Energy Efficiency Investments as an Economic Productivity Strategy for Texas

John A. "Skip" Laitner
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1001 Connecticut Avenue, N.W., Suite 801, Washington, D.C. 20036
(202) 429-8873 phone, (202) 429-2248 fax, www.aceee.org

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EXECUTIVE SUMMARY

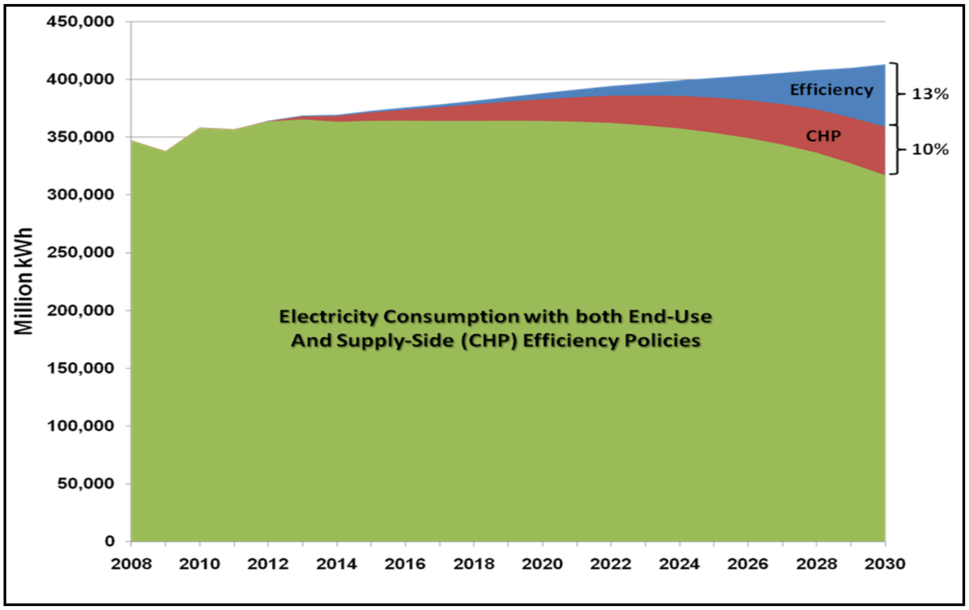
Despite the recent downturn in the economy, Texas is rebounding to remain one of the most rapidly growing states in the country. According to one set of forecasts (Economy.com 2011), the U.S. economy is projected to grow about 2.5% per year while Texas is expected to expand at a healthy 3.2% annually. The difference in those growth rates appears to be one of population growth. The state population is expected to increase about 1.7% annually through 2030, while the larger U.S. population expected to grow about 1.0% annually, also through 2030. In that context, one critical concern in maintaining the robustness of the state economy is the upward demand for electricity services. The challenge is to meet that new demand while maintaining cost-competitiveness. This report assesses the potential for cost-effective investments in energy efficiency to meet future demand for electricity services while maintaining competitive utility rates, saving businesses and consumers money, and spurring greater levels of job creation.

Overview of Results

In this report we review the economy-wide impacts that likely would unfold under a revised energy efficiency target for electricity consumption in Texas. In fact, Texas was the first state to formally recognize the value of energy efficiency, implementing the first energy efficiency standard in the United States in 1999. The Public Utility Commission of Texas (PUCT) continues to recognize the value of integrating greater levels of energy efficiency into the array of energy assets; in July 2010 the PUCT set a target for the state's utilities to meet 30% of the expected growth in the demand for electricity services through energy efficiency. This study shows the plan to be cost-effective but far from optimal. We estimate that the current target would result in a 3.5% reduction in electricity demand compared to standard forecasts for the year 2030. This would, in turn, drive a net consumer savings of about $3 billion over the period 2012 through 2030. The resulting savings on electricity bills would support a net increase of about 9,200 jobs per year by 2030.

On the other hand, Figure ES-1 (below) provides a look at how more cost-effective investments in energy efficiency within the state's households, businesses, and factories, together with greater energy supply efficiencies using combined heat and power (CHP) systems, might expand the electricity savings from a very modest 3.5% to an estimated 23% savings relative to projected 2030 sales. Under this alternative policy scenario, businesses and households in Texas would then enjoy a cumulative net electricity bill savings on the order of $14 billion over the period 2012 through 2030.

Figure ES-1. Potential Share of Texas' Electricity Use Met with Potential Efficiency Gains



As a result of this greater energy productivity, the net employment driven by the cost-effective investments reflected in Figure ES-1 would ramp up the energy bill savings over time. As an example, in the third scenario shown in Table ES-1, the residential sector would enjoy a net annual electricity bill savings, rising from about $7 per average household in the year 2015 (not shown in the table) to about $179 per household by 2030. In that case, employment impacts would rise slowly over time so that by 2030, Texas would be supporting a net gain of about 47,000 new jobs. Should the state choose to pursue a larger employment benefit, the fourth scenario summarized below would extend total electricity savings to 30% of the 2030 forecast (including 20% from demand-side efficiency and 10% from building additional CHP capacity). In that case, households would enjoy an anticipated net savings of $217 by 2030. Net employment benefits would jump to almost 100,000 jobs.

Table ES–1. Benefits of Energy Efficiency Investments for the Texas Economy

Overall Efficiency Target	Total Efficiency Gains from 2030 Forecast	Net Benefits 2012 to 2030 ($ Billions)	Benefit-Cost Ratio 2012 to 2030	Net Household Savings in 2030	Net Jobs in 2030
Current Policy—Efficiency Provides 30% of Growth in Demand	3.5%	$3.2	3.5	$56	9,200
Efficiency Holds Electricity Use at Current Levels	13%	$5.7	1.9	$179	43,500
Electricity at Current Levels Plus 5,600 MW New CHP Capacity within the Industrial Sector	23%	$14.0	2.3	$179	46,900
Electricity at 8% Below Current Levels Plus 5,600 MW New CHP within the Industrial Sector	30%	$12.3	1.7	$217	98,600

Policy Options to Build Market Capacity

While the potential net benefits are significant, both in terms of costs and net employment benefits, the market is likely unable to move toward a more energy-efficient economy without direction, policy guidance, and new finance mechanisms that drive the needed investments. Hence, there is a need for the state to embrace a more robust efficiency target to ensure the larger economic benefits. Rather than maintain the current policy target—one that merely reduces the anticipated growth of electricity consumption by 30% per year (saving only 3.5% of the projected electricity demand in 2030), the analysis here supports at least a four-fold expansion of net benefits that might be catalyzed with cumulative 23–30% electricity savings, again compared to the projected demand for electricity in 2030.

The alternative energy efficiency scenarios would be achieved if the state targeted an annual reduction of about 1.5–2% per year from the electricity consumption projected for the year 2030. These improvements would include efficiency savings within the many homes, schools, office buildings, and industries as well as a greater emphasis on supply-side efficiencies through the deployment of the more energy productive CHP systems. There is also a need to encourage a more proactive and stable energy efficiency finance market to complement a more robust energy efficiency policy target. Finally, state policymakers may also want to reexamine the mix and scale of incentives to ensure that they are appropriate to the level of effort required to deliver the net positive benefits described in this assessment.

Conclusion

To achieve this level of benefit will require investments that drive cost-effective energy efficiency improvements—on both the supply side and the demand side. The scale of these efficiency gains would need to displace conventional electricity use in the year 2030 by about 1.5–2.0% annually. The extent to which the resulting benefits are realized will depend on the willingness of business and policy leaders to redirect investment patterns to this more productive opportunity. Depending on how the program implementation is actually designed, consumer rate impacts should be minimal while electricity bill savings should be significantly net positive.

INTRODUCTION

Texas is one of the most rapidly growing states in the country. Its population is expected to increase 1.7% annually over the next 19 years through the year 2030. Economic activity, as measured by its Gross State Product, is expected to grow 3.2% per year over that same period (Economy.com 2011). With this combined population and income growth, electricity consumption is similarly projected to grow. The immediate good news is that greater levels of energy productivity appear to have slowed the demand for more electricity in the state. Recent forecasts of 1.5–1.7% annual growth in electricity consumption have dropped to perhaps 0.8% annually through 2030.[1] At the same time, however, the state continues to face critical decisions on the mix of investments needed to meet new demands for electricity. Moreover, Texas has one of the most natural gas-dependent electric generation systems within the United States. This lack of resource diversity exposes the state to rising and volatile natural gas prices in addition to the many vulnerabilities associated with growing constraints on its generation and transmission capacity. Hence, there is a clear need for new energy resources to meet the expected growth in electricity consumption.

The challenge confronting Texas is to meet the demand for new electricity services in ways that maintain competitive electricity costs, and that also enhance environmental and other social benefits. In March 2007, the American Council for an Energy-Efficient Economy (ACEEE) published a report suggesting that a combination of energy efficiency and renewable energy technologies could more than offset the state's growing need for electricity (Elliott et al. 2007). The findings of that report indicated that the alternative energy efficiency and renewable energy scenario could help stabilize overall energy prices, lower electricity bills, and reduce impacts on state air quality. In a subsequent analysis (Laitner et al. 2007), ACEEE also reviewed the macroeconomic impacts that likely would unfold under those alternative policy recommendations. That second analysis confirmed that cost-effective investments in the combination of energy efficiency, together with alternative generation technologies, would produce a net electricity bill savings of more than $5 billion by the year 2023 (the last year of analysis in those 2007 assessments). As a result of that greater energy productivity, the state was projected to show a net employment gain of about 38,000 jobs. This is roughly equivalent to the employment that would be directly and indirectly supported by the construction and operation of 300 small manufacturing plants within Texas.

In this follow-up report, we review and update the macroeconomic impacts that likely would unfold under a set of alternative policy targets within Texas. Supported by the growing evidence showing energy efficiency investments to be a robust and cost-effective resource (see, for example, Laitner and McKinney 2008, Itron 2008, and Molina et al. 2010), the Public Utility Commission of Texas (PUCT) has already recognized the value of integrating greater levels of energy efficiency into the array of energy assets. The current target set by the PUCT is to meet 30% of the expected growth in the demand for electricity services through energy efficiency. The analysis described in this report shows the plan to be highly cost-effective but far from optimal. We estimate that the current target would result in a 3.5% reduction relative to electricity demand projected for the year 2030. This would, in turn, drive a net consumer savings of about $3 billion over the period 2012 through 2030. The resulting savings on electricity bills would support a net increase of about 9,200 jobs per year by 2030.

On the other hand, pushing beyond the current target through cost-effective end-use efficiency improvements, together with an expanded deployment of combined heat and power systems, would displace about 23–30% of conventional electricity generation otherwise forecast for 2030. Businesses and households in Texas would then enjoy a net savings on the order of $12–14 billion over the period 2012 through 2030. As a result of these greater energy productivities, net employment would likely increase by about 47,000 to nearly 100,000 jobs per year in 2030. The extent to which these benefits are realized will depend on the willingness of business and policy leaders to implement the mix of policy options required to drive the requisite investments characterized in this assessment.

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[1] For comparison, Economy.com (2011) projects total population in the United States as a whole to grow only 1.0% while U.S. economic activity is expected to grow 2.5% annually. Further, EIA (2010) indicates U.S electricity consumption will grow at a slightly smaller 0.6% annually.

BACKGROUND

In a detailed March 2007 study (Elliott et al.), ACEEE documented the cost-effectiveness and robustness of an array of energy efficiency and alternative energy resources that might be deployed to meet the growing energy needs within Texas. Indeed, the findings of that study underscored the importance of deeming alternative technologies to be critical resources of first choice. The analytical team at that time recommended a series of cost-effective policies that would bring those resources online at the rate that they would actually be needed. More specifically, ACEEE assembled a portfolio of nine policies that were shown to be both cost-effective and politically viable in Texas. Those policies were:

(1) an expanded utility-sector energy efficiency improvement program;
(2) new state-level appliance and equipment standards;
(3) more stringent building energy codes;
(4) an advanced energy-efficient building program;
(5) an energy-efficient state and municipal buildings program;
(6) short-term public education and rate incentives;
(7) increased demand response programs;
(8) specific capacity targets for combined heat and power (CHP); and
(9) onsite renewable energy incentives.

By implementing those clean energy resource policies, ACEEE indicated that Texas could meet its summer peak demand needs without any additional coal-fired power plants or other conventional generation resources.

In general, the March 2007 report found that a combination of energy efficiency investments, combined heat and power technologies, and new onsite renewable resources could provide sufficient generation equivalent to reduce conventional electricity use by 22% over the period 2008 through 2023: energy efficiency by 11%; expanded CHP by 6%; and onsite renewable energy resources by 5%. More critically, the report noted that the required 15-year cumulative investment of nearly $50 billion, including both program and administrative costs, would save about $73 billion in avoided cumulative electricity expenditures. As already noted, a second study (Laitner et al. 2007) found that redirecting the pattern of expenditures away from conventional electricity generation into energy efficiency and alternative generation technologies would boost net employment opportunities in Texas from about 10,000 jobs in 2013 to about 38,000 jobs by 2023. The biggest reason for that boost in employment, as we shall see later in this analysis, is that revenues received by electric utilities generally supports about one-half the number of jobs than money spent almost anywhere else in the economy. To boost employment opportunities within Texas, therefore, policy and business leaders should think about alternative cost-effective investment strategies that change the pattern of spending in favor of other goods and services.

At the same time, the economic circumstances have changed in significant ways since 2007. Among other things, the PUCT approved a new rule in July 2010 to promote energy efficiency investments.[2] Moreover, shifts in economic activity and the availability of new energy efficiency technologies appear to have altered the economic landscape. There is a need, therefore, to update those previous assessments to determine whether there exists a new set of energy efficiency opportunities that can be tapped as a means to support a more productive economy. In the sections of the report that follow, we describe the methodology, model, and findings of our assessment.

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[2] The energy efficiency rule, Substantive Rule § 25.181, Energy Efficiency Goal, was approved by the Public Utility Commission of Texas on July 30, 2010.

STUDY METHODOLOGY

In this updated economic evaluation of the energy efficiency resource, we generally follow five steps that build on the previous ACEEE studies. First, we create a new economic and electricity forecast to determine how current economic conditions and policies in Texas might shape a demand for electricity over the period 2010 through 2030. Second, we identify a set of alternative efficiency scenarios—including their expected costs and benefits—to highlight different magnitudes of net energy bill savings that boost overall employment in the state. In general, we explore the impacts of energy efficiency over the period 2012 through 2030. Third, we calibrate an economic assessment model (described below) to reflect the most economic profile of the Texas economy. Next, we transform the changed investment and spending patterns as inputs into the economic policy model. The resulting inputs include such things as: (1) the level of annual program spending that drives the policy scenario; (2) the electricity savings that result from the various energy efficiency policies or the level of alternative electricity generation from onsite renewable and combined heat and power technologies; and (3) the capital and operating costs associated with those technology investments. Finally, we run the model and check both the logic and the internal consistency of the modeling results. These steps are explained next.

Reference Case Electricity Forecast

There is already good news in the world of energy efficiency that we can report in this update. Both since a 1998 analysis done for Texas Department of Economic Development—examining electricity efficiency potential for the year 2010 (Goldberg and Laitner), and since the March 2007 ACEEE study (Elliott et al.), it does appear that consumers and businesses have significantly increased overall efficiency beyond what was originally expected. Goldberg and Laitner (1998), for example, suggested that under a “business-as-usual” scenario the state’s electricity intensity would decrease from 0.44 kilowatt-hours (kWh) per constant 2005 dollar of gross state product (GSP) in 1988 to 0.37 kWh per constant dollar of GSP. But, in fact, the intensity declined to about 0.32 kWh per constant dollar of GSP. As it turns out, this positive trend was comparable to what Goldberg and Laitner suggested would have happened under what they termed a moderate energy efficiency scenario for the state’s electric utilities.

At the same time, Elliott et al. (2007) indicated that the state’s energy intensity might decline further to about 0.27 kWh per constant dollar of GSP by the year 2023 (the last year of their analysis). As it turns out, the current trends now suggest that this might drop closer to 0.24 kWh per constant dollar of GSP. The end result is that while the 2007 ACEEE assessment mapped a reference case electricity projection of about 450 billion kWh by 2023, revised data now imply that electricity demand in Texas may be closer to 400 billion kWh in that year. Given these positive changes, there is clearly a need to establish a new reference case out to both the year 2023 and in the case of this specific update, out to the year 2030.[3]

In this analysis, we examine the state’s economic growth as published by Moody’s Economy.com (2011) out to the year 2040. This is consistent with the Electric Reliability Council of Texas (ERCOT 2010a) projections, which also rely on Economy.com. However, we truncate the assessment in this study to the year 2030. The ERCOT *Planning Long-Term Hourly Peak Demand and Energy Forecast* through 2019 suggests a moderate growth in electricity consumption of 1.3% (ERCOT 2010b). At the same time, the *Annual Energy Outlook 2011* published by the Energy Information Administration (EIA 2010) provides a new and more recent forecast for the ERCOT region that projects an annual electricity

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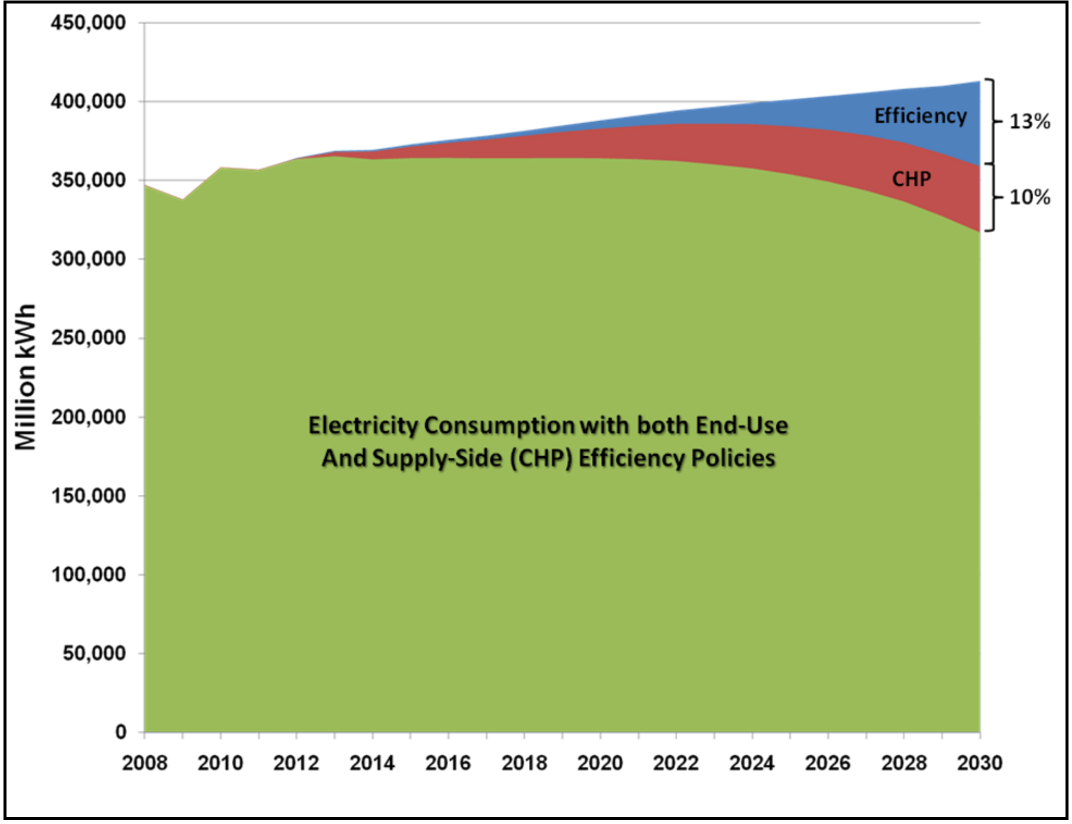
[3] There are always some uncertainties in comparing the previous studies with today’s current projections. First, all approached the data in different ways. And they all used different reference points to begin their analyses. Goldberg and Laitner (1998), for example, were benchmarked to 1995 dollars in providing their estimates at the time. Elliott et al. (2007) were using 2000 dollars as the basis of their assessment. Moreover, current projections now rely on 2005 dollars. At the same time, structural change in the economy as well as policies implemented since each of the studies were completed also impact the differences in outcomes. Notwithstanding these differences, the clear trend emerges that Texas has become much more energy efficient than some might have anticipated. At the same time, as this current assessment suggests, there is still plenty of room for improvement.

growth of only 0.8% per year through 2030. We go with the EIA forecast as the most recent and consistent set of projections. As it turns out, the ERCOT region covers about 85% of Texas, and with a 2008 estimated consumption of 347 billion kWh for Texas in 2008, together with the anticipated growth using the EIA forecast, our new reference suggests an electricity demand of 413 billion kWh for the year 2030. Providing both a revised "business-as-usual" (BAU) forecast, and then looking ahead to what we might call an "enhanced" efficiency scenario, Figure 1 offers a summary of future electricity consumption compared to the reference case. Given the very modest sales growth in the reference case, the present target of reducing growth by 13% is a very limited target. Figure 1 also integrates a suggested mix of energy efficiency and combined heat and power resources (essentially a more efficient set of electricity supply services) out to the year 2030. This extends the cost-effective displacement of conventional electricity generation by another 10%. Hence, this particular scenario shows a combined savings of 23% by 2030. As we shall see, a more robust policy target might extend the cost-effective savings by as much as 30% by 2030.

Figure 1. Potential Share of Texas' Electricity Use Met with Potential Energy Efficiency Gains



The Energy Efficiency Assessment

The analysis of prospective efficiency improvements draws heavily on three prior studies to provide a robust assessment of the possible impacts that might follow future investments in energy efficiency. We integrate their various findings into a consistent set of cost estimates that depend on the level of technology penetration over time. Electricity bill savings are a function of future electricity savings times the annual electricity prices published by the EIA (2011) for the state of Texas. The first set of cost and performance data are taken from Elliott et al. (2007). As described earlier, that assessment provided cost assessments of nine different policy bundles. It was not explicitly reported but, on average, the energy efficiency provisions suggested an average payback of about two years in the early years of the analysis. Slightly increased costs pushed the typical payback to about four years by 2023. The benefit-cost ratio for the savings generated in the 2008–2023 time-frame, using a 4.5% discount rate, was about 2.2. In other words, the nine policy bundles delivered 2.2 times the electricity bill savings as the combined expenditure of program dollars and technology investments.[4]

The second study was done for the PUCT, *Assessment of the Feasible and Achievable Levels of Electricity Savings from Investor Owned Utilities in Texas: 2009-2018* (Itron 2008). Their approach provided a technology-based rather than a policy-based characterization. In that assessment, the electricity savings were a function of specific technology deployments in each of the residential, commercial, and industrial sectors. Moreover, the assessment used a 2007 base year rather than a long-term forecast to evaluate the efficiency potential. The Itron study found a technical potential for electricity savings of 25%, and an economic savings potential that was just short of 18% of the 2007 baseline electricity consumption. At the same time, Itron estimated the economic savings potential to be 23% in the residential sector, 17% in the commercial sector, and 11% in the industrial sector. Neither the ACEEE nor the Itron analyses included an assessment of the potential energy savings from emerging technologies such as light emitting diodes (LEDs), heat pump and integrated space/water heating systems, or advanced energy management systems that are expected to be available during the rollout of advanced metering infrastructure.

By integrating the ACEEE and the Itron data sets, we estimated a statistically-derived set of efficiency measure costs that evolve over time as a function of total efficiency gains by the year 2030. The Itron dataset in particular shows much higher energy efficiency costs as the savings grow beyond 10% for industry and 15% or so for building improvements. With the Itron costs woven into this analysis we provide a very conservative estimate of the amount of cost-effective energy savings. Table 1 (below) highlights the suggested financial impacts for each of the three major end-use sectors, including the average residential, commercial, and industrial end-uses. The results are highlighted as the average payback period—in effect, the number of years necessary to retire the full cost of an investment—necessary to achieve sector-specific efficiency savings as they might sum to the economy-wide targets of 10%, 20%, and 30% electricity savings by 2030.

Table 1. Suggested Energy Efficiency Payback Periods as a Function of Total Savings

End-Use Sector	Payback in Year 2012	Payback in Year 2030		
	Initial Investment	10% Savings	20% Savings	30% Savings
Residential	1.7	3.1 (13%)	6.9 (26%)	15.2 (39%)
Commercial	1.8	2.2 (10%)	3.6 (19%)	5.8 (29%)
Industrial	1.3	1.4 (6%)	1.9 (12%)	2.5 (18%)

Note: The sector payback periods are the suggested years necessary to pay back the full investment necessary to improve overall electricity savings. As shown in this table, the payback periods are statistically derived values adapted from Elliott et al. (2007) and Itron (2008), as characterized in the text of this report. They are a function of time (e.g., out to the year 2030), the overall level of end-use efficiency gains (i.e., 20% average savings as shown in the shade column of this table), and the level of specific sector penetration (e.g., a 26% residential savings, a 19% commercial savings, and a 12% industrial savings). The reader might note that the shaded 20% economy-wide savings is the maximum level explored in this assessment.

Three points require more explanation. First, the payback periods are shown (in years) for each of the three major end-use sectors. Second, they are arrayed as the costs might be incurred first for the year 2012 (the first year of the suggested efficiency gains), and then for three different levels of efficiency gains that might be achieved in 2030. Finally, the sector-specific efficiency gains are shown in parentheses next to each of the 2030 payback periods as a percent of that sector's savings compared to the 2030 reference case or business-as-usual projection for each sector. As an example, if we stretch the economy-wide savings to 30% by 2030, the residential sector will need to achieve a 39% savings with a 15.2 year payback in our Scenario F (described later in this narrative), the commercial

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[4] The reader should note that a benefit-cost ratio for a policy scenario will be different than for an individual customer. For example, if a large commercial business makes efficiency improvements that last 15 years, but that also pay for themselves over the first four years, this will show an undiscounted benefit cost ratio of 3.75. In other words, every dollar invested will earn an average $3.75 over the 15-year life of the efficiency upgrades. If multiple customers are making those same set of improvements both in the first year of a 20-year scenario, and out through the 20th year itself, the benefit-cost ratio for the scenario might fall to less than 2. This is because investments made in the later years will return fewer total savings.

sector will need to achieve a 29% savings with a 5.8 year payback, while the industrial sector will need to attain a smaller 18% savings with a much lower payback of 2.5 years. And as we might imagine, a 15-year average payback for the residential sector is problematic and indicates both that the Itron cost curve for the residential sector is very steep and that the residential target may need to be scaled back. And, in fact, the assessment provided here extends only to a combined 20% economy-wide end-use efficiency savings by 2030 (shown in the shaded column of Table 1). Hence, the overall scenarios remain highly cost-effective. On the other hand, the low 2.5 year payback shown in the very last column of Table 1 for the industrial sector indicates that additional cost-effective savings may be available in this sector—well beyond the 12% industry savings shown in the shaded 20% scenario of Table 1.

Although the industrial sector achieves smaller end-use efficiency improvement than do the building sectors, it further benefits from the integration of greater supply-side efficiency improvements. Both our first study (Elliott et al. 2007) and our third study by Summit Blue Consulting, *Combined Heat and Power in Texas: Status, Potential, and Policies to Foster Investment* (Cooney and Schare et al. 2008), provide useful data to help us explore the costs and benefits of a modest penetration of combined heat and power technologies within the industrial sector. The Summit Blue report was also done for the PUCT.

The reason we view this as an efficiency gain is that the electric generation system in Texas is only about 32% energy efficient. That is, of all of the coal or natural gas used to generate electricity in both the U.S. and in Texas, about two-thirds is lost in the form of waste heat by the time that electricity reaches the end-use consumer. Perhaps even more interesting, that level of inefficiency has barely improved over the last 50 years.[5] The family of CHP technologies can provide system efficiencies of 70–90% by recovering that waste heat and using it to either provide process steam, electricity, or mechanical shaft power, which improves overall system performance. See, for example, Bullock and Weingarden (2006) and Bullock, Beydoun, and Lami (2008). Elliott et al (2007) found that 28.8 billion kWh of conventional electricity generation could be displaced by adding an estimated 3,750 megawatts (MW) of new cost-effective CHP capacity by 2023. The ACEEE analysis found a very positive CHP benefit cost ratio of more than 5 to 1.

The Summit Blue report identified 16,900 MW of CHP technical potential by 2023, which is higher than the value of 14,000 MW found in the 2007 ACEEE assessment. More specifically, the Summit Blue analysis found sufficient economic potential to add as much as 13,400 MW of cost-effective CHP capacity while ACEEE, as previously noted, limited its 2007 scenario analysis to 3,750 MW of economic penetration also by 2023. In this particular assessment we adopt a maximum penetration to 5,600 MW of cost-effective penetration by 2030.[6] CHP already provides about 16,900 MW of the electricity generation capacity in Texas. This is about 16.1% of total generation capacity in the state and makes Texas the top user of CHP capacity within the U.S.[7] It turns out that deploying the more efficient 5,600 MW of CHP capacity will produce electricity that is roughly equivalent to 10% of conventional electricity generation projected for the 2030 business-as-usual case.

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[5] According to data from the Energy Information Administration, the electric system of generation, transmission, and distribution in Texas was operating at 28% efficiency in 1960, rising to only 32% efficiency as of 2011.

[6] The ACEEE 2007 study showed a wide range of capital costs for installed CHP systems. For example, Appendix E of that assessment documented a low of $660 per kilowatt installed for a 40 MW of gas turbine capacity to a high of $1,300 for a 1 MW unit. Fuel cell-based CHP systems and other such systems might range from $2,000 to $5,000 per kW, depending on the size of the unit and the impact of economies of scale and learning over time. Here we focus on units more like the gas turbine systems and adopt a typical capital cost of $1,200/kW. With current projections of natural gas prices and other operating costs, the average production cost for CHP systems is estimated to be about 6.8 cents per kWh. This is considerably higher than the 5.3 cents per kWh for electricity generation costs. At the same time, however, CHP systems also produce process heat that is valued at 2.8 cents/kWh. With a thermal credit for CHP systems, the net cost in this analysis is shown to be 4.0 cents/kWh.

[7] Interestingly, the countries of the Netherlands, Latvia, Denmark, Russia, and Finland all approach or exceed 30% CHP as a share of national power production. Denmark, in fact, is above 50%. See IEA (2009).

Integrating Energy Efficiency Costs and Benefits into Policy Scenarios

With the technology characterization and economic potentials now established, we can integrate different combinations of energy efficiency gains and CHP capacity into a variety of six scenarios over the period 2012 through 2030. This will enable, first, a closer examination of net benefits and costs; and second, an evaluation of the net employment impacts for the Texas. Table 2 below summarizes the key results from a total of six different scenarios that we explore in this analysis.[8]

Table 2. Key Benefit-Cost Scenario Results to Update the Texas Energy Efficiency Assessment

	A	**B**	**C**	**D**	**E**	**F**
Efficiency Target	30% of Growth	50% of Growth	Enhanced Effic	Enhanced Effic	Enhanced Effic	Max Effic
New CHP by 2030	No Additional	No Additional	No Additional	2800 MW	5600 MW	5600 MW
Total Efficiency by 2030	3.50%	5.90%	13.20%	18.20%	23.20%	30.00%
NPV Costs ($ Million)						
Residential	$795	$1,396	$4,136	$4,136	$4,136	$8,815
Commercial	$405	$685	$1,763	$1,763	$1,763	$3,211
Industrial	$92	$151	$355	$2,627	$4,899	$5,135
Total	$1,292	$2,233	$6,254	$8,526	$10,798	$17,161
NPV Benefits ($ Million)						
Residential	$2,660	$3,837	$7,025	$7,025	$7,025	$9,763
Commercial	$1,391	$2,021	$3,737	$3,737	$3,737	$5,216
Industrial	$471	$678	$1,239	$7,623	$14,007	$14,488
Total	$4,522	$6,536	$12,001	$18,385	$24,769	$29,467
Net Benefits ($ Million)						
Residential	$1,865	$2,440	$2,889	$2,889	$2,889	$948
Commercial	$986	$1,336	$1,973	$1,973	$1,973	$2,004
Industrial	$378	$527	$884	$4,996	$9,108	$9,354
Total	$3,230	$4,303	$5,746	$9,859	$13,971	$12,306
Benefit-Cost Ratio						
Residential	3.35	2.75	1.70	1.70	1.70	1.11
Commercial	3.43	2.95	2.12	2.12	2.12	1.62
Industrial	5.09	4.48	3.49	2.90	2.86	2.82
Total	3.50	2.93	1.92	2.16	2.29	1.72
Net Job Gains in 2030	9,200	14,000	43,500	45,200	46,900	98,600

The point of departure for all six of the scenarios we explore in this assessment is the current PUCT target, suggesting that energy efficiency capture 30% of the anticipated growth in electricity demand (see Appendix B for key reference case assumptions out to the year 2030). As it turns out, for this specific analysis, a 30% reduction of growth means a 3.5% savings from the projected 2030 electricity use in Texas. That target, together with the integration of the sector technology costs and benefits characterizations that are described in Table 1, sets the initial benchmark for the analysis summarized as Scenario A.

The data for Scenario A show a very cost effective return for each of the major end-use sectors with an economy-wide benefit-cost ratio of 3.5. This means that for each program and investment dollar spent to promote energy efficiency, the utility bill savings sum to a total savings of $3.50 over the period 2012 through 2030. Given the costs and the electricity bill savings, the present value of cumulative net

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[8] We might note at this point that the purpose of this analysis is not to recommend a specific policy objective or even a particular path that Texas might pursue to achieve any of the scenario targets. Rather, the intent is to show that, under a wide variety of cost assumptions, the state can significantly expand its overall efficiency targets in ways that also will expand both net financial gains and employment benefits.

benefits is $3,230 million over that period.[9] Based on the economic and jobs model (described in further detail in the section that follows), net employment in Texas grows to 9,200 jobs by 2030.[10] Scenario B examines a similar trajectory, extending the target so that efficiency meets 50% of the growth in electricity demand. That revised target would generate an estimated 5.9% savings from the 2030 reference case projection of electricity. As the target is pushed a little harder to deploy more of the energy efficiency resource, the benefit cost ratio falls slightly, from 3.5 to 2.93. The greater level of cost-effective investments grows the net benefits to $4,303 million—again over the period 2012–2030. As a result of that greater investment, net employment grows to 14,000 jobs by 2030.

Scenario C provides "an enhanced level" of end-use energy efficiency. In effect, we asked the analytical model to find the level of building and industrial energy efficiency savings that would provide the maximum level of net energy savings benefits for the state. Given the previous cost assumptions reported in Table 1, it appears that biggest level of net savings is reached at energy efficiency investments lowers demand by 13.2% of the reference case electricity consumption otherwise projected by the year 2030. This is an average of 0.7% of sales each year, which roughly tracks the forecasted load growth. Even though that level of investment lowers the benefit-cost ratio to 1.92, the net benefits to the Texas economy grow to $5,746 million. With that larger investment and net savings, the net employment jumps to 43,500 jobs by 2030.

Scenario D supplements the previous 13.2% efficiency gain by adding a total of 2,800 MW of cost-effective CHP to the states generating capacity. With CHP showing a greater cost-effective return than many of the efficiency gains, the benefit-cost ratio again grows back to a slightly higher ratio of 2.16. The net benefit, in turn, grows to $9,859 million with the net gain of 45,200 jobs.

In addition to the 13% energy end-use savings suggested in Scenario D, Scenario E then doubles CHP to 5,600 MW. The end-use efficiency and CHP capacity combine to reduce electricity sales by an average of 1.4% each year. The result is an effective displacement of conventional electricity consumption that grows to 23.2% of the 2030 forecasted usage. Again because CHP is less expensive than some end-use efficiency gains, the benefit-cost ratio again increases slightly to 2.29. The net benefits grow to their maximum among these scenarios, to $13,971 million through 2030. With that additional stimulus, the employment opportunities expand by a net of 46,900 jobs.

The final Scenario F pushes the limit to what is called "maximum efficiency." In this case, the efficiency target expands to a 20% savings by 2030 (an average of 1.4% of sales each year) with the 5,600 MW of CHP adding the additional 10% displacement to increase total efficiency gains to a full 30% of the 2030 reference case (for a combined average of 1.9% of sales each year). Since we are now pushing the efficiency measures harder than ever, the net benefits fall to $12,306 million. Households are impacted so that their sector benefit cost-ratio drops significantly to 1.11. At the same time, the economy-wide benefit-cost ratio remains at a reasonable 1.72. With the added investment, to deploy more CHP and efficiency upgrades and with cumulative energy bill savings reaching their largest total, net employment jumps significantly to 98,600 jobs by 2030.

Immediate Insights and Lessons

What lessons might we draw from this assessment? While, yes, there are clearly net benefits from the current energy efficiency targets as summarized with the findings from Scenario A, the assessment based on all six scenarios also suggest there is ample room for improvement. If Texas wishes to maximize net benefits only for electricity end-uses, then it seems that the target recapped in Scenario C—pushing efficiency gains to reduce the anticipated 2030 electricity consumption to 13.2% may be

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[9] The net present value calculations are 2009 constant dollars discounted by 5% over the 2012–2030 time horizon.

[10] As described in the modeling appendix, the assessment reflects the growth in "net jobs." That is, while there are more jobs created by new efficiency investments and the spending of electricity bill savings on more labor intensive sectors of the economy (suggested in Figure 2), the model also anticipates that fewer jobs will be available in the electric utility and related sectors. Hence, we note the reference to net job impacts throughout this report.

entirely appropriate. This effectively raises the bar about 10% of 2030 sales more than the current efficiency target, and it does so in ways that increase net economic gains and employment.

By including more energy efficiency supply-side resources among the mix, however, it appears that Texas can cost-effectively promote the equivalent of a 23% efficiency gain with a net employment benefit of an estimated 45,000 jobs. This target summarized in Scenario E would require cost-effective policies and investments that decrease electricity consumption by about 0.6% annually from the anticipated 2011 level of electricity use. On the other hand, if Texas wanted to get out ahead of the curve, and think about energy efficiency as a long-term economic development strategy, then the state might consider the last scenario as a reasonable target. While the net benefits are somewhat smaller, the investments and larger energy bill savings are driving an even greater level of employment. And it would create a positive set of new market dynamics that would likely place Texas as the leader in smart energy efficiency opportunities within the electricity market.

The Economic and Jobs Impact Model

We next turn to describing the DEEPER modeling system used to evaluate all six scenarios summarized in the preceding section of this report. While the year 2030 net employment benefits are highlighted in Table 2 for all scenarios, in this section we provide greater detail for the central scenario on which we focus, Scenario E. But first we provide more background on the model itself—with further details highlighted in Appendix B.

The DEEPER modeling system—or the Dynamic Energy Efficiency Policy Evaluation Routine—is an econometric input-output analytical tool. Although recently given a new name, the model's origins can be traced back to modeling assessments that ACEEE and others first completed in the early 1990s (see Appendix B for historical information and other details on the DEEPER model).

The model is "quasi-dynamic" in that the costs of energy efficiency improvements are based on the level of efficiency penetration as described in Table 1. The greater the efficiency penetration, the higher the costs and their resulting payback periods begin to rise.[11] Moreover, it adjusts labor impacts given the anticipated productivity gains within the key sectors of the Texas economy. As an example, if the construction and manufacturing sectors increase their output as a result of the alternative policy scenario, the employment benefits are likely to be affected based on expected labor productivity gains within each of those sectors.

Input-output models initially were developed to trace supply linkages in the economy. For instance, an input-output accounting framework can show how purchases of lighting technologies or industrial equipment benefit the lighting and other equipment manufacturers in a state. In addition, because the input-output model has coefficients linking not only directly but indirectly affected industries, the model can also reveal the multiplicative impacts that such purchases are likely to have on other industries and businesses that might supply the necessary goods and services to those manufacturers.

The net economic gains of any new investments in energy efficiency and combined heat and power technologies will depend on the structure of the local economy. For instance, states that already produce electronic products or power generation technologies will likely benefit from the expanded local sales of high-efficiency ballasts and heat recovery systems; states without such production capabilities will not benefit in quite the same way. Moreover, different kinds of expenditures support different levels of total economic activity within a state. To illustrate this point, Figure 2, on the following page, compares the direct and indirect employment impacts that are supported for every one million dollars of

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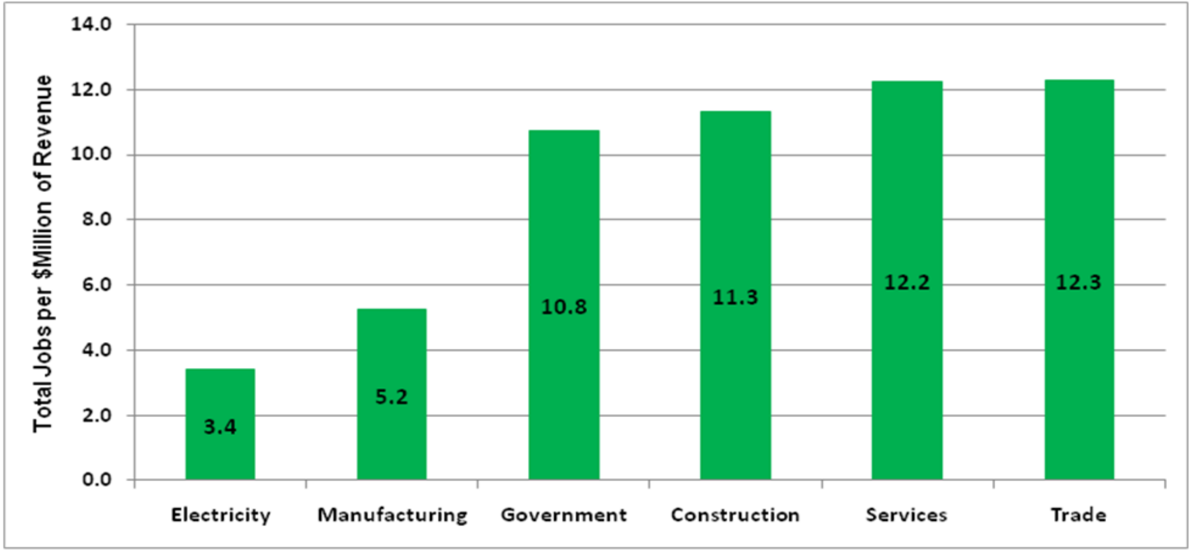
[11] Note that this is a very conservative assumption. Assuming in this exercise that the costs of efficiency investments necessarily increase as market penetration also increases tends to minimize the benefits of a more dynamic market. This is because there are other effects such as expanding economies of scale, and the impact of learning how to produce and deliver efficiency technologies more cheaply, might actually lower unit costs of deployment. In that regard, we might consider the costs reflected here—originally adapted from the Itron (2008) and the ACEEE 2007 (Elliott et al.) studies—as an upper bound of estimated costs.

revenue received by different sectors of the Texas economy. As shown in Figure 2, the employment impacts are summarized for key sectors of the Texas economy. These include electric utilities, manufacturing, services, construction, wholesale and retail trade, and government.[12] For purposes of this study, a job is defined as sufficient economic activity to employ one person full-time for one year.

Of immediate interest in Figure 2 is the relatively small number of jobs supported by electric utility services. Texas' electric utility industry provides, for example, only 3.4 jobs per million dollars of revenues that it receives. This includes both jobs directly supported by the industry as well as those jobs linked to businesses that, in turn, provide goods and services to maintain the utilities' operation. On the other hand, one million dollars spent in construction supports 11.3 jobs, both directly and indirectly.

As it turns out, much of the job creation from energy efficiency programs is derived by the difference between jobs within the utility supply sectors and jobs that are supported by the respending of energy bill savings in other sectors of the economy.

Figure 2. Key Texas Impact Coefficients by Major Economic Sector



Source: 2009 IMPLAN data set for the Texas economy (2011).

An Illustration: Texas Jobs from Improvements in Government Office Buildings

To illustrate how a simplified job impact analysis might be done, we will use the simplified example of installing one million dollars of efficiency improvements in a large office building. Office buildings (traditionally large users of energy due to heating and air-conditioning loads, significant use of electronic office equipment, and the large numbers of persons employed and served) provide

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[12] The model used for the assessment described here relies on the IMPLAN datasets for Texas. IMPLAN stands for "IMpact Analysis for PLANning" (IMPLAN 2000). These 2009 historical economic accounts (IMPLAN 2011) provide a critical foundation for a wide range of modeling techniques, including the input-output model used as a basis for the assessment described here (Laitner 2009). Figure 2 presents what are referred to as Type I impact coefficients, incorporating only the direct and indirect effects of a given expenditure. Adding the induced effect (i.e., the additional level of impact made possible by the respending of wages in the Texas economy) would generate what are known as the Type II impacts (as referenced in the IMPLAN model). However, since household spending is part of the final demand changes we decided to limit the employment and other macroeconomic impacts to the Type I multipliers. This will tend to understate the net effect of the alternative policy scenario. For more information on this point, see, Miller and Blair (1985), pages 25-30.

substantial opportunities for energy-saving investments. The results of this example are summarized in Table 3 below.

The assumption used in this example is that the investment has a positive 4-year payback. In other words, the assumption is that for $1 million of energy efficiency improvements, the upgrades might be expected to save an average of $250,000 in reduced electricity costs over the useful life of the technologies. This level of savings is low but consistent with estimates cited elsewhere in this report. At the same time, if we anticipate that the efficiency changes will have an expected life of roughly 15 years, then we can establish a 15-year period of analysis. In this illustration, we further assume that the efficiency upgrades take place in the first year of the analysis, while the electricity bill savings occur in years 1 through 15. Moreover, we assume that only half the savings occur in the first year as it may take several months to actually start an average project with savings not beginning until halfway through the year.

Table 3. Job Impacts from Government Building Energy Efficiency Improvements

Expenditure Category	**Amount (Million $)**	**Employment Coefficient**	**Job Impact**
Installing Efficiency Improvements in Year 1	1.0	11.3	11.3
Diverting Expenditures to Fund Efficiency Improvements	-1.0	10.8	-10.8
Energy Bill Savings in Years 1 through 15	3.6	10.8	39.2
Lower Utility Revenues in Years 1 through 15	-3.6	3.4	-12.3
Net 15-Year Change			27.3

Note: The employment multipliers are taken from the appropriate sectors found in Figure 2. Based on the efficiency costs described in the text, the annual savings are about $250,000 with only one-half available in the first year. The jobs impact is the result of multiplying the row change in expenditure by the appropriate row multiplier. On average, this building upgrade would be said to support a net gain of 1.8 jobs per year for 15 years. For more details, see the text that follows.

The analysis also assumes that we are interested in the *net effect* of employment and other economic changes. This means we must first examine all changes in business or consumer expenditures—both positive and negative—that result from a movement toward energy efficiency. Each change in expenditures must then be multiplied by the appropriate multiplier (taken from Table 1) for each sector affected by the change in expenditures. The sum of these products will then yield the net result for which we are looking.

In our example, there are four separate changes in expenditures, each with their separate effect. As Table 3 above indicates, the net impact of the scenario suggests a gain of 27.3 job-years (rounded) in the 15-year period of analysis. This translates into an average net increase of about 1.8 jobs each year for 15 years. In other words, the efficiency investment made in the office building is projected to sustain an average 1.8 net jobs each year over a 15-year period compared to a “business-as-usual” scenario. Roughly speaking, if comparable projects like this scaled to more like $100 million in a single year the number of jobs gained will similarly scale upward

Appropriate Modifications in the Energy Efficiency Scenarios

The economic assessment of the alternative energy scenarios was carried out in a very similar manner as the example described above. That is, the changes in energy expenditures brought about by investments in energy efficiency and renewable technologies were matched with their appropriate employment multipliers. There are several modifications to this technique, however.[13]

First, it was assumed that only 77% of both the efficiency investments and the savings are spent within Texas. We based this initial value on the 2009 IMPLAN dataset as it describes local purchase patterns that typically now occur in the state. We anticipate that this is a conservative assumption since most efficiency and CHP installations are likely (or could be) carried out by local contractors and dealers.

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[13] For a more complete review of how this type of analysis is carried out, see Laitner, Bernow, and DeCicco (1998).

And if the set of policies encourages local participation so that the share was increased to 90%, for example, the net jobs might grow another 10% or more compared to our standard scenario exercise. At the same time, the scenario also assumes Texas provides only 40% of the manufactured products within the state. But again, a concerted effort to build manufacturing capacity for the set of clean energy technologies would increase the benefits from developing a broader in-state energy efficiency manufacturing capability.

Second, an adjustment in the employment impacts was made to account for assumed future changes in labor productivity. As outlined in the Bureau of Labor Statistics *Outlook 2008–2018*, productivity rates are expected to vary widely among sectors (BLS 2009). For instance, the BLS projects a 2.2% annual productivity gain as those sectors better integrate information technologies and become even more critical to the economy. To illustrate the impact of productivity gains on future employment patterns, let us assume a typical labor productivity increase of 2.2% per year. This means, for example, that compared to 2008, we might expect that a $1 million expenditure in the year 2030 will support only 63% of the number of jobs as in 2009.[14]

Third, for purposes of estimating energy bill savings, it was assumed that current electricity prices in Texas would follow the same growth rate as those in the ERCOT region, as published by the Energy Information Administration in its *Annual Energy Outlook* 2011 (EIA 2010; see also the reference case assumptions in Appendix B). Fourth, it was assumed that the large-scale efficiency and CHP investments upgrades are financed by bank loans that carry an average 6% interest rate over a 20-year period. While this does raise the cost to end-users as a result of the interest that must be paid on bank loans, raising or lowering the interest rates in this analysis will not appreciably affect the net outcome of the results otherwise reported. Also, to limit the scope of the analysis, no parameters were established to account for any changes in interest rates as less capital-intensive technologies (i.e., efficiency investments) are substituted for conventional supply strategies, or in labor participation rates—all of which might affect overall spending patterns within the state.

While the higher cost premiums associated with the energy efficiency investments might be expected to drive up the level of borrowing (in the short term), and therefore interest rates, this upward pressure would be offset to some degree by the investment avoided in new power plant capacity, exploratory well drilling, and new pipelines. Similarly, while an increase in demand for labor would tend to increase the overall level of wages (and thus lessen economic activity), the job benefits are small compared to the current level of unemployment or underemployment. Hence the effect would be negligible.

Fifth, for the buildings and industrial sectors it was assumed that a program and marketing expenditure would be required to promote market penetration of the efficiency improvements. Based on other program reviews, this was set at 15% of the efficiency investment in the early years but declining to 5% of the much larger investments in the last year of the assessment.[15]

Finally, it should again be noted that, by design, this analysis does not account for the full effects of the efficiency investments since the savings beyond 2030 are not incorporated into the modeling assumptions. Nor does the analysis include other productivity benefits that are likely to stem from the efficiency investments. These can be substantial, especially in the industrial sector. Industrial investments that increase energy efficiency often result in achieving other economic goals such as improved product quality, lower capital and operating costs, increased employee productivity, or capturing specialized product markets.[16] To the extent these "co-benefits" are realized in addition to the energy savings, the economic impacts would be amplified beyond those reported here.

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[14] The calculation is $1/(1.022)^{21} * 100$ equals $1/1.579 * 100$, or 63%.

[15] The assumption here is that program spending is necessary to encourage, monitor, and verify the requisite efficiency gains. In addition, training programs as well as increased research & development expenditures may also be needed to improve technology performance and market penetration. This range is generally consistent with the findings of Friedrich et al. (2009). For other examples that integrate program spending into efficiency policy assessments, see Laitner et al. (2010) among other studies.

[16] For a more complete discussion on this point, see Elliott, Laitner, and Pye (1997) and Worrell et al. (2003).

ECONOMIC IMPACT OF A COST-EFFECTIVE ENERGY EFFICIENCY SCENARIO

The investment and savings data from the efficiency and CHP scenario identified in Scenario E were used to estimate the financial and the economy-wide impacts for the key benchmark years of 2012, 2015, 2020, 2025, and 2030. Each change in sector spending was evaluated by the Investment and Spending module within the DEEPER model for a given year—relative to the baseline or business-as-usual scenario. These were then matched to their appropriate sector impact coefficients. These negative and positive changes were further evaluated by DEEPER's macroeconomic module to estimate the larger net job and wage benefits for the Texas economy.

Table 4. Key Annual Financial and Economic Impacts from the Scenario E Policy Run

	2012	2015	2020	2025	2030	Average 2012-2030
Financial Costs (Million 2009 $)						
Program Costs	15	50	49	68	204	71
Efficiency Investments	100	424	544	1,017	4,079	1,023
Annualized Efficiency Payments	9	119	330	668	1,694	518
Energy Bill Savings	60	507	1,518	3,513	8,250	2,611
Net Energy Bill Savings	36	338	1,139	2,778	6,352	2,021
Net Savings per Household (actual $)	2	7	22	66	179	50
Macroeconomic Impacts						
Employment (actual)	1,288	5,554	5,216	13,223	46,939	12,036
Percent from Reference Case	0.01%	0.04%	0.04%	0.08%	0.27%	
Wages (Million 2009 $)	50	209	127	367	1,788	388
Percent from Reference Case	0.01%	0.03%	0.01%	0.03%	0.15%	

Starting with very small impacts in 2012, the combined end-use energy efficiency and CHP target of a 23% savings by 2030 spur both program costs and technology investments that, in turn, begin to change the production patterns of electricity consumption and production. Program spending of $15 million in 2012, coupled with a policy target established by Scenario E, is assumed to drive an initial $100 million in technology investments in that year. But these investments are assumed to be financed over time so that the actual outlays in 2012 are only $9 million. The initial impacts on electricity production are quite small, reducing electricity bills by only $60 million (about 0.2% of the reference case electricity expenditures otherwise projected in that year). However, both program spending and the annualized efficiency payments rise to 204 and 1,694 millions of dollars by 2030, respectively.

The cumulative impact of activities over the 19-year time horizon steadily reduces the demand for conventional electricity generation so that by 2030 a combination of efficiency and CHP capacity displaces the forecasted electricity production by 23%. The net savings on electricity bills (i.e., the savings after program costs and the annual payments for investments have been paid) exceeds $6 billion (rounded) in 2030, which is about 16.4% of the state's reference case electricity bill for that year. The net residential or household savings starts at only $2 in 2012, slowly increasing to $7 in 2015, and then rises steadily to an annual $179 savings for an average household by 2030.

As might be expected, the program spending and changed investment patterns have a distinct economic impact within Texas. The second set of impacts in Table 4 highlights the key employment and wage impacts for the same years. For example, the net employment benefits begin with about 1,288 jobs in 2012, but grow steadily as both investments and electricity savings increase over time. But 2030, the net employment benefits reach 46,939 jobs, about 0.27% of the jobs otherwise available in that year. Wages similarly increase to just short of $1.8 billion by 2030.

POLICY OPTIONS

By almost any measure, Texas has significant room for a cost-effective expansion of its electricity efficiency improvements—by a factor of four or more, depending on the criteria. Indeed, the evidence suggests that consumers and businesses alike can lock in significantly greater economic returns policymakers enable a more effective market response. To summarize, although the current policy objective is a cost-effective target, it yields a much smaller net benefit for the state than might otherwise be available. While the remaining opportunities are significant, the market is likely unable to move toward a more energy-efficient economy without direction and policy guidance. Though not a major focus of this assessment, there are three policy mechanisms that may be helpful in building up a more robust energy efficiency market. These steps include: (a) establishing a more prosperous efficiency objective that, in cooperation with the market, provides appropriate guidance to businesses and consumers; (b) aligning performance-based incentives at a scale that reflects the desired policy target; and (c) exploring financial mechanisms that redirect investment opportunities toward those more productive outlays within the state's economy.

An Energy Efficiency Resource Standard

Corporate management guru Peter Drucker noted that objectives are the "fundamental strategy of a business." They must be capable of becoming the basis for work and achievement. More fundamentally, he suggested, objectives "must make possible the *concentration* of resources and efforts" to achieve a desired outcome (emphasis in the original; see Drucker 2008, page104). In that same spirit, if Texas wishes to ensure the widespread availability of cost-competitive electricity services, the first step is to establish a policy objective that highlights and promotes a larger set of net benefits. Again, current policy, identified as Scenario A in Table 2 of this report, only reduces the anticipated rate of growth of electricity consumption by 30% per year. This will save only 3.5% of the projected electricity demand in 2030 with a net cumulative savings of $1.3 billion over the period 2012 through 2030. On the other hand, Scenario E generated more than four times the level of net benefits, or $14 billion, by expanding productive investments in energy efficiency—on both the customer side of the meter (end-use efficiency) as well as the utility side of the meter (supply-side efficiency). Those energy efficiency benefits were achieved with an objective that saved 23% of the consumption otherwise projected in the year 2030.

How might this larger objective be set as a policy target that also includes reasonable milestones? As laid out in this report, the 23% savings are achieved by reducing the projected 2030 consumption at a 1.5% annual rate over the period 2012 through 2030. If state policy follows the trajectory shown in Figure 1, which includes both end-use and CHP or supply-side efficiency improvements, the market will generate the net benefits summarized as Scenario E in Table 2. But that depends on a somewhat elusive estimate of future consumption. The more direct route may be establishing an energy efficiency resource standard, or EERS, that achieves an annual savings relative to a recent historical value.

The strongest EERS requirements now exist in Vermont and Massachusetts, which require around 2.5% savings annually. In Arizona all investor-owned electric utilities have been ordered to achieve 2% annual savings beginning in 2013, increasing to 2.5% in 2016 and beyond. By 2020 the Arizona utilities should reach a 20% cumulative savings relative to their 2005 sales (Sciortino 2010). We can similarly translate the savings envisioned in Scenario E as a percent of historical sales rather than future sales. In fact, Table 5 below provides both a "future" and "historical" perspective for the three key scenarios whose costs and benefits are summarized in Table 2. In short, while the economic analysis in this report explored the net economic benefits of different energy efficiency scenarios from the vantage point of 2030 projected sales, Table 5 shows cumulative and annual savings from both the projected 2030 and the historical 2010 electricity sales in Texas.

Again, Scenario A reflects current policy, and the energy efficiency investments driven by the existing target show a small net savings when viewed from the 2030 vantage point. With the 2010 historical sales as the benchmark, however, Scenario A shows, instead, a significant 11.3% growth in electricity usage by 2030. In the same way, the Scenario E savings shows a savings of only 11.5% when compared to 2010 sales. If Texas were to adopt an EERS-like benchmark that is sufficient to generate the $14 billion in net benefits highlighted in the last column of the table, then the policy objective might be set at a 0.7% annual savings from the 2010 level of sales.

Table 5. Translating 2030 Future Targets into Impacts Based on 2010 Historical Sales

Policy Target	Total Savings as Percent From		Annual Savings Rate from 2012 through 2030		Net Benefits ($ Billions)
	2030 Projected	2010 Historical	2030 Projected	2010 Historical	
Scenario A	-3.5%	+11.3%	-0.2%	+0.6%	+$3.2
Scenario B	-5.9%	+8.6%	-0.3%	+0.5%	+$4.3
Scenario C	-13.2%	+0.2%	-0.8%	+0.0%	+$5.7
Scenario D	-18.2%	-5.6%	-1.1%	-0.3%	+$9.9
Scenario E	-23.3%	-11.5%	-1.5%	-0.7%	+$14.0
Scenario F	-30.1%	-19.4%	-2.0%	-1.2%	+$12.3

Finally, if Texas chooses to move closer to targets set in other states like Arizona, Massachusetts, and Vermont, then policymakers may want to think about adopting the greater total savings reflected in Scenario F. The net savings are somewhat smaller but the total job impacts are substantially larger as suggested in Table 2. There are two things of note when thinking about Scenario F as a possible policy objective. First, the 30% savings compared to the 2030 sales provides only a 19% reduction when benchmarked against 2010 historical data. This still generates a significant economic return, however. Second, the annual rate of efficiency gains necessary to achieve a 19% electricity savings increase from the 0.7% rate for Scenario E to an annual rate of 1.2% through 2030. At the same time, Texas consumers and businesses can enjoy the benefits of energy efficiency that much sooner by scaling up the target to compete with Arizona's 2.5% annual savings, requiring that the end date be moved up from 2030 to more like the year 2021.

Financial Mechanisms to Offset Rate Impacts

It remains the case that it still takes money to make money. For understandable reasons policymakers, consumers, and businesses may worry that however good the return, ratepayers may not be able to afford the potentially large scale investments suggested in Table 2. As with most any other policy decisions, the sum of the total program costs and efficiency investments should be reviewed in context. A critical first observation is that Texans will pay a total of $28 billion for electricity services in 2012. This will rise to nearly $39 billion by 2030. Over the timeframe of this analysis (again 2012 through 2030), the cumulative electricity expenditures in Texas will be about $622 billion (in undiscounted 2009 constant dollars). Unpacking the total costs shown in Table 2 to also remove the effect of discounting (and also reflecting only 2009 constant dollars), the electricity savings in Scenario E will require a total investment on the order of $21 billion while Scenario F will require $36 billion. Those program costs and investments are only 3.3% and 5.7% of the reference case electricity expenditures for Scenarios E and F, respectively. At the same time, both scenarios are anticipated to save residential, commercial, and industrial consumers a cumulative of $50 billion and $60 billion, respectively. So the good news is that the investments appear to be entirely affordable.

Even if a given policy is affordable over the long run there are still legitimate concerns about initial ratepayer impacts. In another recent study of utility energy efficiency programs, ACEEE researchers found that utilities directly funded anywhere from 30% to 60% of total program costs and investments (Friedrich et al. 2009). This also includes incentives that might induce further customer participation. If we assume that Texas utilities fund up to 40% of total costs for Scenario E, it turns out that this might add $1.43 to the average residential customer's monthly bill over the full period of analysis. At the same time, households will save an average of nearly $6 per month of the 19-year period.[17] Assuming the same 40% share of utility program spending, the larger set of expenditures in Scenario F would push monthly household expense to $3.18 with the concomitant increase in benefits rising to more than $8

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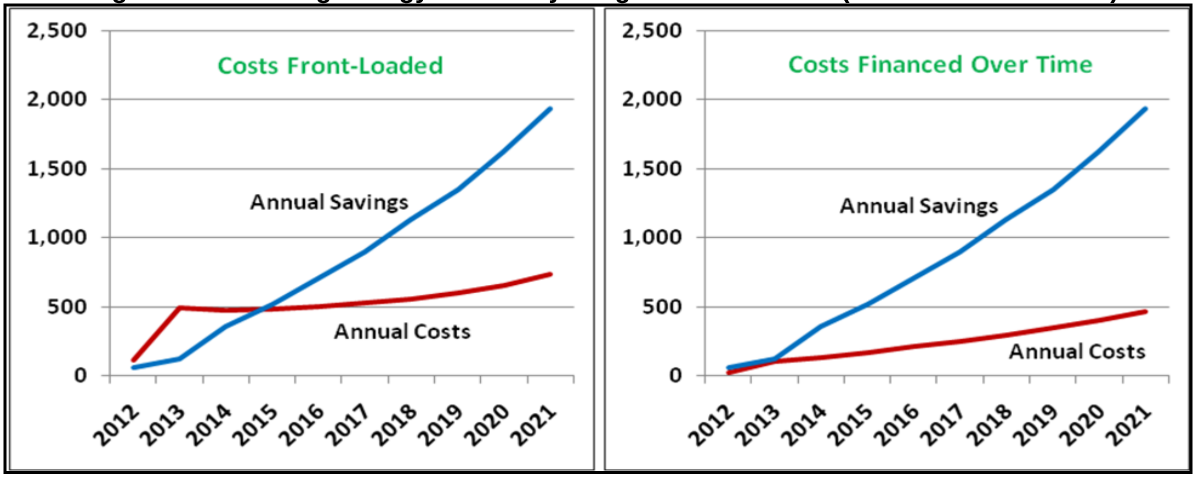
[17] Even customers who are not able or do not choose to participate in any energy efficiency programs would benefit in significant ways, albeit indirectly so. First, the penetration of greater energy efficiency measures would minimize the demand for more costly generating facilities, which would help maintain lower electricity costs for everyone. Moreover, the downward pressure on power plant generating fuels, especially natural gas, would lower the cost of energy for all remaining purposes whether heating the homes with natural gas or reducing the utility expenditures for those fuels. Finally, as the economy is strengthened and the electricity bill savings are translated into lower consumer costs, the purchasing power of all customers would likely increase.

per month.[18] To bring the monthly residential cost in Scenario F back down to levels reflected in Scenario E, the utility share of direct expenditures would need to drop from 40% to about 18%. At the same time, if Texas chooses to accelerate the program benefits—in effect, to spend roughly the same amount of money over a shorter time horizon, that will also increase the monthly customer charge. Hence there is a need to integrate an active financial market to pick up a greater share of the total scenario costs. The good news here is that a robust financial market in Texas can, indeed, go a very long way to minimize or even mitigate prospective rate impacts. Figure 3 provides an illustration of this very real prospect.

Figure 3. Financing Energy Efficiency Programs Over Time (in Millions of Dollars)



The chart on the left in Figure 3 shows the impacts for the most aggressive Scenario F if the utilities and their customers are paying both the program costs and the full investment costs during the year in which the efficiency improvements are made. This includes the incentives that might be provided by utilities as well as the customer match of those incentives to cover the full balance of the required investments. In this example, looking out over a 10-year funding horizon for Scenario F (see Table 2 for the summary of net benefits and employment impacts), new programs are launched in 2012 and continue to accrue costs past 2021. The benefits steadily mount and continue well past 2021, as shown in this figure. And as can be seen, the area under the savings curve is clearly bigger than the area under the cost curve. But the quick ramping up of costs in the first three years does suggest a prospective need for a small increase in rates. The chart on the right in Figure 3, however, shows the same level of spending as those costs have been spread over the 10-year financing period. The assumption here is that a mix of state-authorized financing together with a blend of federal and private funds, together with on-bill financing might generate a weighted interest rate of 6% (for a more complete review of state finance options, see Saha, Gander, and Dierkers 2011). With the costs financed and spread over time, the programs immediately break-even and there is no "rate-shock" for consumers. Appendix A provides more detail on how program design, integrated with larger financial mechanisms might impact the overall monthly residential electricity rates.

Even without immediate concerns about reducing the upfront utility costs, the energy efficiency market will be greatly enhanced by encouraging and developing new finance mechanisms that more routinely channel low-cost capital into productive investments. One new business model that might work well as a complement to EERS program effort, the so-called "Aggregate Investment Model," has a number of design features that might allow the energy efficiency finance market to scale up the prospective "Texas-size" efficiency potential (Sweatman and Managan 2010). This emerging model has four key design features that might be enabled by state policymakers and business leaders: (i) the creation of a standardized set of energy efficiency assets; (ii) development of multi-channeled origination, (iii) on-bill repayment, and (iv) the potential for securitization with (or without) government credit enhancement.

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[18] These last calculations assume an average 11 million households in Texas over the full study period (Economy.com 2011). They further assume 19 years of program activity.

With this and other opportunities, the state may want to evaluate the development of this kind of financial mechanism to complement a more aggressive efficiency policy option. Not to be overlooked, however, is perhaps the need to also explore whether the current mix and size of financial incentives—for both the state's utilities and the many service providers and small to medium enterprises who will be tasked with building the efficiency market—are appropriate for the scale of the larger effort that is actually needed (Hayes et al. 2011).

FURTHER DISCUSSION

While the economic gains reported here are clearly positive, there are a number of issues that merit additional discussion. These include the impact such a transition might have on the electric utility sector and the cost of living within the state. Finally, it is helpful to review the context of this report as it might compare with other similar studies.

As might be expected, the electric utilities incur overall losses in jobs and compensation—at least initially. But this result must be tempered somewhat as the industries themselves are undergoing internal restructuring. For example, as the electric utilities engage in alternative energy investment activities, they will undoubtedly employ more people from the construction and service sectors (including engineering and business services). Hence the negative employment impacts within the traditional electric utility sector should not necessarily be seen as pure job losses, rather they might be more appropriately valued as a redistribution of jobs within the overall economy and future occupational tradeoffs.

Explained differently, while the electric utilities may lose an estimated 6,000 to 8,00 traditional jobs or more due to the selling of less electricity, they are likely to gain many if not all of those jobs back if they move aggressively into the energy efficiency and alternative energy generation services. In the results shown from this set of modeling runs, for example, employment in the construction and service sectors is up by 35,000 to 50,000 jobs in Scenario E, and even more in Scenario F. In effect, if utilities expand their participation in the energy efficiency and CHP markets (i.e., absorbing some of the job gains assigned to other sectors such as the construction and service sectors), their job totals could increase relative to the estimates based on a more conventional definition of an electric utility as an energy supplier.

In fact, there are five big "winners" under the alternative energy scenario. These are the construction, manufacturing, services, trade, and finance sectors. These sectors are winners largely for two reasons. First, they benefit from the actual investments in energy efficiency programs and renewable technologies made cumulatively through the year 2030. Second, they benefit from the higher level of goods and services produced and sold specifically in Texas as ratepayers and businesses re-spend their energy bill savings elsewhere in the economy and as investments are made in energy efficiency and renewable technologies. Again, sectors that appear to be losers might actually benefit from an alternative energy policy if they interpret the market transition as a signal to diversify their business into these new markets.

Yet another perspective on the impacts from the alternative policy scenario is the potentially positive effect on the cost of living in Texas. In a first calculation, some analysts might point out from Table 1 that the electric utility industry supports an average wage of $60,000 ($140,000 divided by 2.4 jobs). At the same time, the additional 47,000 jobs in the policy scenario, together with the added $1.8 billion in wage and salary compensation, may support an average wages of only $38,000. Hence, we might have slightly more jobs but at a smaller average compensation. At the same time, however, the $14 billion (rounded) in net consumer savings shown in Table 2 is considerably larger than the implied loss in average job compensation. While not a strictly comparable set of results, the lower cost of living implied by the alternative policy scenario is likely to provide a much larger benefit compared with the smaller net wages implied by the net increase in jobs.

In addition to wage-driven concerns, there are some early transition job losses that might occur if the scenario moves too aggressively toward the alternative policy scenario in ways that quickly ramp down jobs from power plant construction. The reason is that there are large ongoing jobs within the utility and construction sectors that, if immediately stifled rather than transitioned to new construction and engineering jobs, could reduce employment by a small amount in the period generally 2011 through 2014. At the same time, however, it is clear that the net employment effects from the alternative policy scenario are both steadier and more sustainable compared to traditional power plant expansion. This impact is a fairly robust one that is consistent with any number of other similar state-level studies (See, for example, Laitner, Eldridge, and Elliott 2007, Bailie et al. 2001, and Bernow et al. 2000).

Perhaps one particularly useful comparison to underscore the robustness of the results in this assessment is a 1998 study funded by the Texas Department of Economic Development (Goldberg and Laitner 1998). Like the current study, the 1998 assessment analyzed the economic benefits of accelerated investments in energy efficiency and renewable energy technologies. It analyzed two alternative energy strategies for Texas.

The first assessment in the 1998 study followed a so-called “moderate” energy path. That scenario—looking from a 1998 vantage point out to the year 2010 (hence, a 12-year time horizon compared to the 15-year study period examined here)—identified a cumulative electricity bill savings of about $22 billion. The second alternative energy strategy for Texas followed what was termed an “advanced energy course.” That strategy identified a potential savings of about $32 billion in lowered electricity bills over that 12-year study period (i.e., 1998 through 2010). Using a similar input-output model of the Texas economy, the 1998 report suggested a net employment increase between 36,300 and 49,300 jobs by 2010. Despite the changes in base years, electricity prices, and sector productivity gains, the results of the 1998 and the current study are reasonably similar. Hence, we might plausibly conclude that increased investments in both energy efficiency and renewable energy technologies would be an important step toward promoting a sustainable economic and energy future for the state.

CONCLUSION

Texas is one of the most rapidly growing states in the country. One of the critical concerns in maintaining the robustness of the Texas economy is supporting the growing demand for electricity—especially when that growth is rising more quickly than for the United States as a whole. The challenge is to meet the new demand for electricity in ways that maintain competitive electricity costs and also reduce environmental impacts. In March 2007, ACEEE published a report suggesting that a combination of energy efficiency and renewable energy technologies can meet the growing need for electricity (Elliott et al. 2007). The findings of that report indicated that the alternative energy efficiency and renewable energy scenario could help stabilize overall energy prices, lower electricity bills, and increase system reliability within the state’s utility sector. A subsequent report (Laitner, Eldridge, and Elliott 2007) confirmed those initial results and further suggested a net employment benefit for Texas of about 38,000 new jobs by 2023. The question answered in this companion study is whether an updated alternative policy scenario could enable, perhaps even spur, continued economic growth within Texas.

In this follow-up to the 2007 assessments, we review the macroeconomic impacts that likely would unfold under these alternative policy recommendations. Generally, we find that cost-effective investments in the combination of energy efficiency and alternative generation technologies can actually reduce overall electricity costs, boost net employment, and reduce air pollutants within the state. For example, by 2030 (the last year of this analysis), businesses and households in Texas are expected to enjoy a net savings of more than $12 to $14 billion. As a result of this greater energy productivity, the state would likely show a net employment increase of perhaps 50,000 to 100,000 jobs. This is roughly equivalent to the employment that would be directly and indirectly supported by the construction and operation of 400 to 800 small manufacturing plants within Texas. The extent to which these benefits are realized will depend on the willingness of business and policy leaders to implement the recommendations that are found in the earlier assessment.

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APPENDIX A. EXAMINING RATEPAYER IMPACTS OF ENERGY EFFICIENCY PROGRAMS

Across any number of assumptions, energy efficiency investments will generate substantially larger returns for Texas compared to many standard investments. Over the past two hundred years, for example, the real equity market returns have averaged 7% (Siegel 2001). On the other hand, energy efficiency investments with a 3-year payback can be said to generate a 33% return while those with a 7-year payback can be said to generate a 14% return (where the efficiency return is estimated as the reciprocal of the payback period). Still there is understandable concern for the potential impact energy efficiency programs might have on ratepayers. This appendix provides a comparison of the different ways we might estimate the impact of energy efficiency programs on residential or household monthly electricity bills.

The current rule enforced by the PUC now caps residential customer costs for energy efficiency programs at $1.30 per month in 2011 and 2012. These increase to $1.60 per month in 2013 (see, for example, Frontier Associates 2011). But what might these rate impacts look like over time? How might financing the efficiency improvements modify residential rate impacts? Because the efficiency gains are so cost-effective, programs that target any of the major end-use sectors can benefit from a variety of flexibility mechanisms that provide the initial upfront capital while still minimizing consumer rate impacts over time.

As it turns out, the monthly rate impacts will vary according to the scale of efficiency gains that are needed to offset expected growth in electricity sales. They will further vary as the number of households grow over time and the share of energy efficiency savings are obtained from within the residential sector compared to the economy as a whole. They can also differ as a function of total costs necessary to drive the required savings. More expensive programs will drive up potential rate impacts. The array of costs that will impact rates include program costs, consumer incentives, and the size of the matching funds that participating households will need to contribute to the total investments that are made. Another factor in the costs is how well the utilities and other service providers market not only the electricity bill savings but also the many non-energy benefits associated with efficiency upgrades (Amann 2006, Knight et al. 2006). Finally, the rate impacts will change as the greater energy efficiency gains put a downward pressure on the costs of fuels needed to power the remaining generating plants. Table A-1 illustrates an indicative set of outcomes for the six scenarios described in the main body of the report.

Table A–1. Estimating Residential Rate Impacts

Overall Efficiency Target	Total Efficiency Gains from 2030 Forecast	Net Economy-Wide Benefits 2012 to 2030 ($ Billions)	Residential Electricity Savings as % of Total	Residential Monthly Cost if Expensed	Residential Monthly Cost if Financed
Scenario A. Current Policy—Efficiency Provides 30% of Growth in Demand	3.5%	$3.2	48%	$0.24	$0.16
Scenario B. Current Policy—Efficiency Provides 50% of Growth in Demand	5.9%	$4.3	48%	$0.45	$0.26
Scenario C. Efficiency Holds Electricity Use at Current Levels	13%	$5.7	48%	$1.43	$0.64
Scenario D. Electricity at Current Levels Plus 2,800 MW New CHP Capacity within the Industrial Sector	18%	$9.9	35%	$1.43	$0.64
Scenario E. Electricity at Current Levels Plus 5,600 MW New CHP Capacity within the Industrial Sector	23%	$14.0	27%	$1.43	$0.64
Scenario F. Electricity at 8% Below Current Levels Plus 5,600 MW New CHP within the Industrial Sector	30%	$12.3	32%	$3.18	$1.22

The table above integrates the residential cost assumptions summarized for the various scenarios in Table 2 of the main report. It then compares the residential ratepayer costs as a function of whether all utility program costs and incentives are expensed or financed over the 2012 to 2030 time horizon. In general the very modest gains suggested in Scenario A reflect a 2-year payback over the 19-year period of analysis. On the other hand, the greater level of efficiency gains in Scenario F pushes the typical payback from 2 years up to 7 years by 2030 (as suggested in the data in Table 1). As a result, the costs to be recovered are much greater. If expensed, the full costs of the incentives given to participating consumers are borne in the year in which the improvements are made. If financed (assuming a 6 percent interest rate paid out over a 20-year period), the incentives are spread out over time in the form of the annualized payments made to the financial market. Moreover, the table further assumes that only 40% of the total program costs and incentives are paid by all residential ratepayers. As we might imagine, a lower percentage would reduce rate impacts since the consumers who immediately benefit from the efficiency gains would pick up more of the costs compared to ratepayers as a whole.

Under the conditions described above, and with the current policy extended out to the year 2030 (Scenario A), the average monthly cost to residential ratepayers is estimated to be 24 cents if expensed and 16 cents if the costs are financed over time. Pushing a greater level of savings as shown in Scenario F suggest a monthly consumer rate impact of $3.18 if expensed, and $1.22 if financed. The important insight from Table A-1 is the positive benefit of integrating a strong financing mechanism into any energy efficiency policy that Texas might choose to pursue. Just as the investments in power plants are recovered over time to avoid rate shock, so might we also envision energy efficiency investments to be spread out over time to also minimize the impact on consumer rates. Depending on the many different variables and program designs, financing rather than expensing such improvements can easily cut the rate impacts for consumers by half—while still enabling the larger energy productivities to benefit the state's economy.[19]

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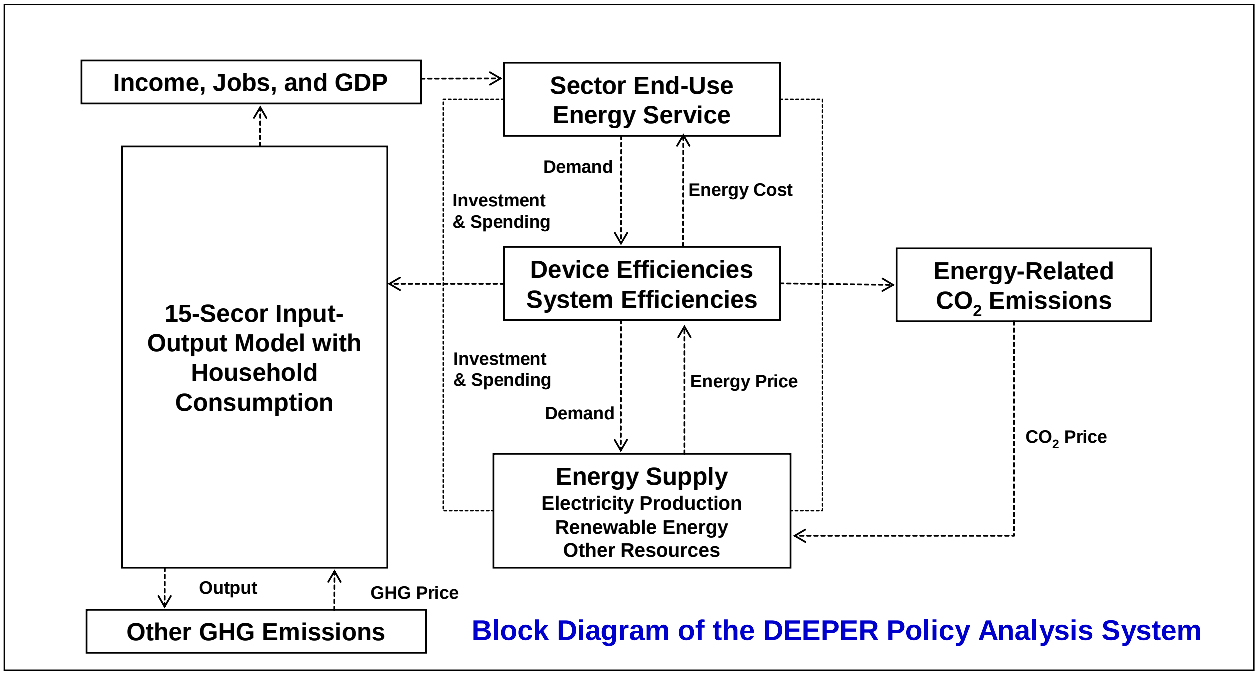
[19] Although not explored in this appendix or elsewhere in the report, one can also imagine the financing of program administrative and R&D costs over time as well as the actual efficiency investments. If that legal authority is developed with sufficient scale, and if that specific objective is pursued as part of the program objective, one can further imagine a rate impact that is closer to zero. In effect, the benefiting consumers would then be picking up all of the costs as well as enjoying the full array of energy and non-energy savings associated with the improvements.

APPENDIX B. METHODOLOGY OF THE DEEPER MODELING SYSTEM

The **D**ynamic **E**nergy **E**fficiency **P**olicy **E**valuation **R**outine — the DEEPER Modeling System — is a 15-sector quasi-dynamic input-output model of the U.S. economy.[20] Although an updated model with a new name, the DEEPER model has an 18-year history of use and development. See Laitner et al. (1998) for an example of an earlier set of modeling results. Laitner and McKinney (2008) also review past modeling efforts using this modeling framework. The model is used to evaluate the macroeconomic impacts of a variety of energy efficiency, renewable energy, and climate policies at both the state and national level. The timeframe of the model for evaluating policies at the national level is 2010 through 2050, or in the case of evaluating the variety of energy efficiency and CHP technologies in this study, the period 2010 through 2030. As we chose to implement it for this analysis, the model maps in the changed spending and investment patterns based on the off-line analysis described in the main body of the report. It then compares that changed spending pattern to the employment impacts assumed within a standard reference case.

Although the DEEPER modeling system includes a representation of both energy-related CO_2 emissions and all other greenhouse gas emissions, in this analysis it focuses on the use of energy in all sectors of the economy. DEEPER is an Excel-based analytical tool with three linked modules combining approximately two dozen interdependent worksheets. The primary analytic modules are: (i) the Energy and Emissions Module, (ii) the Electricity Production Module, and (iii) the Macroeconomic Module. The block diagram of the DEEPER Modeling System below lays out the analytical framework of the model.



Block Diagram of the DEEPER Policy Analysis System

The model outcomes are usually driven by the demands for energy services and alternative investment patterns as they are shaped by changes in policies and prices. In this case, however, because the economy-wide impacts are reasonably small, we maintain the current set of electricity and other prices

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[20] There are two points worth noting here. First, the model solves recursively. That is, the current year set of prices and quantities is dependent on the previous years' results. As the model moves through time, there are both secular and price-quantity adjustments to key elasticities and coefficients within the model. Second, there is nothing particularly special about this number of sectors. The problem is to provide sufficient detail to show key negative and positive impacts while maintaining a model of manageable size. If the analyst chooses to reflect a different mix of sectors and stay within the 15 x 15 matrix, that can be easily accomplished. Expanding the number of sectors will require some minor programming changes and adjustments to handle the larger matrix.

as established by the *Annual Energy Outlook 2011* projections (EIA 2010). This tends to provide a conservative result in that even small downward pressure on the price of remaining uses of energy would provide further net benefits to the larger economy. Although the DEEPER Model is not a general equilibrium model, it does provide sufficient accounting detail to match import-adjusted changes in investments and expenditures within one sector of the economy and balance them against changes in other sectors.[21]

In addition to energy prices as noted above, the DEEPER Model is benchmarked to the Texas macroeconomic parameters of Economy.Com (2011) and the *Annual Energy Outlook* 2011 (EIA 2010), which now extends out through 2035. In the event we want to provide an assessment over a longer time horizon, as noted earlier, and shown in the table below, the model has the capacity to evaluate policies through the year 2050.

Key Reference Case Scenario Data for DEEPER Policy Runs in Key Benchmark Years

Indicator	**2010**	**2012**	**2020**	**2030**	**Annual Growth Rate 2010-2030**
Total Population (Thousands)	25,239	26,143	30,118	35,443	1.71%
Total Employment (Thousands)	12,160	12,511	14,548	17,141	1.73%
Gross State Product (Billions of 2009 Dollars)	1,117	1,223	1,620	2,117	3.25%
Total Electricity Consumption (Million kWh)	358,218	364,511	388,338	413,304	0.72%
Residential Electricity Price (2009 $/kWh)	0.115	0.103	0.108	0.119	0.17%
Average Electricity Price (2009 $/kWh)	0.090	0.077	0.081	0.094	0.20%
Residential Electricity Bill (Billion 2009 $)	16.0	14.0	15.2	18.1	0.63%
Total Economy-Wide Electricity Bill (Billion 2009 $)	32.3	28.0	31.4	38.8	0.92%

The main reference case assumptions are shown in the table above for key benchmark years 2010 through 2030. In general the Texas economy is expected to grow at a rate of about 3.2% (rounded) annually; total end-use electricity consumption will grow 0.7% per year. Rising electricity prices, growing at about 0.2% per year in real terms (with all values in 2009 dollars) will increase total household electricity expenditures at a rate of about 0.9% annually. This will escalate electricity expenditures from an estimated $28 billion in 2012 to about $39 billion by 2030.

In this macroeconomic module of DEEPER, a set of spreadsheets contains the "production recipe" for the U.S. economy for a given "base year." For this study, the base year used was 2009. The input-output (or I-O) data, currently purchased from the Minnesota IMPLAN Group (IMPLAN 2011), is essentially a set of economic accounts that specifies how different sectors of the economy buy (purchase inputs) from and sell (deliver outputs) to each other. Further details on this set of linkages can be found in Hanson and Laitner (2009).

For this study, the model was run to evaluate impacts of the selected policies upon 15 different sectors, including: Agriculture, Oil and Gas Extraction, Coal Mining, Other Mining, Electric Utilities, Natural Gas Distribution, Construction, Manufacturing, Wholesale Trade, Transportation and Other Public Utilities (including water and sewage), Retail Trade, Services, Finance, Government, and Households.[22] As described below, examining the job intensities of the different sectors in Figure 2 in the main report provides early insights of likely scenario outcomes.

The principal energy-related sectors of the U.S. economy are not especially job-intensive. It turns out, for example, that the in Texas the electricity sector supports only 3.4 direct and indirect jobs for every one million dollars of revenue received in the form of annual energy bill payments. The rest of the

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[21] When both equilibrium and dynamic input-output models use the same technology assumptions, both models should generate reasonably comparable set of outcomes. See Hanson and Laitner (2005) for a diagnostic assessment that reached that conclusion.

[22] While there are only 14 sectors shown in the table above, household spending is allocated to each of the sectors using the personal consumption expenditure data provided with the IMPLAN data set.

economy, on the other hand, supports between 5 and 12 direct and indirect jobs per million dollars of receipts (again, see Figure 2 in the main part of the report). *Thus, any productive investment in energy efficiency that pays for itself over a short period of time will generate a net energy bill savings that can be spent for the purchase of goods and services other than energy.* The impact of a one million dollar energy bill savings suggests there may be roughly a net gain of about 6 jobs (that is, 9 jobs supported by a more typical set of consumer purchases compared to the 3 total jobs supported by the electric utilities). Depending on the sectoral interactions, however, this difference may widen or close as the changed pattern of spending works its way through the model, and as changes in labor productivity changes the number of jobs needed in each sector over a period of time.[23]

Based on the scenarios mapped into DEEPER, the set of worksheets in the Macroeconomic Module translates the selected energy policies into an annual array of physical energy impacts, investment flows, and energy expenditures over the desired period of analysis. DEEPER evaluates the policy-driven investment path for the various appliance efficiency standards, as well as the implied energy bill savings anticipated over the modeling time horizon (again, through 2030 for this analysis). It also evaluates the impacts of avoided or reduced investments and expenditures otherwise required by the electric generation sector. These quantities and expenditures feed directly into the final demand worksheet of the module. The final demand worksheet provides the detailed accounting that is needed to generate the implied net changes in sector spending.

Once the mix of positive and negative changes in spending and investments has been established, the net spending changes in each year of the model are converted into sector-specific changes in final demand. This then drives the input-output model according to the following predictive model:

$X = (I-A)^{-1} * Y$

where:

X = total industry output by sector
I = an identity matrix consisting of a series of 0's and 1's in a row and column format for each sector (with the 1's organized along the diagonal of the matrix)
A = the matrix of production coefficients for each row and column within the matrix (in effect, how each column buys products from other sectors and how each row sells products to all other sectors)
Y = final demand, which is a column of net changes in spending by each sector as that spending pattern is affected by the policy case assumptions (changes in energy prices, energy consumption, investments, etc.)

This set of relationships can also be interpreted as

$\Delta X = (I-A)^{-1} * \Delta Y$

which reads, a change in total sector output equals the expression $(I-A)^{-1}$ times a change in final demand for each sector.[24] Employment quantities are adjusted annually according to exogenous assumptions about labor productivity in each of the sectors within the DEEPER Modeling System (based on Bureau of Labor Statistics forecasts; see BLS 2009). From a more operational standpoint, the macroeconomic module of the DEEPER Model traces how each set of changes in spending will work or ripple its way through the U.S. economy in each year of the assessment period. The end result is a net change in jobs, income, and GDP (or value-added).

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[23] Note that unlike many policy models, DEEPER also captures sector trends in labor productivity. That means the number of jobs needed per million dollars of revenue will decline over time according to sector-specific trends published by BLS (2009). For example, if we assume a 1.9% labor productivity improvement over a 20-year period, one million dollars today might provide work for 12 people; by the year 2030, however, it might be more like 8 jobs.

[24] Perhaps one way to understand the notation $(I-A)^{-1}$ is to think of this as the positive or negative impact multiplier depending on whether the change in spending is positive or negative for a given sector within a given year.

For each year of the analytical time horizon (i.e., 2012 to 2030 for the efficiency gains evaluated in this report), the model copies each set of results into this module in a way that can also be exported to a separate report. For purposes of this separate report, and absent any anomalous outcomes in the intervening years, we highlight the decadal results in order to focus attention on the differences in results emerging from various alternative policy scenarios. For a review of how an I-O framework might be integrated into other kinds of modeling activities, see Hanson and Laitner (2009). While the DEEPER Model is not an equilibrium model, as explained previously in this appendix, we borrow some key concepts of mapping technology representation for DEEPER, and use the general scheme outlined in Hanson and Laitner (2009). Among other things, this includes an economic accounting to ensure resources are sufficiently available to meet the expected consumer and other final demands reflected in different policy scenarios.