Recent estimates of energy efficiency potential in the U.S.

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Abstract

Understanding the potential for reducing energy demand through increased end-use energy efficiency can inform energy and climate policy decisions. However, if potential estimates are vastly different, they engender controversial debates, clouding the usefulness of energy efficiency in shaping a clean energy future. A substantive question thus arises: is there a general consensus on the potential estimates? To answer this question, this paper reviews recent studies of U.S. national and regional energy efficiency potential in buildings and industry. Although these studies are based on differing assumptions, methods, and data, they suggest technically possible reductions of ~ 25%–40% in electricity demand and ~ 30% in natural gas demand in 2020, and economic reductions of ~ 10%–25% in electricity demand and ~20% in natural gas demand in 2020. These estimates imply that electricity growth from 2009–2020 ranges from turning U.S. electricity demand growth negative, to reducing it to a growth rate of ~ 0.3% per year (compared to ~ 1% baseline growth).

Keywords: energy efficiency; greenhouse gas mitigation; potential study

1 Introduction

Energy efficiency and sustainable energy technologies are at the center of discussions on climate change. In the U.S., the commercial, residential and industrial sectors account for approximately 50% of U.S. greenhouse gas (GHG) emissions (U.S. Environmental Protection Agency, 2008). Improving the energy efficiency of these sectors is a key component of regional and state climate policies and proposed federal climate legislation. At the US federal level, the American Clean Energy and Security Act of 2009 ("Waxman Markey" bill) implements energy efficiency through a combination of building energy codes, appliance standards, a renewable energy/energy efficiency resource standard, and funding of efficiency programs (Waxman and Markey, 2009). At the state level, the California Global Warming Solutions Act ("AB 32") Scoping Plan requires an additional 10% of energy efficiency savings in 2020 beyond the efficiency savings from existing policies, roughly 1% savings per year. Twenty-four states have also enacted energy efficiency resource standards that require utilities (or other program administrators) to implement programs that deliver ~ 0.5–1% savings per year, up to 2% in outer years (ACEEE 2010).

Besides employment and health benefits, the federal and state legislative actions are driven by recent reports of significant and cost-effective opportunities for increased energy efficiency across the U.S. A case in point is that ~ 50% of the potential GHG emissions reductions measures, specifically the energy efficiency ones, can be had at a negative cost, with energy saving benefits exceeding the energy-efficiency investment costs (McKinsey 2007 and 2009a). This finding has drawn national attention towards energy efficiency.

However, if potential estimates are vastly different, they engender controversial debates, clouding the usefulness of energy efficiency in shaping a clean energy future. Is there general consensus on the potential estimates? To answer this question, this paper reviews four U.S. national and regional energy efficiency potential in buildings and industry that include McKinsey (2007) ("McK07"), McKinsey (2009a) ("McK09"); EPRI (2009) ("EPRI"); and Annual Energy Outlook of Energy Information Administration (2008) ("AEO").

These studies were chosen because they constitute a relatively recent set of public studies of national level energy efficiency potential in the U.S. that utilize a common baseline energy forecast (the Annual Energy Outlook 2008 base case) and estimate savings over a common time frame (2010-2030). By utilizing a common energy forecast, the treatment of existing codes and standards, demand side management programs, and 'natural' adoption of energy efficiency is consistent. The analysis conducted in this article could be repeated with more recent studies. However, the overall goal of this study, to understand if there is consensus on the existence of energy efficiency potential, remains valid with the set of studies evaluated in this analysis.

Although these studies use differing assumptions, methods, and data, they suggest technically possible reductions of ~ 25%–40% in electricity demand and ~ 30% in natural gas demand in 2020, and economic reductions of ~ 10%–25% in electricity demand and ~20% in natural gas demand in 2020. These estimates imply that electricity growth from 2009-2020 ranges from turning U.S. electricity demand growth negative, to reducing it to a growth rate of ~ 0.3% per year (compared to ~ 1% baseline growth). The efficiency potentials constitute ~ 10%-100%+ of the greenhouse gas reduction goals for 2020 as required by the Waxman Markey climate bill.

This paper is related to the literature of the "energy efficiency gap": the observed energy efficiency investment is far below economic energy efficiency potential due to multiple market barriers (Hirst and Brown 1990). Factors contributing to the gap include market barriers that qualify as market failures (e.g., under-pricing of energy below social marginal cost, imperfect information, lack of financing, and tax policies that discourage capital investment) and additional market barriers (e.g., high consumer discount rates, renters lacking investment incentives, and consumer inertia caused by status quo bias) (Brown 2001; Brown and Chandler 2008; Jaffe and Stavins 1994; Jaffe et al. 2004; Sanstad and Howarth 1994; Lutzenhiser 1994; Hassett and Metcalf 1993; Metcalf 1994; Sanstad et al. 1995; Fisher and Rothkopf 1989; Eyre 1998). In particular, our review confirms that the energy efficiency gap is projected to be alive and well, with the potential estimates remaining up to several times what is likely to be realized in the future. The US is taking policy actions to remedy this gap.

2 Description of national studies

2.1 Review of energy efficiency definitions

To provide a methodological context of the studies chosen for our review, this section describes what an energy efficiency analysis is (National Action Plan for Energy Efficiency 2007; Rufo and Coito 2002; Frisch 2008; Gellings et al. 2006). The analysis typically estimates the benefits and costs of energy efficiency "measures", usually to support utility planning or state/federal energy policy. A measure is any action, including equipment upgrades, control strategies or behavioral changes, that increases energy efficiency in a given end-use application. The scope of the study can range from individual measures for a specific end use in a utility's service territory to a comprehensive group of measures on a national level. Summary results typically describe the energy savings for a given timeframe, relative to a baseline, and may include the costs to achieve these reductions (e.g., 10% reduction in electricity use within 10 years at a cost of $50 Billion).

There are four major types of “potential”. The first type is the technical potential. It represents the theoretical maximum amount of energy use displaceable by energy efficiency, disregarding non-engineering constraints, such as costs of energy efficiency investment or consumer acceptance. The technical potential is computed from the baseline energy consumption forecast (which may be preexisting or be determined as part of the efficiency analysis) by disaggregating the baseline energy consumption by sector and end-use and applying efficiency improvements of different measures that are appropriate to the baseline stock characteristics. The timing of the measures varies by type; appliances are usually replaced at the end of their natural lifetime, while measures such as lighting or commissioning can be adopted sooner.

Technical potentials (and potential studies generally) tend to ignore price response, such as energy reductions due to conservation-encouraging electricity rate structures, or increased energy consumption because technology-based efficiency investments result in lower costs of service — the so called ‘rebound’ effect. This phenomenon has been empirically examined in many studies and found to be bounded, generally, at ~30% and lower in many instances (Sorrell et al. 2009; Greening et al. 2000). Price response can be incorporated, for example, by using energy-economic modeling that combines both technology and price as drivers of efficiency; this approach was used in a well-known national study (Interlaboratory Working Group 2000).

The second potential type is economic potential. It is a subset of the technical potential that is cost effective, as compared to supply side energy resources or energy price. Its estimation entails defining the appropriate cost test (e.g., total resource vs. participant) and selecting cost-effective measures (represented by a benefit-to-cost ratio that exceeds one) from the technical potential. Assumptions on discount rate and measure life strongly influence the economic potential.

The third potential type is the maximum achievable potential (sometimes referred to as 'achievable potential'). It is a subset of economic potential that can be expected with an aggressive program (e.g., end users are compensated for the entire incremental cost of efficiency). Its computation entails applying market penetration rates to the economic potential.

The fourth potential type is the realistic achievable potential (sometimes referred to as 'program potential'). It is a subset of the maximum achievable potential and reflects modest program funding levels. Its computation entails applying program implementation factors to the maximum achievable potential.

2.2 Methods and scope comparison

EPRI reports electricity savings for the residential, commercial and industrial sectors. Yearly savings up to 2030 for realistic achievable potential (RAP), maximum achievable potential (MAP), economic potential (EP) and technical potential (TP) are reported. They closely follow potential study formalisms and apply a participant cost test to estimate the EP.

The McK09 study follows potential study conventions closely. The McK09 key scenario is an economic type of potential, which they describe as the net-present-value (NPV) positive energy efficiency potential. I refer to the NPV positive energy efficiency potential as an economic potential (EP). With permission from McKinsey, the unpublished technical potential (TP) energy savings for the McK09 study are reported. McK09 estimates energy efficiency savings for 2020.

The McK07 report estimates potential GHG emissions reductions for several measures, including energy efficiency. I report the energy efficiency savings portion for the highrange and midrange scenarios estimated for 2030. Electricity and natural gas energy savings are estimated using measure level potential GHG emissions reductions provided by McKinsey.

Two AEO 2008 side scenarios related to end-use energy efficiency are included for comparison — the best available technology scenario (BT), which is interpreted roughly as a technical potential, and a high technology scenario (HT), which is interpreted roughly as an achievable potential. These do not employ energy efficiency potential study methods, but use the National Energy Modeling System (NEMS) model. The BT addresses buildings only, while the HT addresses industry and buildings. I generated a hybrid BT/HT scenario by including the industrial efficiency savings from the HT scenario.

Table 1 lists the methods, data and assumptions for the studies. It is worth emphasizing that (i) the baseline energy consumption data are consistent across the EPRI, AEO-08 and McK09 studies, (ii) the modeling approaches employed by EPRI and McKinsey are similar, and (iii) the broad categories of energy efficiency measures are similar, although the McK09 report considered a wider scope of measures (McKinsey 2009b). On the other hand, the applied cost-effectiveness tests and assumed discount rates vary among the three studies. McKinsey employed their own test, which considered a measure to be economic if the net present value of the energy savings, maintenance, and operational cost savings exceeded the present value of the incremental cost of the efficiency measure. The energy savings were estimated using industrial retail rates. EPRI used a 5% discount rate and a variation of the participant cost test, in which the present value of consumer energy savings (based on AEO projected retail rates by consumer class) were compared to the consumer cost for purchasing the incremental value of the energy efficiency measure.

The selection of the cost test and discount rate depends on the purpose of the analysis and has been a subject of debate for decades (Gillingham et al. 2009; Hassett and Metcalf 1993; Metcalf 1994; Sanstad et al. 1995). The discount rate is important because it determines the value of energy efficiency savings over the lifetime, relative to capital investments. Utility energy efficiency programs typically evaluate cost effectiveness using the ‘total resource cost test’, which represents economic impacts to society overall; the discount rate used is the utility weighted average cost of capital, typically ~ 5-6% (real) and ~ 7-8% (nominal); these are comparable to the discount rates employed in the studies evaluated. The discount rate from the participant perspective varies considerably and depends on factors such as required rate of return and risk tolerance. For businesses, an appropriate discount rate is the firm’s weighted average cost of capital, typically ~10-12%. However, commercial and industrial customers often require very short payback periods, implying discount rates much greater than 20%. The National Action Plan on Energy Efficiency cost effectiveness resource guide provides an excellent overview of utility program cost effectiveness (National Action Plan for Energy Efficiency 2008).

The choice of the discount rate greatly affects the economics of energy efficiency. The complexity in selecting an appropriate discount rate and cost test underscore common controversies in conducting energy efficiency potential analysis. The McKinsey studies elicited many criticisms, for example, “If so many negative-cost opportunities are available, why are they not already being taken up by consumers?” In addition to cost-effectiveness, several market failures (e.g., lack of information) and behavioral reasons (Gillingham et al. 2009) contribute towards the adoption of energy efficiency. Even if consumers are aware and the economics are attractive, households and businesses may simply choose not to invest in cost-effective energy efficiency because a non-energy investment may have more value from their perspective. The decision to adopt energy efficiency ultimately resides with the consumer and the economics from the consumer perspective may not warrant an investment in energy efficiency even if the investment is cost-effective to societal overall as determined by the total resource cost test.

Table 1 Methods, data and key assumptions from national studies

Study	Modeling approach	Baseline data	Discount rate	Cost benefit test	Sample measures
EPRI TP	Buildings: bottom-up Industry: top-down Equipment replacements occur at end of life	AEO 2008	--	--	Efficient HVAC equipment, appliances, motors, lighting, cool roofs, building envelopes, controls (water reset temperatures, programmable thermostats, energy management systems), air-side economizers, retro-commissioning
EPRI EP	Subset of TP that passes cost/benefit test	AEO 2008	5%	Variation of participant cost test [a]	
EPRI MAP	"Market acceptance rates" applied to TP for each measure	AEO 2008	5%		
EPRI RAP	"Program implementation factors" applied to MAP for each measure	AEO 2008	5%		
McK07	Bottom up stock and flow modeling; Equip replacements occur at end of life	AEO 2007 [b]	7%	Net-present value positive test [c]	Efficient electronics, lighting, building shells HVAC, commercial CHP, water heaters, control systems
McK09	Bottom up stock and flow modeling; early equip retirement if economical	AEO 2008	7%	Net-present value positive test [c]	Measures in 2007 report considered, plus additional ones
AEO-08 BT	NEMS model used Addresses buildings only Cost ignored	AEO 2008	--	--	Efficient equipment and building shells
AEO-08 HT	NEMS model used. Buildings & industry modeled. Cheaper & more efficient equipment available earlier	AEO 2008	--	--	Efficient equipment and building shells (including use of Energy Star)

[a] Incremental cost to a consumer for the efficient technology is compared to the expected bill savings over the useful life (EPRI, 2009). The participant was assumed to pay the full amount of the incremental cost (Wickler 2009).
[b] McK07 potentials were roughly adjusted to AEO 2008 baseline data by removing efficiency measures included in the Energy Independence and Security Act of 2007.
[c] This includes the portion of energy savings for which the direct energy, operating ,and maintenance cost savings over the equipments' useful life, brought to present value, minus the equipment and installation costs, is positive. Energy savings were calculated using industrial retail rates and converted present value terms.

3 National energy efficiency potential results

The tables and figures reported here draw upon a combination of information from the published reports and raw data provided by the reports' authors. EPRI reports their estimated potentials relative to both the AEO 2008 baseline and an adjusted EPRI baseline. In this paper, all reported EPRI savings are relative to the AEO 2008 baseline. McK07 and McK09 also report energy savings from combined heat and power (CHP). In McK09 they are excluded from the total and listed separately. In representing the McK07 savings, industrial CHP savings are not included for consistency with the other studies.

3.1 Aggregate national level energy savings

Table 2 lists the national-level potential energy efficiency potentials in 2020 and 2030 with the electricity savings illustrated in Fig. 1. These studies estimate technically possible reductions of ~ 25%–40% in electricity demand and ~ 30% in natural gas demand in 2020, and economic reductions of ~ 10%–25% in electricity demand and ~20% in natural gas demand in 2020.

The estimated electricity savings vary significantly, ranging from a 3% realistic potential in 2020, as estimated by EPRI, to an economic potential of 25% in 2020 as estimated by McK09, and technical potentials of ~25-40% in 2020. The achievable potentials for the EPRI range from ~ 3-10% in 2020. The achievable potentials in 2020 and 2030 across the McK07 and EPRI studies, on a normalized basis, are ~ 0.4-1%/y.

Table 2 Energy demand reductions from national studies

Scenario [a]	Reductions (%) [b]		Normalized savings (% per year)		2030 savings achieved by 2020 (%)
	2020	2030	2020	2030	
Electricity					
EPRI TP [c]	25	27	2.1	1.2	85
EPRI EP	11	11	0.9	1.5	95
EPRI MAP	9	8	0.7	0.4	97
EPRI RAP	3	5	0.3	0.2	60
McK07 highrange [d,e]	--	~23	--	~1.1	--
McK07 midrange [d,e]	--	~20	--	~0.9	--
McK09 TP	38	--	3.8	--	--
McK09 EP	25	--	2.5	--	--
AEO-08 BT/HT	13	17	1.1	0.8	67
AEO-08 HT	4	5	0.3	0.2	63
Nat gas					
McK07 highrange [d,e]	--	~17	--	~0.8	--
McK07 midrange [d,e]	--	~11	--	~0.5	--
McK09 TP	32	--	3.2	--	--
McK09 EP	19	--	1.9	--	--
AEO-08 BT/HT	7	10	0.6	0.5	66
AEO-08 HT	2	3	0.1	0.1	56

[a] Author and type of potential where "TP" is technical potential, "EP" is economic potential, "MAP" is maximum achievable potential, and "RAP" is realistic achievable potential

[b] All savings are relative to the baseline energy consumption reported in AEO 2008 as "sales" to industrial, residential and commercial sectors.

[c] EPRI savings are relative to the AEO 2008 baseline, not EPRI baseline.

[d] The natural gas and electricity reduction potentials were estimated from measure-level CO_2 emissions reductions provided by McKinsey. These estimates have not been validated by McKinsey.

[e] Energy savings relative to the AEO 2008 baseline were roughly approximated by removing the savings from measures covered under the Energy Independence and Security Act (EISA) of 2007.

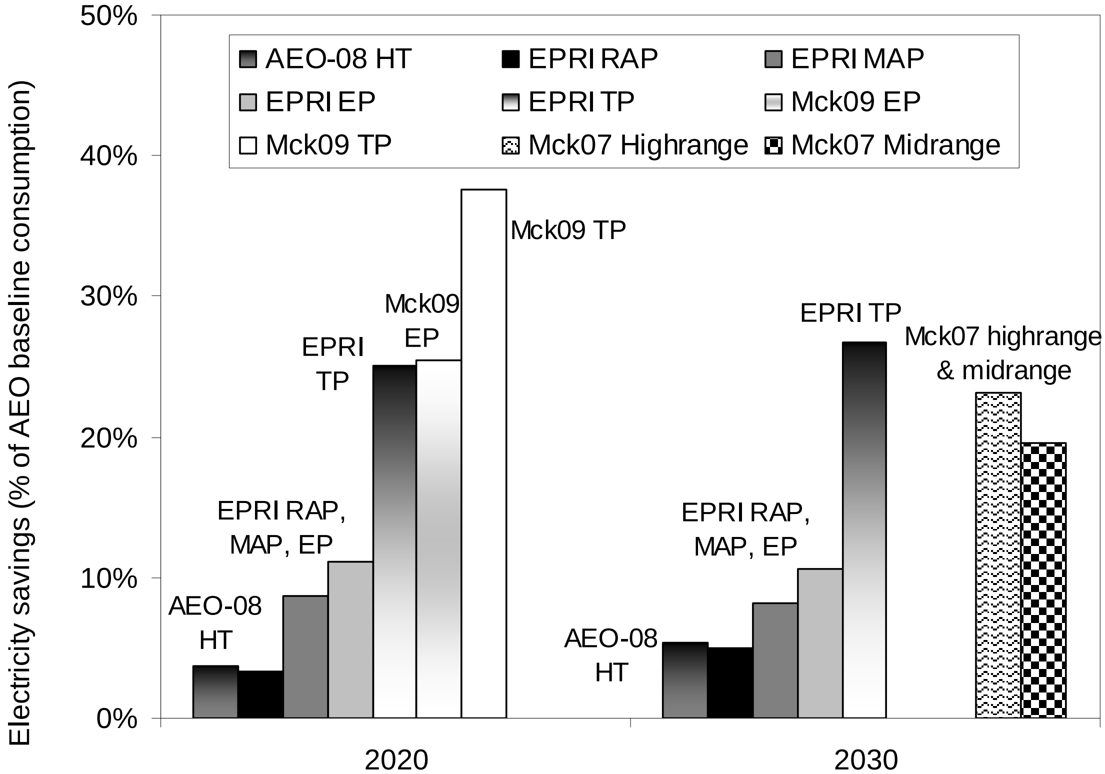

Figure 1. U.S. energy efficiency potential in 2020 and 2030

The studies estimate significant economic and technical energy efficiency potentials for natural gas, ranging from 2%-20% in 2020 and 3%-11% in 2030. Note, however, the AEO-08 side scenarios cannot be compared directly to the McKinsey results because the fundamental modeling methodology differs. Furthermore, as discussed the AEO side scenarios do not include the equivalent of an all-sector technical potential.

The relative magnitude of different potential types — such as technical to economic, or economic to achievable potentials — reflect the assumptions on economic and market penetration factors. A relatively larger achievable-to-economic potential ratio indicates assumptions of larger market penetration and acceptance rates; a larger economic-to-technical potential suggests lower costs of energy efficiency, lower discount rates, or both. The EPRI economic potential (electricity) is ~45% (2020) and ~40% (2030) of the technical potential, and maximum achievable potentials are ~80% (2020) and ~70% (2030) of the economic potentials. The McK09 economic potential is ~65% of its technical potential for electricity and ~60% for natural gas in 2020. Compared to EPRI, a larger fraction of the technical potential is economic, likely from lower assumed costs of saved energy. The McK07 midrange potential, which may be construed roughly as an achievable potential, is ~90% of the McK07 highrange potential, which may be construed roughly as a technical potential.

In all cases, a majority of the 2030 savings are achieved by 2020, suggesting that many of the savings from measures adopted through 2020 are available in 2030. These studies did not evaluate how program timing impacts the economics of reaching long term energy efficiency goals. However, this factor is likely to influence the cost-effectiveness of reaching long term goals due to the stock-roller effect. That is, by waiting to pursue energy efficiency, some cost-effective opportunities may become unavailable, for example if a home owner replaced their refrigerator or air conditioning unit just prior to the program start date.

Table 3 describes the impact on electricity growth rates. The impacts vary from lowering the electricity growth rate from 1% to 0.7% (EPRI RAP) or 0.3% (EPRI MAP), to turning it negative (McK09 potentials, McK07 highrange scenario, and EPRI TP). The AEO-08 high technology scenario roughly estimates the same demand reductions over these periods as the EPRI RAP scenario.

Table 3 Impact on national electricity growth rates

Scenario	Demand growth (TWh) [a]	Average annual growth (%)

	2008-2020	2008-2030	2008-2020	2008-2030
Baseline (AEO 08)	490	930	1.0	1.0
EPRI TP	-585	-320	-1.4	-0.4
EPRI EP	15	430	0.0	0.5
EPRI MAP	115	550	0.3	0.6
EPRI RAP	345	695	0.7	0.8
McK09 TP	-1110	--	-2.5 [b]	--
McK09 EP	-595	--	-1.3 [b]	--
AEO-08 BT/HT	-55	130	-0.1	0.2
AEO-08 HT	330	680	0.7	0.8

[a] Rounded to the nearest 5 TWh.
[b] Approximated using 2008 and 2020 electricity demand (in lieu of calculating year-to-year impacts).

3.2 Greenhouse gas emissions reductions

To illustrate an approximate relationship between energy efficiency potentials and GHG emissions, and the relative contribution of efficiency to goals specified in recent legislation, potential CO_2 emissions reductions are estimated from the energy efficiency potentials by applying average electricity generation emissions factors from non-baseload units and natural gas combustion emissions factors (Table 4). The electricity emissions factor, obtained from the Environmental Protection Agency, is a proxy for a marginal emissions factor. The efficiency potentials overall constitute ~ 10%-100%+ of the greenhouse gas emissions reduction goals for 2020 as required by the Waxman Markey climate bill (H.R. 2454); the economic electric efficiency potentials constitute ~ 35%-80% of these goals.

The achievable GHG emissions reductions from potential electricity energy savings range from ~105-270 $MMTCO_2$ in 2020 and 170-280 $MMTCO_2$ in 2030. Reductions from the technical and economic potentials range from ~ 345-1165 $MMTCO_2$ in 2020 and ~ 365-915 $MMTCO_2$ in 2030 (The upper limit for 2020 is from McK09, which did not publish savings for 2030). For context, the GHG emissions reductions required in 2020 and 2030 by the Waxman Markey bill are 960 and 2850 $MMTCO_2$ (on a CO_2 equivalent basis), respectively. The approximated energy efficiency CO_2 emissions reductions of the electricity potential savings are a higher percentage of Waxman Markey required reductions in 2020, ranging from ~10% (EPRI RAP and AEO-08 high technology case) to ~120% (McK09 TP). The wide range between the EPRI MAP and EPRI EP, and the McK09 EP suggest that energy efficiency could provide anywhere from a third to a majority of the required GHG emissions reductions in 2020, if appropriate policies were affected. For 2030, the approximated CO_2 emissions reductions from electricity savings are significantly less, with the EPRI technical potential constituting about a third of the total required GHG emissions reductions.

Table 4 Possible carbon dioxide emissions reductions

Scenario	From electricity savings ($MMTCO_2$) [a]		From natural gas savings ($MMTCO_2$) [b]	
	2020	2030	2020	2030
EPRI TP	750	880	--	--
EPRI EP	330	350	--	--
EPRI MAP	260	270	--	--
EPRI RAP	100	165	--	--
McK 07 highrange	--	~ 760	--	~ 140
McK07 midrange	--	~ 645	--	~ 90
McK09 TP	1120	--	255	--
McK09 EP	755	--	150	--
AEO-08 BT/HT	380	560	55	85
AEO-08 HT	110	175	15	25
GHG reductions required in Waxman Markey, H.R. 2454 ($MMTCO_2e$) [c]				
2020	960			
2030	2850			

[a] CO_2 reductions estimated using an emission factor of 0.70 kg CO_2 /kWh (rounded to 5 $MMTCO_2$) which represents the 2007 U.S. CO_2 emissions rate from non-baseload units. (http://www.epa.gov/cleanenergy/energy-resources/refs.html, accessed July 14, 2012)
[b] CO_2 reductions estimated using an emission factor of 0.047 kg CO_2 / MJ (5.0 kg CO_2/therm) (rounded to 5 $MMTCO_2$)
[c] U.S. Environmental Protection Agency, 2009

3.3 Savings by sector and region

Fig. 2 illustrates the potentials by sector (residential, commercial, industrial). Energy saving opportunities exist across all sectors. For electricity, each study indicates a significantly larger technical potential in the residential sector, followed by the commercial and then industrial sectors. Each study also indicates that a greater portion of the commercial and industrial measures are economic, compared to the residential measures. The magnitude of economic and technical industrial electricity savings measures rank below the residential and commercial sectors, although both McK09 and EPRI find a greater percentage of industrial opportunities economical, compared to the commercial and residential opportunities. The natural gas savings also indicate large economic and technical potential in the residential sector, although the relative magnitude of the economic savings suggest many measures are not cost effective. Industrial and commercial opportunities are generally more economic.

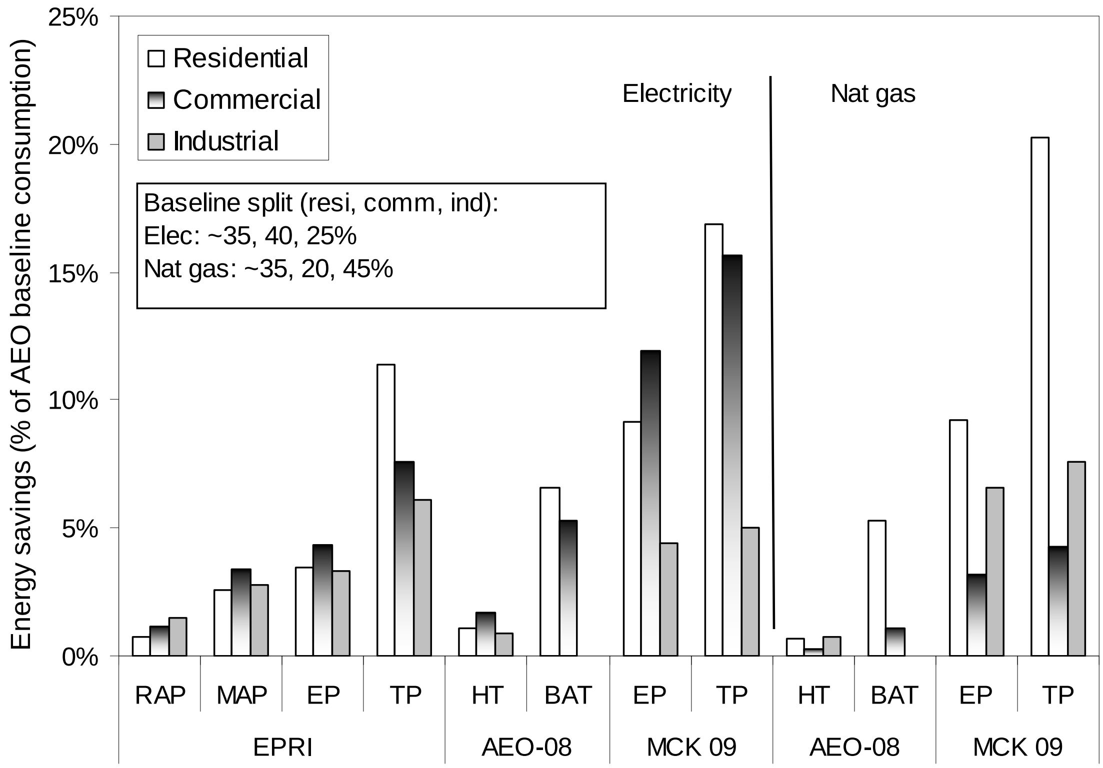

Figure 2.Site energy savings by sector in 2020 and 2030

Assuming a comprehensive scope of measures, the technical potentials in each sector, normalized to the sector baseline consumption (indicated on Fig. 2), indicates the modelers' assessment of that sector's current state of energy efficiency. McK09 and EPRI indicate the residential sector to be the least efficient with ~30-60% reductions technically feasible; ~20-25% of industrial consumption are technically feasible. While McK09 suggests the industrial sector to be the most efficient, EPRI suggests the commercial sector to be more energy efficient.

Fig. 3 shows how electricity savings vary by region. Almost uniformly, each study suggests significantly more electricity savings opportunities in the South, relative to the other three census regions; these savings are due both to the larger baseline energy use and lower levels of energy efficiency in the South, relative to the other regions. One exception is the EPRI realistic achievable potential, which does not indicate greater savings in the South, relative to the other regions. Note that the EPRI report does indicate larger absolute realistic savings in the South, relative to other regions. However, the discrepancy between Fig. 3 and the figures in EPRI (2009)[1] is due to the differences between the EPRI and AEO 2008 baseline; specifically, the EPRI baseline indicates significantly larger projected energy consumption in the South and Northeast for 2020. We observed negligible differences in the regional breakdown of energy savings (on a normalized basis) for the economic, maximum achievable and technical potentials.

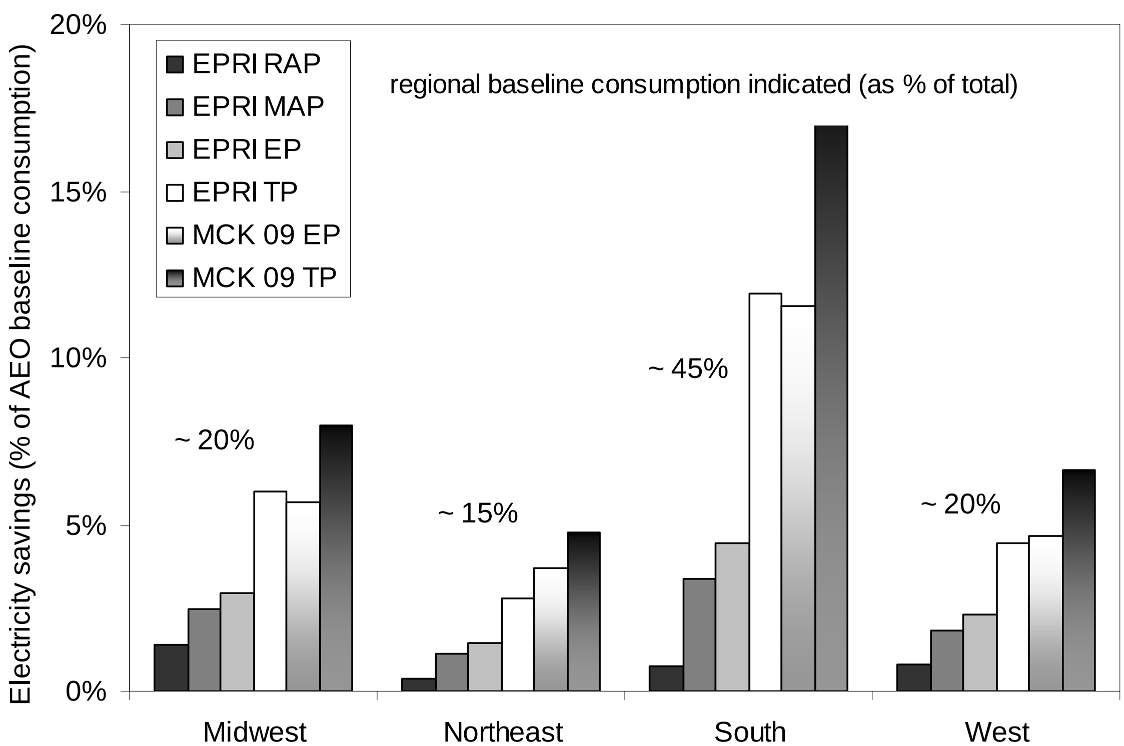

Figure 3. Site energy savings by region in 2020

[1] See Figure ES-13 for the regional breakdown of the EPRI RAP for 2020 (EPRI 2009).

While the absolute EPRI economic potential is greatest in the South, the relative portion of the technical potential that is economic is lower compared to other regions. While there are significant cost-effective opportunities in the South, some combination of high technology costs or low financial savings from energy efficiency due to low energy prices may prevent a greater portion of the technical opportunities from being economic.

EPRI estimates a greater relative disparity between the realistic achievable and maximum achievable potentials in the South. Factors such as utility financing limits, political and market barriers to energy efficiency limit the implementation of energy efficiency. These limits are reflected in the assessment of realistic potential and are, based on the observed disparity between the RAP and MAP, assumed to be larger in the South than in other areas.

Fig. 3 also indicates the regional breakdown of baseline electricity consumption. When the regional efficiency potentials are normalized by its regional consumption, there is little disparity in the efficiency potentials across the studies, although the South does exhibit somewhat lower relative maximum achievable and realistic achievable savings.

Overall, the national studies are consistent with recent reports that estimate large efficiency potential in the Southeast — Chandler and Brown (2009) and Chandler (2010), which are meta-level analysis of energy efficiency potential studies and Brown et al. (2010), a study employing NEMS.

3.4 Reconciling differences between EPRI and McKinsey studies

Fig. 4 reproduces (with permission) the reconciliation between the EPRI and McK09 economic potentials (McKinsey 2009b). The differences between the economic potentials are explained by differences in the scope, type and costs of technologies considered, and assumptions on technology innovation. With the exception of the categories of heat pumps and commercial lighting, the technology assumptions applied by EPRI are less aggressive than those assumed by McKinsey.

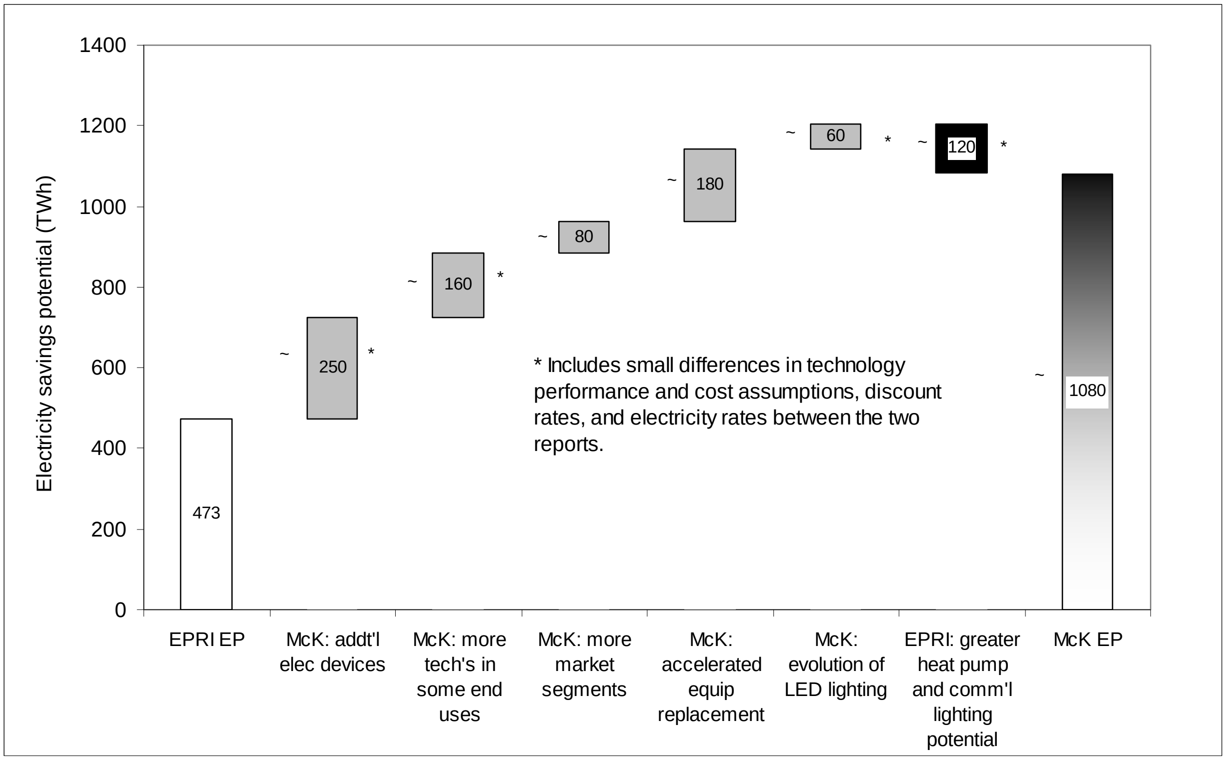

Figure 4 Comparing EPRI and McKinsey 2020 economic potentials (McKinsey, 2009)

The difference between the EPRI and McK09 economic potentials is ~610 TWh or ~14% of the AEO 2008 baseline consumption in 2020. Three categories account roughly for this entire difference — the inclusion of additional electrical devices by McKinsey (~250 TWh or ~40% of the difference), the inclusion of additional technologies in some end uses by McKinsey (~160 TWh or ~25% of the difference), and accelerated equipment replacement by McKinsey (~180 TWh or ~30% of the difference). Accelerated equipment replacement occurred when the full equipment cost (not incremental) could be offset by energy savings; potential studies typically assume "natural" equipment turnover, rather than accelerated replacement (National

Action Plan for Energy Efficiency 2007). The “additional electrical devices” include items such as more energy efficient televisions and other products.

To better understand how economic assumptions vs. technology performance or scope assumptions drive the results, I compare the ratio of technical potentials with the ratio of economic potentials (i.e., McK09 to EPRI). The technical potential ratio is 1.5 and economic potential ratio is 2.3. While differences in scope and additional technologies cause the McK09 technical potential to be ~ 50% larger than the EPRI potential, differences in economic assumptions drive the economic potentials further apart. EPRI assumes a 5% discount rate and consumer specific retail rates, while McK09 assumes a 7% discount rate and industrial rates. Both assumptions would serve to drive the economic potentials closer together. Lower technology costs and accelerated deployment assumed by McK09 compensate for the counter effects of the discount rate and electricity rates and drive the economic potentials such that the McK09 economic potential is ~130% larger than the EPRI potential.

3.5 Costs for achieving energy efficiency potentials

The costs reported in EPRI and McK09 are summarized.[2] McK09 estimates a total upfront investment cost of ~$520 Billion to pay for the estimated efficiency savings (or ~$50 Billion over 10 years). These costs represent capital investments only; McK09 did not estimate program administration costs. EPRI provides a low and high range of costs, based on historical levelized costs of saved energy, to achieve the realistic and maximum achievable potential savings in

[2] For the purposes of this paper, capital investments include equipment, installation, operational costs for energy efficiency; program administration costs are a separate cost to the capital investments. Depending on the level of the incentive, total program costs may include capital investments in addition to program administration costs.

2010, 2020 and 2030. The total implementation costs, on an annualized basis, for 2020 are estimated at ~$12-$34 Billion for the maximum achievable potential and ~$5-$18 Billion for the realistic potential. These include program administration and capital investments.

It is not possible to directly compare these investments since the McK09 estimate represents total upfront capital investments for all fuel savings, and excludes program administration costs, while the EPRI estimate represents annualized implementation costs for 2020, rather than upfront investments, and are for electricity savings only. The average cost of saved energy, however, provides a basis for comparison. The average cost of saved energy to reach the McK09 2020 economic potential is ~$0.018/kWh, while EPRI assumes a range of ~$0.03-0.06/kWh (EPRI 2009; Wickler 2009).

It is appropriate to provide context of these costs based on published cost estimates of energy efficiency programs. Gillingham et al (2006) provides an excellent review on the efficacy and costs of energy efficiency policies and cites energy efficiency costs of utility programs from $0.008/kWh to $0.229/kWh across the literature. Other studies, using econometric methods, estimate costs of energy efficiency at an average of $0.05/kWh (5% discount rate) (Arimura et al. 2012) and range of $0.05-$0.13/kWh (Auffhammer et al. 2008).

4 Comparison with recent state and regional studies

Table 5 lists the results of recent state and regional studies of energy efficiency. With different baselines, timelines, data, and assumptions on technology, it is challenging to directly compare these with the national results; but they still provide useful policy input. Table 5 reports the normalized annual savings (total savings divided by total years) and compound annual savings. While it is hard to draw general conclusions from the numbers because of variability among the studies, achievable potentials average at ~ 1%/y (based on either a normalized or compound average savings rate); economic potentials are roughly double achievable savings and technical potentials are roughly double the economic potentials.

Table 5 Energy demand reductions from recent state and regional studies [a]

Region	Source	Years	Total savings (%)			Normalized savings (%/y) [b]			Compound savings rate (%/y) [c]		
			TP [d]	EP [d]	MP [d]	TP	EP	MP	TP	EP	MP
Electricity:											
California	Rufo and Coito 2002	10	19%	14%	10%	1.9%	1.4%	1.0%	1.2%	1.1%	1.1%
Georgia	ICF 2005	5	29%	20%	6%	5.8%	4.0%	1.1%	1.3%	1.2%	1.0%
Iowa	Eng Cent Wisc 2009	11		22%	13%		2.0%	1.2%		1.3%	
Mass	RLW 2007	5		19%			3.8%			1.2%	
New Mex	Itron 2006	10			8%			0.8%			1.1%
North Carolina	GDS 2006	11	33%	20%	14%	3.0%	1.8%	1.3%	1.4%	1.2%	1.1%
Texas	OEI 2007	15			20%			1.3%			1.2%
Utah	Tellus 2001	6			9%			1.5%			1.1%
Vermont	GDS 2006	6	35%	19%		5.8%	3.2%		1.4%	1.2%	
Wisconsin	Eng Cent Wisc 2009	7		18%	11%		2.6%	1.6%		1.2%	1.1%
					Avg	4.1%	2.7%	1.2%	1.3%	1.2%	1.1%
					Min	1.9%	1.4%	0.8%	1.2%	1.1%	1.0%
					Max	5.8%	4.0%	1.6%	1.4%	1.3%	1.2%
Natural gas:											
California	ACEEE 2003	20	35%	21%	9%	1.8%	1.1%	0.5%	1.5%	1.3%	1.1%
Georgia	ICF 2000	5	10%	11%	4%	2.0%	2.2%	0.7%	1.1%	1.1%	1.0%
Iowa	Eng Cent Wisc 2009	11		22%	20%		2.0%	1.8%		1.3%	1.2%
Midwest	Quantec 2005	20	10%		25%	0.5%		1.3%	1.1%		1.3%
New York	OEI/VEIC/ACEEE 2002								1.7%	1.3%	1.0%
Utah	GDS/Quantum 2004	10	38%		20%	3.8%		2.0%	1.5%		1.2%
Wisconsin	Eng Cent Wisc 2009	7	19%	16%	7%		2.3%	1.0%		1.2%	1.1%
					Avg	3.5%	2.6%	1.1%	1.4%	1.2%	1.1%
					Min	0.5%	1.1%	0.3%	1.1%	1.1%	1.0%
					Max	9.3%	5.6%	2.0%	1.7%	1.3%	1.3%

[a] Summary data are drawn from the National Action Plan for Energy Efficiency (2007), Frisch (2008) and Energy Center of Wisconsin and ACEEE (2009).
[b] Total savings divided by the years to reach the savings.
[c] Calculated by (1-total savings) raised to the exponent (1/years-1).
[d] TP = technical potential, EP = economic potential, MP – maximum achievable potential

The state studies are comparable to the savings estimated by Mck07 and Mck09 but more aggressive than EPRI or AEO-08 side scenarios. There is a rough trend where studies with shorter timelines exhibit larger energy efficiency potentials, in part, possibly because many potential studies do not assume technological innovation over time (which makes it harder for estimated energy efficiency gains to offset growth in consumption).

5 Conclusions

From a policy perspective, transparent methods, assumptions and data are essential to interpret and validate the results of studies to estimate energy efficiency potential. For the purposes of this paper, many issues were confirmed offline with the authors. Potential studies should address issues such as uncertainty of input data assumptions and details on how measures are modeled, including how interactive effects among measures are treated (e.g., savings from efficient heating systems are affected by building envelope improvement). As shown by the McKinsey and EPRI study reconciliation, scope and cost-effectiveness assumptions can have dramatic impacts on results.

Despite the variations in the methods, data and results, the reviewed potential studies inform U.S. national-level energy efficiency potential and energy policy. Both McK09 and EPRI underscore the huge potential for energy efficiency in the south. The national studies estimate achievable potentials of ~0.2%/y - 1%/y and state/regional studies estimate average savings of ~1%/y. Following the completion of the analysis in this paper, the National Academies evaluation of energy efficiency potential was released (National Academies 2010). The findings of the National Academies study suggest significant achievable energy efficiency potential and contain results that are generally comparable to the results in the studies evaluated in this article;

for example, energy efficiency could reduce U.S. energy use ~30% below forecasted 2030 consumption levels and potentially reduce consumption below 2008 levels.

Since the completion of the studies reviewed in this paper, natural gas prices have decreased substantially due to fracking and economic growth has slowed. These factors would alter the baseline and serve to lower estimates of energy efficiency potential. The analysis conducted in this report could be repeated with more recent studies (to the extent they have common baseline and scope). However, the objective of this paper was to identify consensus of energy efficiency potential among a comparable set of recent studies. Lower natural gas prices and slower economic growth is likely to affect each study similarly, thus, not affecting the overall objective.

These studies may be useful for informing energy efficiency goals that could be achieved through either voluntary or regulatory programs, such as energy efficiency resource standards, and are already the basis for utility energy efficiency program goals in some states, such as California. By understanding the relative impact of market barriers, which reduce economic to achievable potentials, complementary policy mechanisms can be designed to target specific end-uses or consumer classes. Energy efficiency potential studies may be useful, also, for informing climate policy design, in which multiple strategies are being explored and will likely be needed.

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Figure Captions