technical, economic, and market constraints. This potential does not include the impact of future codes and standards not yet enacted, or any other regulatory or policy changes (such as carbon legislation); that may contribute to even greater levels of savings.

Also highlighted are the estimated program costs associated with attaining the achievable potential reductions in electricity consumption and peak demand. The report summarized here is the first of a series of studies planned by EPRI to assess energy efficiency potential under a variety of scenarios.

## Electricity Consumption

Electricity consumption in the U.S. residential, commercial, and industrial sectors has grown at an average rate of 1.7% per year from 1996 through 2006. The U.S. Energy Information Administration (EIA) in its 2008 Annual Energy Outlook Reference Case forecast (AEO 2008) projects that electricity consumption in the residential, commercial and industrial sectors will grow at an annual rate of 1.07% from 2008 through 2030, with consumption increasing by 26%, to 4,696 terawatt-hours (TWh) in that period. AEO 2008 is predicated on a relatively flat electricity price forecast in real dollars through 2030. The forecast accounts for the impacts of currently legislated building codes and appliance standards (including those in the Energy Independence and Security Act of 2007) as well as market-driven trends towards efficiency. It also assumes continued contributions of utility- and government-sponsored energy efficiency programs established prior to 2008.<sup>1</sup>

Going forward, EPRI estimates that energy efficiency programs have the potential to realistically reduce this growth rate by 22% to 0.83% per year from 2008 through 2030. Under conditions ideally conducive to energy efficiency programs, this growth rate can be reduced by up to 36% to 0.68% per year. In 2030, this represents an achievable reduction in electricity consumption of between 236 billion and 382 billion kilowatt-hours (kWh) from the AEO 2008 forecast. This corresponds to a realistic achievable potential of 5% to a maximum achievable potential of 8% in 2030.<sup>2</sup>

## Peak Demand

Summer peak demand in the U.S., aggregated from non-coincident regional peaks, is estimated as 801 GW in 2008, and is expected to increase to 1,117 GW by 2030, an increase of 39%. Summer peak demand is expected to grow at a faster annual rate than electricity use due primarily to the expected growth in the share of air conditioned homes and buildings.

EPRI estimates that the combination of demand response and energy efficiency programs has the potential to reduce non-coincident summer peak demand by 157 GW to 218 GW. This represents a range of achievable potential reduction in summer peak demand in 2030 of 14% to 20%. This can also be expressed as a reduction in the forecast growth rate in

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<sup>1</sup> The savings impact of energy efficiency programs “embedded” in the AEO 2008 Reference Case is estimated in Chapter 2 of EPRI report 1016987. Removing this estimate of embedded savings from the AEO 2008 Reference Case results in an adjusted baseline forecast that is higher.

<sup>2</sup> The values for realistic- and maximum- achievable potentials in 2030 measured with respect to the adjusted baseline forecast described in footnote 1 (and detailed in Chapter 3 of EPRI report 1016987) are 398 and 544 billion kWh, respectively, or 8 to 11%. These values represent the total savings impact of energy efficiency programs in 2030 inclusive of savings embedded in the AEO 2008 Reference Case.

peak demand of 46% to 65% through 2030. Half the peak demand savings result from energy efficiency actions and the other half from activities specifically designed to reduce peak demand, referred to as demand response.

Peak demand in the U.S. has grown at an average rate of 2.1% per year from 1996 through 2006, and is projected by the EIA to grow at an annual rate of 1.5% from 2008 through 2030. The combination of energy efficiency and demand response programs has the potential to realistically reduce this growth rate to 0.83% per year. Under conditions ideally conducive to energy efficiency and demand response programs, this growth rate can be reduced to as low as 0.53% per year.

## Comparing estimates with recent program results

Our analysis of energy efficiency potential is based on the turnover of currently installed energy-consuming devices (as well new construction) to efficient technologies commercially available today, and since most devices have a useful life of less than fifteen years, it is instructive to examine the results for the year 2020, by which time the existing stock of most energy-consuming devices has turned over. Over the twelve year period of 2008 through 2020, the achievable potential of energy efficiency programs identified in this study equates to an annual incremental reduction in electricity consumption of 0.40% to 0.85%.per year.

How do these estimates compare with recent program results for the nation? A recent study released by ACEEE has determined that energy efficiency programs operated in 2006 reduced electricity consumption in the U.S. by an average of 0.24% in 2006. This finding underscores that, for the nation as a whole, current energy efficiency program efforts will need to expand by 40% to capture the moderate case (i.e. realistic achievable potential) for savings identified in this study. By the same token, according to the ACEEE study, in 2006 eighteen states attained annual electricity savings from programs within the range of the national achievable potential (i.e. above 0.40%). Of these eighteen states, in fact, three states – Rhode Island, Vermont, and Connecticut – implemented programs in 2006 that reduced electricity consumption that year by more than 1%.

## Defining “Potential”

In this study, EPRI has applied the condition that new technology does not replace existing equipment instantaneously or prematurely, but rather is “phased-in” over time as existing equipment reaches the end of its useful life. The following three categories of potential analyzed in this study all conform to this condition, and may be termed “phase-in” potentials.

- **Technical Potential** represents the savings due to energy efficiency and demand response programs that would result if all homes and businesses adopted the most efficient, commercially available technologies and measures, regardless of cost. Technical Potential provides the broadest and largest definition of savings since it quantifies the savings that would result if all current equipment, processes, and practices in all sectors of the market were replaced at the end of their useful lives by the most efficient available options. Technical Potential does not take into account the cost-effectiveness of the measures.
- **Economic Potential** represents the savings due to programs that would result if all homes and business adopted the most efficient, commercially available, cost-effective measures. It is a subset of the Technical Potential and is quantified only over those measures that pass a widely recognized economic cost-effectiveness screen. The cost-effectiveness screen applied in this study is a variation of the *Participant Test*, which compares the incremental cost to a consumer of an efficient technology relative to its baseline option, and the bill savings expected from that technology over its useful life. Only those technologies for which the net present value of benefits exceeds its incremental cost to consumers pass the test.



- **Achievable potential** refines Economic Potential by taking into account various barriers to customer adoption.
  - **Maximum Achievable Potential (MAP)** takes into account market, societal, and attitudinal barriers that limit customer participation in utility- or government- administered voluntary programs. These barriers reflect, among other phenomena, customers’ resistance to doing more than the absolute minimum required or a dislike of a given efficiency option. MAP presumes no impediments to the effective implementation and delivery of programs, such as perfect information, and essentially extrapolates the impacts of the best run, most effective programs nationally.
  - **Realistic Achievable Potential (RAP)**, discounts MAP by taking into account impediments to program implementation, including financial, political, and regulatory barriers that are likely to limit the amount of savings that might be achieved through energy efficiency and demand response programs. RAP considers recent utility experience and reported savings, and as such represents a forecast of likely customer response to programs.

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

One baseline for this study is the 2008 AEO estimate of 3,717 TWh for U.S. electricity use in 2008, with residential consumption at 38%, commercial at 36%, and industrial at 26%. In both residential and commercial sectors, lighting and cooling are major end uses. Both sectors also have a substantial “other” category which includes various so called “plug loads” (miscellaneous appliances and devices which can be plugged into conventional 120 volt outlets) not classified among the other end uses. Office equipment is a large use in the commercial sector. Machine drives (motors) are the largest electric end use in the industrial sector.

## Energy Efficiency Drivers

The Reference Case forecast includes expected energy efficiency savings from several drivers, including:

- Codes and Standards
  - Federal, state, and local building efficiency codes already enacted
  - Appliance and equipment standards already enacted; this includes the Energy Independence and Security Act of 2007, which, among its features, mandates higher lighting efficiency standards
  - Other possible related effects, including structural changes in the economy that impact overall electric energy intensity
- Market-Driven Efficiency
  - Trends in customer purchases of energy-efficient equipment attributable to market-driven effects outside of utility programs
- Implicit Programs
  - An estimate of the impact of utility- and state agency-administered efficiency programs implemented prior to 2008

This study estimated the aggregate impact of these drivers by developing a “frozen efficiency” case that represents what consumption would be if the electricity energy intensity of the economy (expressed in terms of kWh per dollar of real U.S. GDP) were held fixed at 2008 levels (0.33 kWh/\$GDP). This case, depicted in Figure 1, represents a 2.5% annual growth rate, on par with the historical growth rate of the previous three decades. The difference between the frozen efficiency forecast and the AEO 2008 Reference Case can be considered to be the cumulative impact of market-driven efficiency, efficiency codes and standards, and other effects. (Figure 1).

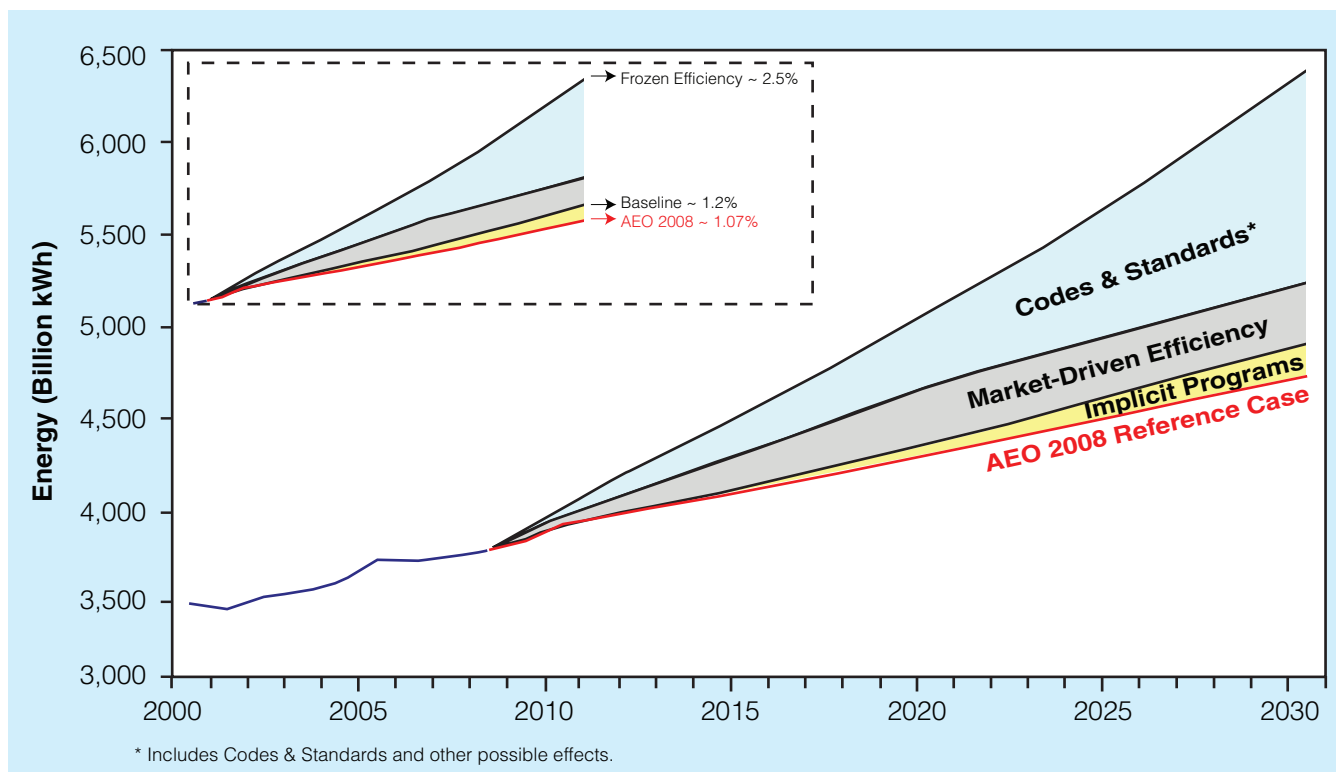


Figure 1  
Estimated Impact of Energy Efficiency Drivers Inherent in AEO 2008 Reference Case

As shown in Figure 1, the estimated impact of energy efficiency programs “embedded” in the AEO 2008 Reference Case was “added back” to construct an adjusted “baseline” forecast, in accordance with standard industry practice. This baseline represents a projection of electricity consumption absent of any assumed impact of energy efficiency programs.

## Potential for Electricity Savings from Utility Programs

Table 1 summarizes measures from utility programs. The full set of measures is included in the estimation of technical potential, while only the subset that passes the economic screen is included in economic and achievable potential.

Table 2 presents energy-efficiency potential estimates for the U.S. in 2030. Relative to the AEO 2008 Reference Case:

Realistic Achievable Potential is 236 TWh, or 5% reduction in projected consumption.

Maximum Achievable Potential is 382 TWh, or 8% reduction in projected consumption.

These estimates suggest that energy efficiency programs can realistically reduce U.S. electricity consumption by 236 TWh in 2030 relative to the AEO 2008 Reference Case. This represents a reduction in the expected annual growth rate over the period 2008 to 2030 by 22%, from 1.07% to 0.83%.

Table 1  
Summary of Energy-Efficiency Measures

Residential Sector Measures	Commercial Sector Measures
Efficient air conditioning (central, room, heat pump)	Efficient cooling equipment (chillers, central AC)
Efficient space heating (heat pumps)	Efficient space heating equipment (heat pumps)
Efficient water heating (e.g. heat pump water heaters & solar water heating)	Efficient water heating equipment
Efficient appliances (refrigerators, freezers, washers, dryers)	Efficient refrigeration equipment & controls
Efficient lighting (CFL, LED, linear fluorescent)	Efficient lighting (interior and exterior)
Efficient power supplies for Information Technology and consumer electronic appliances	Lighting controls (occupancy sensors, daylighting, etc.)
Air conditioning maintenance	Efficient power supplies for Information Technology and electronic office equipment
Duct repair and insulation	Water temperature reset
Infiltration control	Efficient air handling and pumps
Whole-house and ceiling fans	Economizers and energy management systems (EMS)
Reflective roof, storm doors, external shades	Programmable thermostats
Roof, wall and foundation insulation	Duct insulation
High-efficiency windows	Industrial Sector Measures
Faucet aerators and low-flow showerheads	Process improvements
Pipe insulation	High-efficiency motors
Programmable thermostats	High-efficiency heating, Ventilation and air conditioning (HVAC)
In-home energy displays	Efficient lighting

Table 2  
Energy Efficiency Potential for the U.S.

Year	AEO 2008 Reference Case	Baseline Forecast	Realistic Achievable Potential	Maximum Achievable Potential
Forecasts (billion kWh)				
2020	4,253	4,319	4,112	3,881
2030	4,696	4,858	4,460	4,314
Savings Relative to AEO 2008 Reference Case (billion kWh)				
2020			141	372
2030			236	382
Savings Relative to Baseline Forecast (billion kWh)				
2020			207	438
2030			398	544

## What is realistically achievable?

Figure 2 (below) illustrates realistic achievable savings by sector and end use. Two broad categories of opportunity include: the following:

- End uses with a track record in energy efficiency, including commercial lighting, industrial motors, and residential cooling fall into this category.
- The expanding importance of consumer electronics and computing equipment as a component of utility loads.

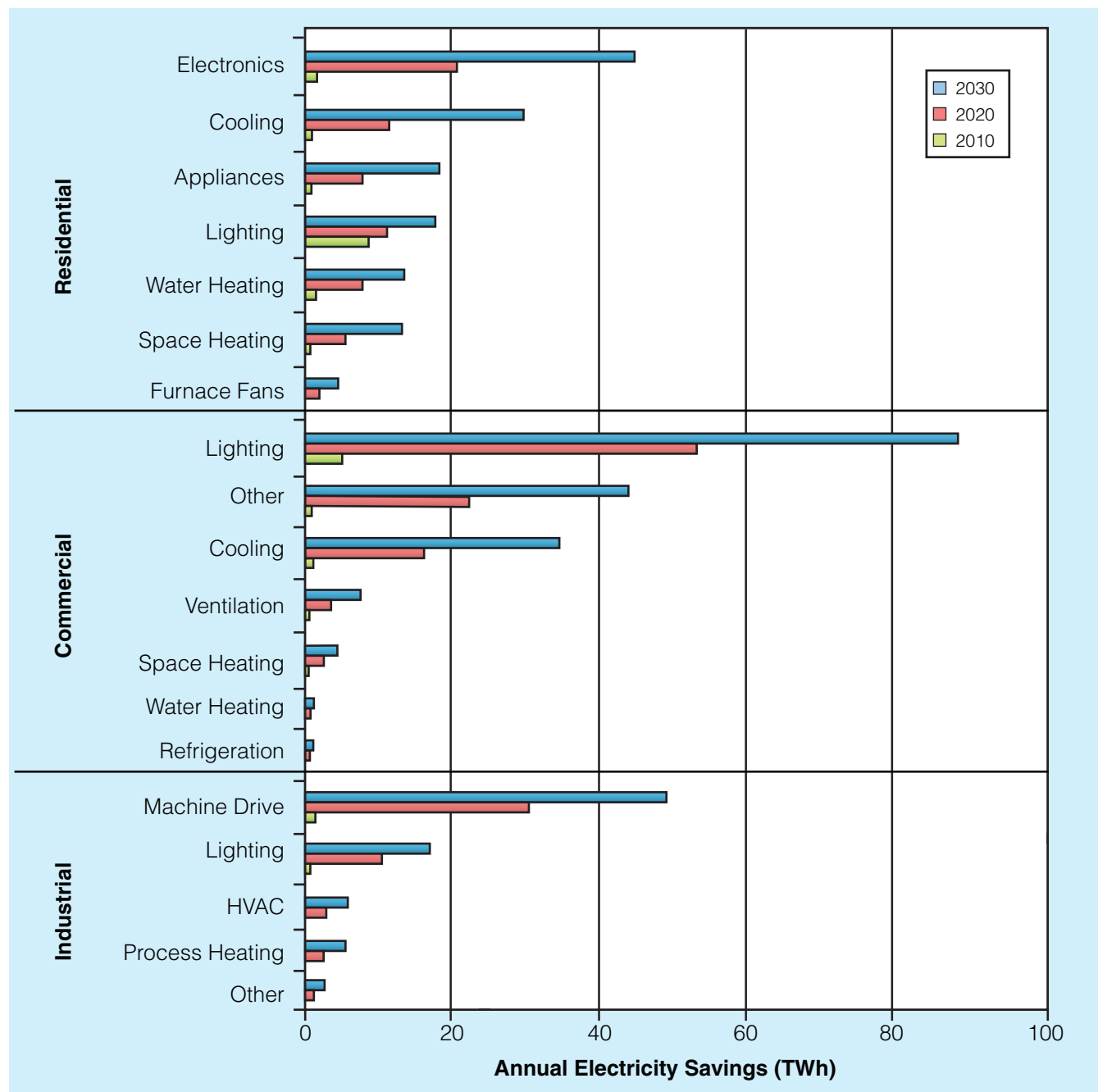


Figure 2  
Realistic Achievable Potential by End-Use (Relative to Baseline)

## Realistic achievable potential by regions and end use

A variety of factors influence achievable potential in the four U.S. Census regions, including end use patterns and legacy of energy efficiency programs. Here's how the regions compare:

- **South:** Highest electricity consumption, expected to grow at an annual rate of 1.4% per year through 2030. Greatest potential for energy efficiency in absolute terms.
- **Northeast:** Lowest consumption, projected to grow at an annual rate of 0.90% through 2030. Least potential of the four regions but ranks second in share of total load.
- **Midwest:** Second largest current and forecast consumption, but lowest projected annual growth rate of 0.7%
- **West:** Highest forecast growth rate at 1.6% per year and has the largest potential in percentage terms.

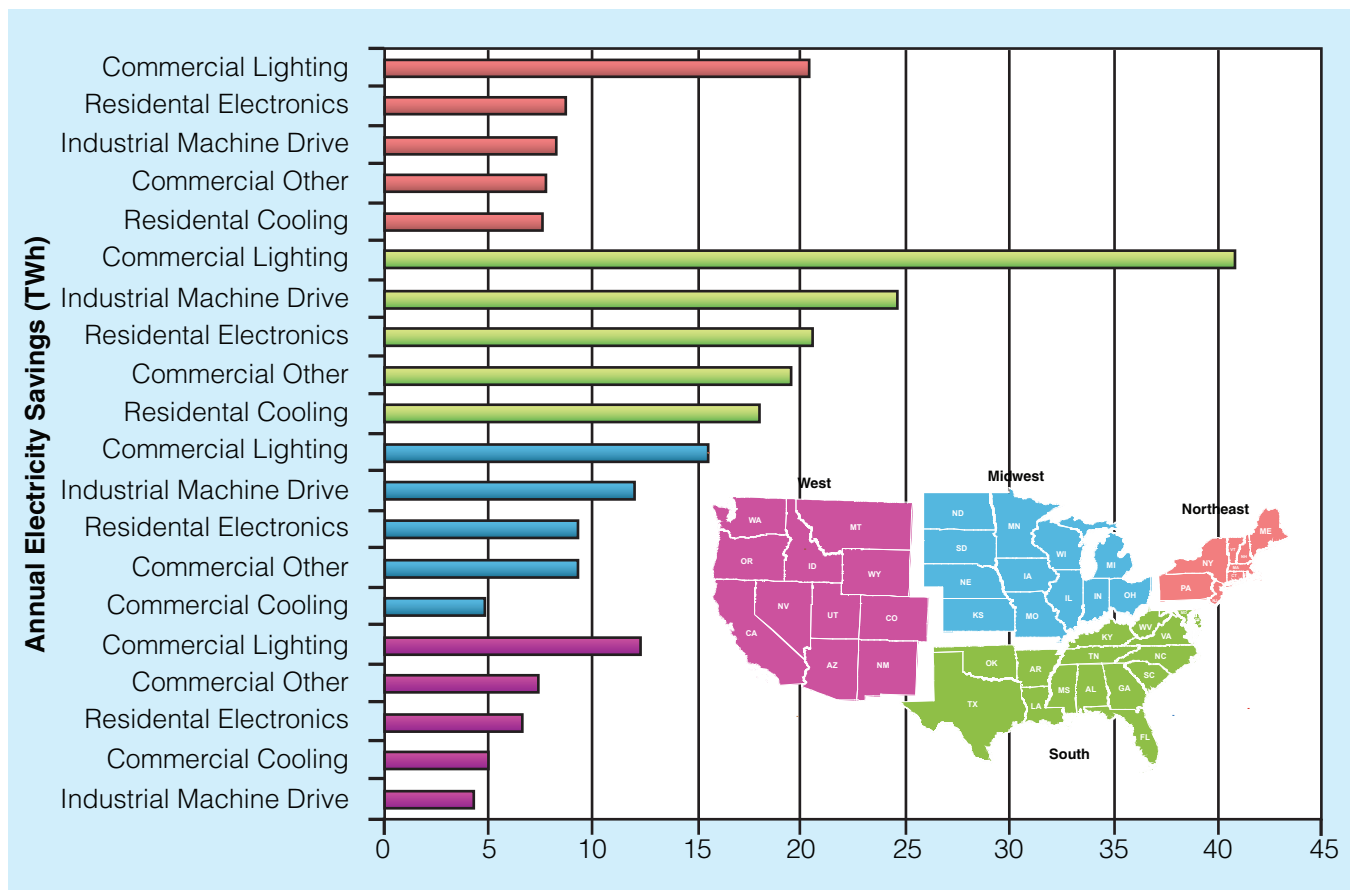


Figure 3  
Realistic Achievable Potential (billion kWh) by Region and End Use in 2030 (Relative to Baseline)

## Potential for Summer Peak Demand Savings from Utility Programs

In addition to the impacts on annual electricity use, the study assessed two types of summer peak demand savings. First, energy efficiency measures inherently reduce summer peak demand insofar as their usage is coincident to the overall summer peak. Second, utility demand response programs specifically targeted at peak demand reduction result in additional savings. Together, energy efficiency and demand response contribute to an achievable peak demand reduction potential of 157 to 218 GW in 2030, or 14 to 20% of projected U.S. summer peak demand in 2030.<sup>3</sup>

Table 3  
Potential for U.S. Summer Peak Demand Savings (GW)

<b>Realistic Achievable Potential</b>	<b>2010</b>	<b>2020</b>	<b>2030</b>
Energy Efficiency	1.6	34.8	78.5
Demand Response	16.6	44.4	78.4
<b>Total</b>	<b>18.2</b>	<b>79.2</b>	<b>156.9</b>
<b>Maximum Achievable Potential</b>	<b>2010</b>	<b>2020</b>	<b>2030</b>
Energy Efficiency	10.8	81.7	117.0
Demand Response	29.8	65.9	101.1
<b>Total</b>	<b>40.6</b>	<b>147.6</b>	<b>218.1</b>

Table 4  
Potential for Summer Peak Demand Savings from Energy Efficiency and Demand Response

<b>Summer Peak Demand Savings</b>	<b>2010 (%)</b>	<b>2020 (%)</b>	<b>2030 (%)</b>
Realistic Achievable Potential (RAP)	2.2	8.2	14.0
Maximum Achievable Potential (MAP)	4.9	15.3	19.5

Demand response programs considered in the analysis include the following:

- **Residential sector:** direct load control (DLC) for air conditioning, direct load control for water heating, and dynamic pricing programs, including time-of-use (TOU), critical-peak pricing (CPP), real-time pricing (RTP), 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)

According to this analysis, the range of achievable potential for demand response programs in 2030 is 7% to 9% of peak demand. The expected savings from demand response measures are roughly equal across the three sectors. Direct load control, dynamic pricing, and interruptible demand, each deliver roughly the same level of savings. Tables 5 and 6 present the contributions of major types of demand response programs to peak demand reduction for realistic and maximum achievable potentials, respectively.

<sup>3</sup> U.S. summer peak demand in this study represents an aggregation of "non-coincident" summer peak demand of each U.S. census region.

Table 5

Summer Peak Demand Savings from Demand Response – Realistic Achievable Potential (MW)

<b>Residential DR</b>	<b>2010</b>	<b>2020</b>	<b>2030</b>
DLC – Central AC	3,128	8,194	11,742
DLC – Water Heating	1,431	2,868	3,931
Price Response	1,539	6,918	10,967
<b>Commercial DR</b>	<b>2010</b>	<b>2020</b>	<b>2030</b>
DLC – Cooling	1,336	3,833	4,822
DLC – Lighting	364	1,049	1,358
DLC – Other	256	824	1,159
Interruptible Demand	4,337	8,806	19,450
Price Response	771	4,018	8,368
<b>Industrial DR</b>	<b>2010</b>	<b>2020</b>	<b>2030</b>
DLC – Process	413	1,124	2,245
Interruptible Demand	2,550	3,973	8,701
Price Response	515	2,765	5,697
<b>TOTAL</b>	<b>16,639</b>	<b>44,372</b>	<b>78,441</b>
<b>Percentage of Peak</b>	<b>2.0%</b>	<b>4.6%</b>	<b>7.0%</b>

Table 6

Summer Peak Demand Savings from Demand Response – Maximum Achievable Potential (MW)

<b>Residential DR</b>	<b>2010</b>	<b>2020</b>	<b>2030</b>
DLC – Central AC	4,119	9,498	12,558
DLC – Water Heating	1,960	3,473	4,503
Price Response	4,318	13,122	16,093
<b>Commercial DR</b>	<b>2010</b>	<b>2020</b>	<b>2030</b>
DLC – Cooling	1,766	4,309	5,099
DLC – Lighting	516	1,377	1,698
DLC – Other	508	1,316	1,623
Interruptible Demand	8,536	13,680	26,410
Price Response	2,180	7,600	12,418
<b>Industrial DR</b>	<b>2010</b>	<b>2020</b>	<b>2030</b>
DLC – Process	824	1,826	3,129
Interruptible Demand	3,572	4,554	9,142
Price Response	1,451	5,154	8,422
<b>TOTAL</b>	<b>29,750</b>	<b>65,910</b>	<b>101,093</b>
<b>Percentage of Peak</b>	<b>3.6%</b>	<b>6.8%</b>	<b>9.1%</b>

Figure 4 illustrates the realistic achievable potential of demand response for peak demand reduction by sector and program type.

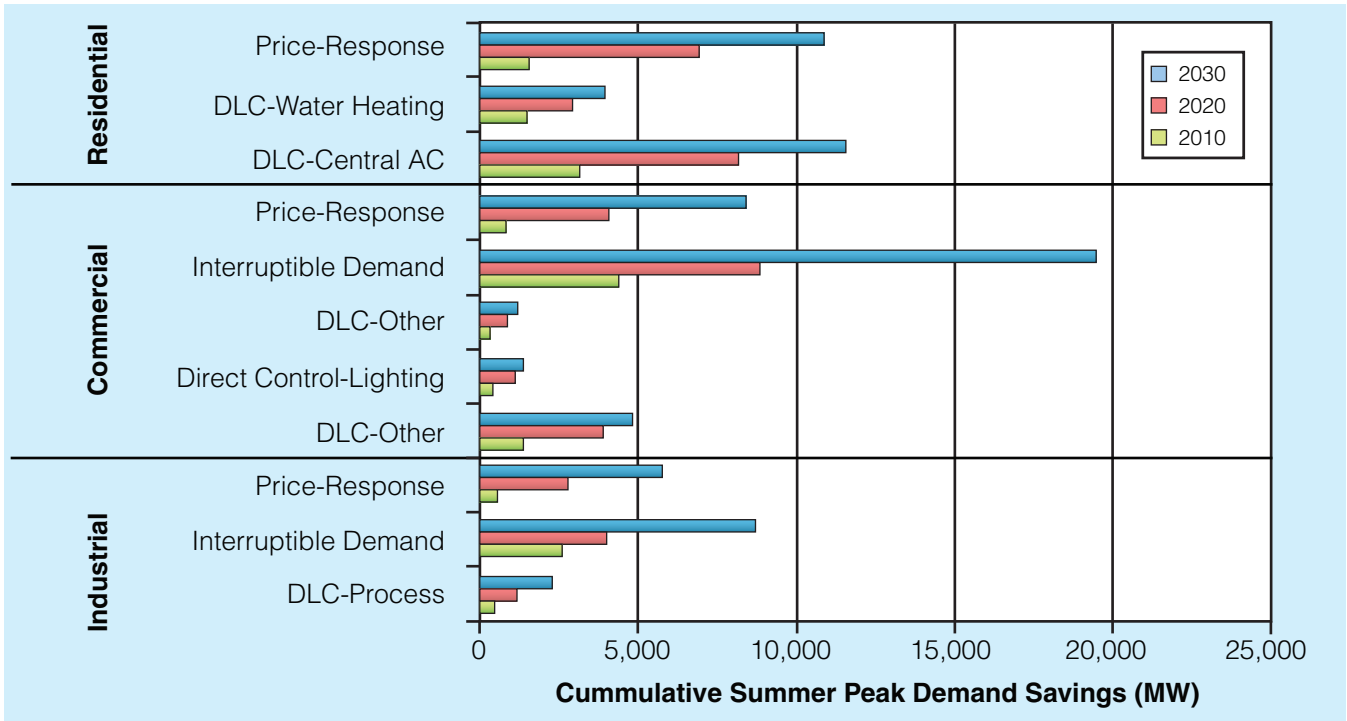


Figure 4  
Realistic Achievable Potential for U.S. from Demand Response

### The Cost of Achievable Potential

Achieving savings in electricity consumption and peak demand will require significant industry investment in energy efficiency and demand response programs. The total resource cost of achievable potential, inclusive of technologies or measures and the administration costs necessary for utilities or third-party entities to deliver that potential, was estimated based on published energy efficiency program cost data and program experiences.<sup>4</sup>

Table 7 summarizes, and Figure 5 illustrates, the estimated cost range to implement energy efficiency and demand response programs to realize the achievable potential.

Table 7  
Estimated Cost Range of Achievable Potential

Achievable Potential	2010 (\$ Billion)	2020 (\$ Billion)	2030 (\$ Billion)
Realistic (RAP)	1 – 2	8 – 20	19 – 47
Maximum (MAP)	3 – 7	16 – 41	25 – 63

<sup>4</sup> A key reference for this cost estimate analysis was: Gellings C., G. Wikler, and D. Ghosh. "Assessment of U.S. Electric End-Use Energy Efficiency Potential." The Electricity Journal, Volume 19, Issue 9. November 2006.



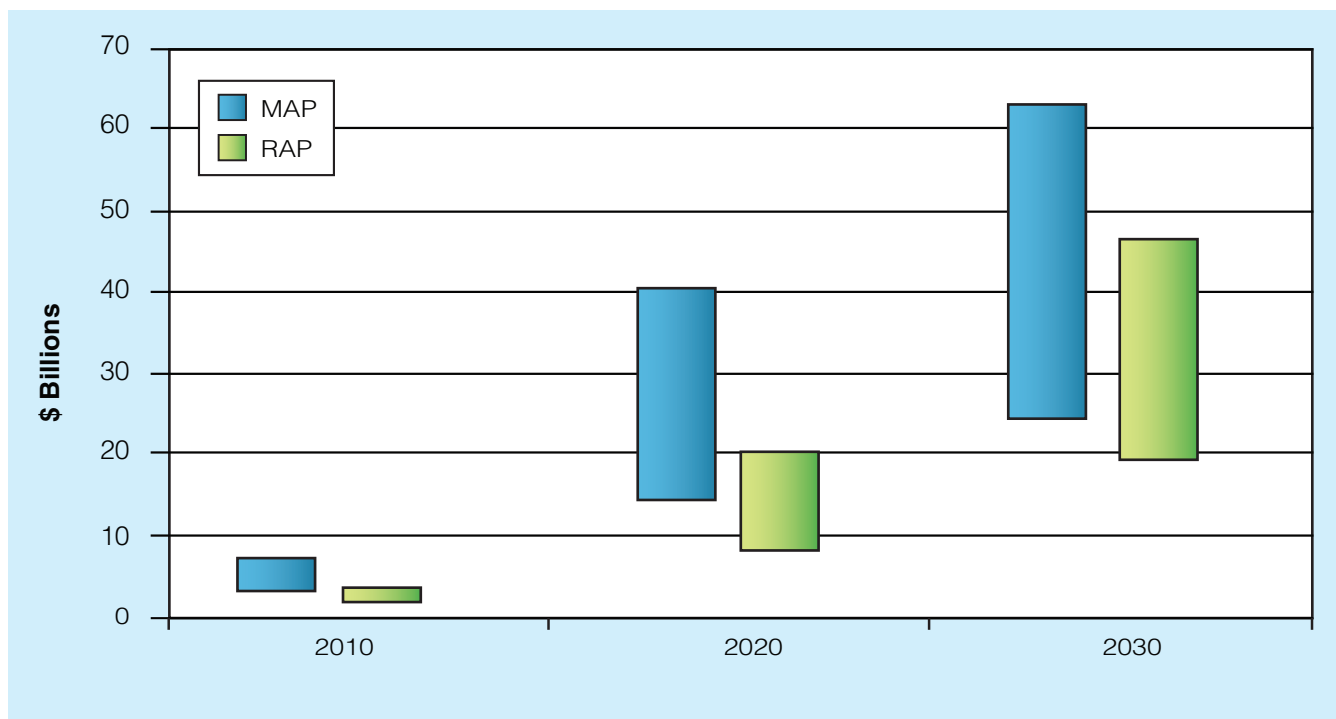


Figure 5  
Estimated Cost of Achievable Potential for Energy Efficiency and Demand Response Programs

## About the Study – Objectives and Methods

The objective of this study is to provide an independent, technically-grounded estimate of the potential for electricity energy savings and peak demand reduction from energy efficiency and demand response programs through 2030 that can help inform the decisions of both policy makers and electric utilities. Such estimates are fundamental to informing legislative and regulatory initiatives regarding energy efficiency and utility business models.

This study generally applies a bottom-up methodology based on equipment stock turnover and adoption of energy-efficiency measures at the technology and end-use levels within sectors for the four U.S. census regions. This approach is consistent with studies usually conducted by utilities or states. It differs from most national studies of energy efficiency potential, which employ macro, or “top-down” approaches. These are typically based on large key assumptions, the variations of which bring significant “sensitivities” to bear on final results. The bottom-up approach is grounded in: actual technology efficiencies; costs and assumptions about customer adoption predicated on experience and observation of the range of results realized by program implementers. It also allows investigators to conduct detailed analyses by region, sector, end use and technology, and explain what is assumed to happen in the forecast.

It is worth emphasizing that while other studies co-mingle the effects of existing and anticipated codes and standards (i.e., those not yet legislated) with programmatic effects, this study isolates the impact of programs. Therefore any subsequent codes and standards or other externalities would contribute to greater levels of overall efficiency.

The study began with development of baseline forecasts of electricity consumption and summer peak demand absent any new utility programs or programs administered by state agencies or third parties. The forecasts are consistent with the Energy Information Administration’s “Reference Forecast” for electricity consumption as presented in its 2008 Annual Energy Outlook (AEO) and the North American Electric Reliability Corporation’s (NERC’s) 2007 Peak Demand and

Energy Projection Bandwidths extrapolated to 2030. The study estimates the potential for annual energy efficiency and demand-response savings for 2009 through 2030 at the end-use level for residential, commercial, and industrial sectors. This analysis yields forecasts of changes in electricity use and summer peak demand<sup>1</sup>, as well as changes in annual energy and summer peak-demand savings, for the U.S. and each of its four census regions.

## Analysis Approach

For the residential and commercial sectors, the study implemented a bottom-up approach for determining electric energy efficiency savings potential. This approach begins with a detailed equipment inventory (e.g., the number of refrigerators), the average unit energy consumption (per household or per square foot in the commercial sector), and the diversified load during the non-coincident summer peak. In each sector, annual energy use and peak demand are the product of the number of units and the unit consumption annually, and at peak.

This process is repeated for all devices across vintages and sectors. AEO 2008 provided both the number of units and the unit consumption. Diversified peak-load estimates were also developed as part of the study.

For the industrial sector, the study applied a top-down approach in which the sector forecast is allocated to end uses and regions. The study used a modeling tool for forecasting energy use, peak demand, and energy efficiency and demand response savings, which incorporates a comprehensive technology database that includes the latest findings from EPRI energy efficiency research.<sup>5</sup> Energy efficiency savings potentials are developed by aggregating the impact of discrete technology options within end uses across sectors and regions. This follows industry best practices and has been applied successfully in numerous forecasting and potential studies for utilities.

## Follow-on Research

This study features a forecast for the adoption of energy-efficient technologies currently available in the market through utility or similar programs, taking into consideration technical, economic, and market constraints. This analysis was informed by actual program experiences, results, and best practices. Macro-economic conditions such as economic growth and the price of fuels and electricity were held consistent with the forecasts assumed by the EIA in its AEO 2008 Reference Case forecast, which was released prior to the economic downturn in the fourth quarter of 2008,

There are several factors that could have a significant impact on the potential for energy efficiency savings. These factors include higher electricity prices, regulatory incentives to encourage greater investment in energy efficiency, carbon policy, the future level of codes and standards, and accelerated R&D and commercialization of advanced efficient technologies. This summary does not consider the impact of such factors, nor of a more pessimistic projection of economic growth, which could alter consumer behavior and reduce projected load growth. EPRI plans subsequent studies to further develop and quantify the impact of such factors under multiple scenarios.

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<sup>5</sup> The modeling tool employed was Global Energy Partners' Load Management Analysis and Planning (LoadMAPTM)



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