ASSESSING THE COSTS AND BENEFITS OF UTILITY ENERGY EFFICIENCY PROGRAMS IN HUMBOLDT COUNTY, CA

HUMBOLDT STATE UNIVERSITY

By

Lucas E. Scheidler

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ABSTRACT

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An assessment of the energy efficiency potential, the costs, and the economic impacts of utility efficiency programs in Humboldt County, California is provided in this thesis. The county is currently assessing the feasibility of meeting at least 75% of their electricity needs with renewable energy. As such, Humboldt County is in particular need of cost-effective efficiency programs to reduce demand and limit the costly renewable energy capacity they must install.

Aggressive utility efficiency programs could save 830 GWh and 4.56 MMtherms in existing residential and commercial buildings over the next 20 years (approximately 4% and 1% of yearly electricity and natural gas use, respectively). These savings could be achieved at an estimated cost to the utility of no more than $0.05/kWh and $0.34/therm. These costs are 14% below the Humboldt Bay Generating Station's marginal generation cost and 49% less than PG&E's natural gas acquisition costs.

These programs are anticipated to have positive net economic impacts in Humboldt County. A fully customizable Energy Efficiency Impact Assessment Model (EEIAM) was developed to calculate economic impacts from efficiency investments. It

is estimated that 5.4 full-time jobs/yr will be created installing efficiency measures and administering local programs with associated earnings of $247,000/yr and increased countywide economic output of $895,000/yr. Additionally, consumer energy bill savings are anticipated to be $3.7 million/yr. When a portion of these savings are spent within the community, an estimated 9.0 net full time jobs/yr would be induced, with associated net earnings of $214,000/yr and countywide net economic output of $872,000/yr.

ACKNOWLEDGMENTS

The research in this thesis was conducted largely a result of my work at the Schatz Energy Research Center. I would like to thank everyone at the Schatz Lab for both the opportunity to work with them and for their critical insight and guidance. Jim Zoellick, Charles Chamberlin, Collin Sheppard, and Peter Alstone were particularly helpful in the technical analysis of energy efficiency, and Eileen Cashman was a valuable committee member. Many thanks are extended to Steve Hackett. As my supervisor at the Schatz Lab and thesis committee chair, he has provided me with opportunity, guidance, and continual support. Because of him, I emerge from this master's program with an unanticipated but invaluable set of tools and the skills to put them to work.

Special thanks are due to Matthew Marshall and Dana Boudreau of the Redwood Coast Energy Authority for the tireless efforts to promote energy efficiency in the county and their insight into my research. Thanks are also due to Jean Shelton of Itron, Inc for providing me with the primary dataset used in this analysis. Marshall Goldberg, of MRG and Associates, was instrumental in my understanding of the economic analysis methods utilized in this thesis.

Finally, I am eternally grateful for the love and support of my family, which has given me endless opportunity. My parents, brother, and I all became interested in energy and sustainability several years ago, and we have all continued to learn about these topics

on separate but interwoven paths. Their knowledge, passion, and perspective have given me inspiration and direction.

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CHAPTER 1. INTRODUCTION

Energy is a crucial and pervasive component of our lives. Among a myriad of applications, we use enormous amounts of energy to construct buildings, process and cook food, manufacture cars, and to light, heat, and cool our homes. According to the Energy Information Administration, total U.S. electricity demand in 2008 was 3,873 billion kilowatt hours (kWh) with an expected growth to 5,021 billion kWh by 2035 (EIA 2010). The vast majority of this electricity (~71%) is currently produced by burning fossil fuels (EIA 2010). U.S natural gas demand is expected to grow modestly from 23.3 trillion cubic feet in 2008 to 24.9 trillion cubic feet in 2035 (EIA 2010). Rising concerns over global climate change and domestic energy security have initiated a transition to renewable energy power production, but this movement faces multiple regulatory and technical hurdles, is capital intensive, and will take time. There are, however, steps that can be take right now to begin meeting our energy goals more sustainably. One of the largest, most practical, and least expensive of these is investing in energy efficiency.

Improvements in energy efficiency are widely recognized as a low cost means of reducing energy demand as well as being a low cost carbon mitigation strategy. Often overlooked, however, are the economic development benefits that accompany investment in energy efficiency. The State of California has been implementing progressive efficiency policies since the late seventies and is often held up as an example of successful energy efficiency efforts. The California Public Utilities Commission (CPUC) reports that, “California’s building and appliance standards have saved the State’s consumers over $56 billion in natural gas and electricity costs since 1978 and averted building 15 large power plants" (CEC and CPUC 2006). Roland-Horst (2008) estimates these consumer savings have created about 1.5 million jobs with a total annual payroll of $45 billion. California's building codes and appliance standards are regularly updated and should continue to reduce greenhouse gas emissions while saving utilities and consumers large amounts of energy and money. These successes should serve as a model nationwide. Even in California, though, over half of the building stock was in place before codes and standards were established. One of the most effective ways of improving the energy efficiency of the existing building stock is through utility energy efficiency programs.

This thesis assesses the energy efficiency potential, the costs of achieving that potential, and the economic impacts of utility energy efficiency programs in Humboldt County, California. Humboldt is a county of approximately 130,000 residents along California's northern coast that is progressive in its energy goals. As part of a California Energy Commission (CEC) funded Renewable Energy for Secure Communities (RESCO) grant, the Schatz Energy Research Center (SERC) is currently exploring the feasibility of meeting at least 75% of the county's electricity needs, as well as a significant portion of their heating and transportation needs, with renewable energy. As such, Humboldt County is in particular need of cost effective utility efficiency programs that will help them reduce their overall energy demand so as to limit the amount of costly renewable energy generating capacity they must install. This thesis developed as a result of the author's contributions to the *Humboldt County as a Renewable Energy Secure Community: Economic Analysis Report* (Hackett, Scheidler and Garcia Jr. 2011), which details the costs and economic development benefits of renewable energy and energy efficiency investment within the county.

This thesis finds that there is a considerable energy efficiency "resource" available in Humboldt County at a low cost. It is estimated that full incentive level efficiency programs could save 830 GWh and 4.56 MMtherms in the existing residential and commercial building stock over the next 20 years. This amounts to a 4 percent annual reduction in total electricity use and a 1 percent annual reduction in total natural gas use relative to 2008 countywide consumption (CEC 2011a). It is estimated that these savings could be achieved for $0.05/kWh and $0.34/therm, which is 14 percent lower than the marginal cost of generation at the Humboldt Bay Generating Station and 49 percent less than PG&E's natural gas acquisition costs.

Furthermore, full incentive level programs are anticipated to have a small but positive local economic development potential. A fully customizable Energy Efficiency Impact Assessment Model (EEIAM) was developed to calculate economic impacts from efficiency measure installation and energy bill savings. It is estimated that installing energy efficiency measures and administering the local programs would continuously employ 5.4 persons over the 20-year forecasting period. These jobs have anticipated earnings of $247,000/yr and an overall increase in the county's economic output of $895,000/yr. Additionally, consumer energy bill savings are anticipated to be $3.7

million annually. Saving on energy bills means that consumers will have more money to spend on local goods and services. An estimated 9.0 net full time jobs/yr would be induced from this savings, with associated net earnings of $214,000/yr and countywide net economic output of $872,000/yr.

The next chapter will provide background on energy efficiency programs and resource potential at the national, state, and local levels. An important concept to be drawn from this chapter is the large difference between the resource potential that technically exists versus the potential that is realistically achievable. It is useful to realize that ratepayer funded utility efficiency programs such as those analyzed in this thesis capitalize on just one component of the realistically achievable efficiency potential. Overcoming the real or perceived barriers to energy efficiency outlined in Chapter 2 would allow for substantially more energy savings and economic development than is currently possible through utility programs.

Chapter 3 presents the literature review on the economic impacts of energy efficiency investment. It begins by highlighting the results of several prominent studies and then examines the economic modeling techniques employed. The literature review concludes with a thorough discussion of input-output economics, which is the analysis method utilized in this study to estimate economic impacts.

Chapter 4 details the methods used to estimate energy efficiency potential, cost, and consumer energy bill savings in Humboldt County. The methods chapter also describes the process and assumptions used in building the EEIAM. Chapter 5 presents the full results of this thesis as well as a discussion of the policy implications and possible strategies for Humboldt County to begin capitalizing on the energy savings and economic development opportunities from energy efficiency. Finally, the major conclusions and caveats of this study are presented in Chapter 6.

CHAPTER 2. BACKGROUND

Energy efficiency is defined as the ratio of energy services provided to the quantity of energy consumed (EIA 2010). When consumers purchase electricity or natural gas, they rarely care how many units of energy they are buying. Instead, they are concerned with the level of energy services they receive from that purchase. For instance, replacing a 100-watt incandescent light bulb with a 23-watt compact fluorescent (CFL) bulb can provide the same level of lighting service while using less than one quarter of the energy in the same time period. Thousands of currently available, inexpensive technologies such as this can maintain or increase our energy service levels while costing less and consuming less. Despite recent improvements in energy efficiency, it remains a substantial and largely underutilized energy resource worldwide.

The US Energy Efficiency Resource

Untapped energy savings are often referred to as an energy *resource*. While saved energy is not a physical *source* of energy, it is a way of displacing traditional electricity generation. Because investments could be made either to install additional generation capacity to meet growing demand or to reduce demand through efficiency and thus avoid installing additional capacity, these two energy *sources* are fully fungible. Several authoritative sources present varied estimates of the energy efficiency resource in the United States. This is partially due to the inherent difficulty determining what would have happened without comprehensive efficiency programs. Estimating such a baseline requires assumptions about, among others, overall economic growth, technology advancement, public awareness, electricity prices, appliance standards, and building codes. Two of the most recent and comprehensive estimates of U.S. energy efficiency potential are the Electric Power Research Institute's (EPRI) *Assessment of Achievable Potential from Energy Efficiency and Demand Response Programs* (2009) and McKinsey and Company's *Unlocking Energy Efficiency in the U.S. Economy* (2009). For the electricity sector, the EPRI study uses the EIA's AEO 2008 Reference Case as the baseline while McKinsey and Company relies on its own analysis (which matches the Reference Case to within 1.2%). The Reference Case starts with a projected 2008 electricity use of 3717 terawatt hours (TWh) (~4% less than actual 2008 consumption) divided among the residential, commercial, and industrial sectors as depicted in Figure 1.

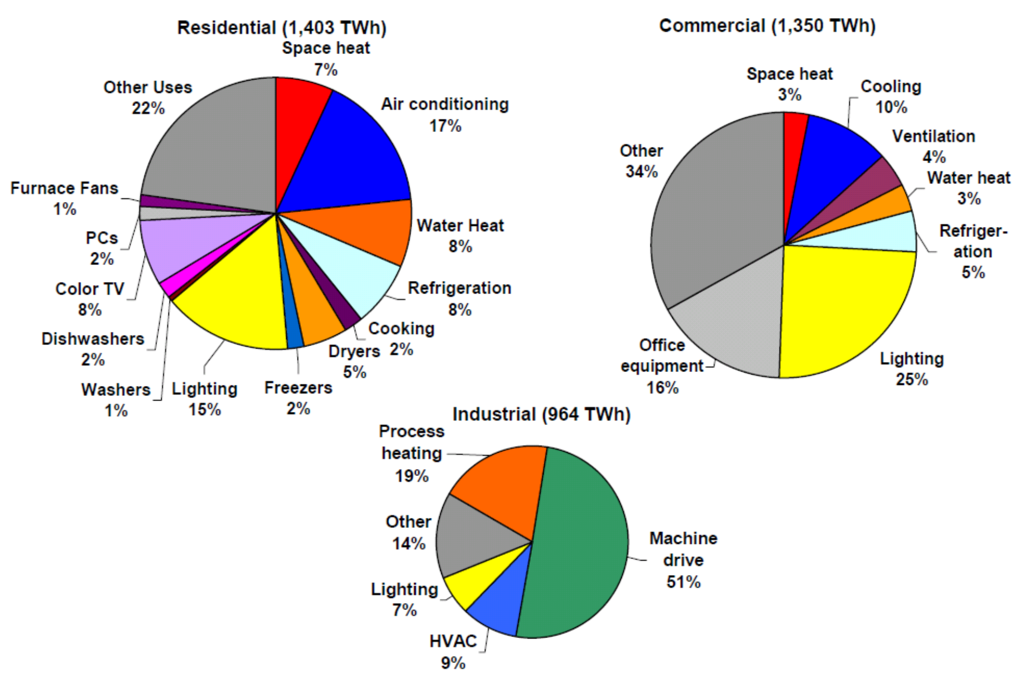

Figure 1. US Electricity Consumption by Sector and End Use (EPRI 2009)

From 2008 to 2030, the AEO 2008 projects a growth rate in electricity consumption across all sectors to be approximately 1.07%/yr. This is markedly less than that the 7.8% yearly growth rate observed in the pre-middle east oil embargo period (1950-1973) and the post-embargo (1974-2007) rate of 2.3%/yr. The forecast growth rate accounts for U.S. population, employment, Gross Domestic Product (GDP), value of shipments, housing starts, and building construction as the main macroeconomic drivers. During this time period, GDP is forecast to grow at more than twice the rate of electricity consumption (2.5%), indicating a decline in energy intensity per unit GDP.

This decline is a result of the Reference Case's inclusion of electricity savings from existing or expected efficiency drivers that are likely to occur even in the absence of future utility efficiency programs. These include:

- Codes and Standards
    - Existing federal, state, and local building efficiency codes
    - Existing appliance and equipment standards such as those defined in the 2007 Energy Independence and Security Act
    - Structural changes in the economy resulting in decreased energy intensity
- Market-Driven Efficiency
    - Energy efficient technology adoptions resulting from market-driven effects exogenous to implicit efficiency programs

- Implicit Programs
    - Savings impacts from existing utility sponsored efficiency programs

The estimated impacts from each of these efficiency drivers through 2030 are seen in Figure 2.

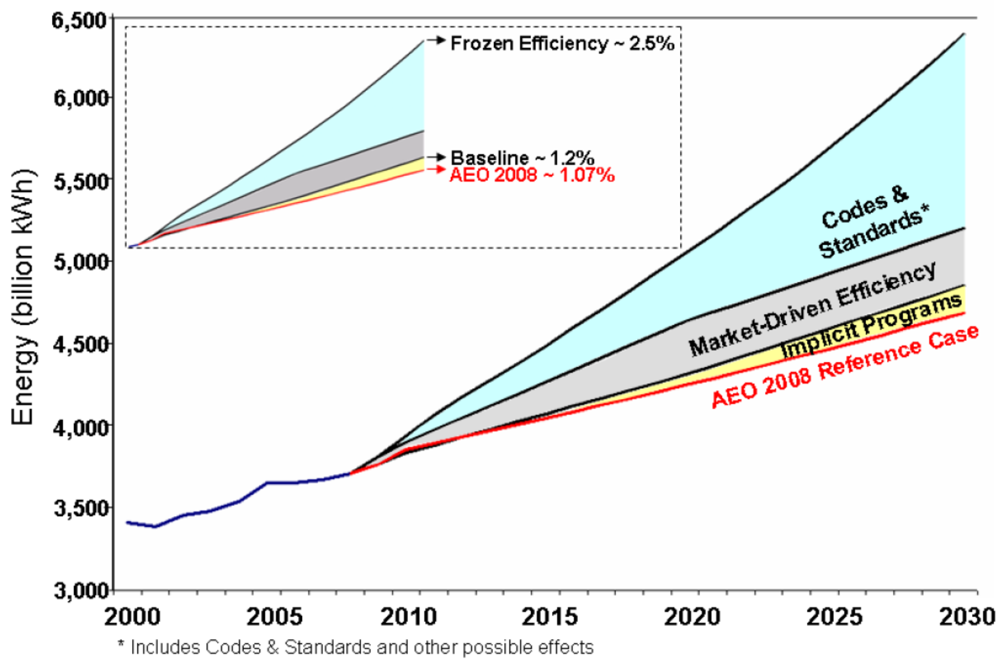

Figure 2. Impacts of Efficiency Drives Embedded in the AEO 2008 Reference Case (EPRI 2009)

The uppermost line in Figure 2 represents the estimated electricity consumption through 2030 if energy intensity were frozen at the 2008 level (0.33 kWh/$GDP, or an annual growth rate of 2.5%). Subtracting the forecasted savings from existing codes and standards, existing utility programs, and estimated impacts from naturally occurring market-driven efficiency results in the AEO 2008 Reference Case forecast growth rate of 1.07%/yr.

In order to quantify additional efficiency savings from utility programs (relative to the baseline), EPRI and McKinsey utilize a bottom-up approach in the residential and commercial sectors. A bottom-up approach begins with a detailed inventory of existing devices (measures) that consume electricity by region, sector, building type, and end-use category (i.e. water heating, lighting, refrigeration, etc.) and then uses that inventory to estimate the number of upgrades that could realistically be installed, the associated costs, and the realized energy savings. For the industrial sector, EPRI uses a top-down approach in which a savings estimate is made for the entire sector, which is then allocated to regions and end-uses. McKinsey employs a hybrid bottom-up, top-down approach for the industrial sector. These are common methodologies in energy efficiency potential studies and are consistent with those described in EPRI's "Energy Efficiency Planning Guidebook" (EPRI 2008) and the National Action Plan for Energy Efficiency "Guide to Conducting Energy Efficiency Potential Studies" (NAPEEE 2007).

<u>EPRI Results</u>

Using this approach, EPRI estimates a maximum achievable potential (MAP) in 2030 of 544 TWh and a realistic achievable potential (RAP) of 398 TWh.[1] The MAP and RAP amount to 8% and 5% reductions in consumption relative to the AEO reference case, respectively. The estimate for RAP translates into a 22% reduction in annual electricity consumption growth rate relative to the reference case (from 1.07%/yr to 0.83%/yr).

Using measure level cost information from Gellings, et al. (2006), EPRI calculates the cost of these reductions. Individual measure costs were weight averaged by their energy savings potential within each sector. A similar approach was used to aggregate costs across all sectors. After adding a 15% administrative cost, a lifecycle cost analysis was performed using a real discount rate of 10% and an average measure lifetime of 10 years.[2]

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[1] By EPRI's definition, MAP "takes into account those barriers that limit customer participation under a scenario of perfect information and utility programs. MAP involves incentives that represent 100% of the incremental cost of energy efficient measures above baseline measures, combined with high administrative and marketing costs." RAP "represents a forecast of likely customer behavior. It takes into account existing market, financial, political, and regulatory barriers that are likely to limit the amount of savings that might be achieved through energy-efficiency and demand-response programs," (EPRI 2009). Note that both MAP and RAP are subsets of economic potential, which ignores market barriers to adoption. Economic potential includes all measures that pass a cost effectiveness screening test called the participant test. This is a widely recognized method that compares the incremental cost of an efficient technology relative to the baseline technology and the monetary savings expected from that technology over its lifetime. Measures for which the net present value of benefits exceeds its incremental cost pass the test. Economic potential is a subset of technical potential, which is an estimate of energy savings that would results if all sectors installed the most efficient, commercially available technologies, irrespective of cost.

[2] EPRI acknowledges that these average administration costs and measure lifetimes are crude estimates, but in a study with such a large scope, some simplifying assumptions are required. Also, a 10% real discount rate is quite high but reflects the high cost of capital for utilities. Discount rates for energy efficiency analysis are commonly in the range of 5-10%.

This analysis resulted in a levelized cost of energy (LCOE) saved ranging from $0.0217/kWh in 2010 to $0.0322/kWh in 2030.[3]

McKinsey Results

The McKinsey analysis uses a somewhat different methodology than EPRI and was performed for a different purpose. While EPRI focuses on achievable potential based on current programs and best practices so as to inform utility program planners of the realistic opportunity for savings, McKinsey aims to quantify the economically advantageous energy savings opportunity that exists and identify barriers that keep the full economic potential from being realized. Rather than realistic achievable potential or maximum achievable potential, their quantification of energy savings is the "NPV-positive" potential. This means that all measures whose net present value of lifetime benefits (avoided direct energy, operation, and maintenance costs) exceeds the lifetime costs (direct equipment and installation) will be installed without regard to market barriers or customer behavior. This methodology results in a 2020 savings potential of 1080 TWh (approximately a 20% reduction relative to the 2020 baseline), which is nearly twice the MAP savings estimated by EPRI in 2030. Clearly however, these results are not strictly comparable. Figure 3 provides a summary of how these widely varied estimates are largely reconciled by evaluating EPRI's results for economic potential (rather than MAP) in 2020 and accounting for differences in methodology. The McKinsey estimate of economic potential is higher than EPRI's because McKinsey and

[3] A full description of the levelized cost of energy can be found in Chapter 4.

Company includes a wider set of efficiency measures, including emerging technologies, and they assume that many existing devices will be replaced with efficient ones before the end of their useful lives. Both studies, however, agree that there is an enormous economically advantageous resource available. While utility programs are one of the quickest and most straightforward modes of starting to capitalize on this resource, less than half of the economic potential is considered achievable through utility programs by EPRI. This suggests that significant barriers to energy efficiency are present that must be addressed if we are to take advantage of the full potential. Major barriers and possible solutions will be discussed below.

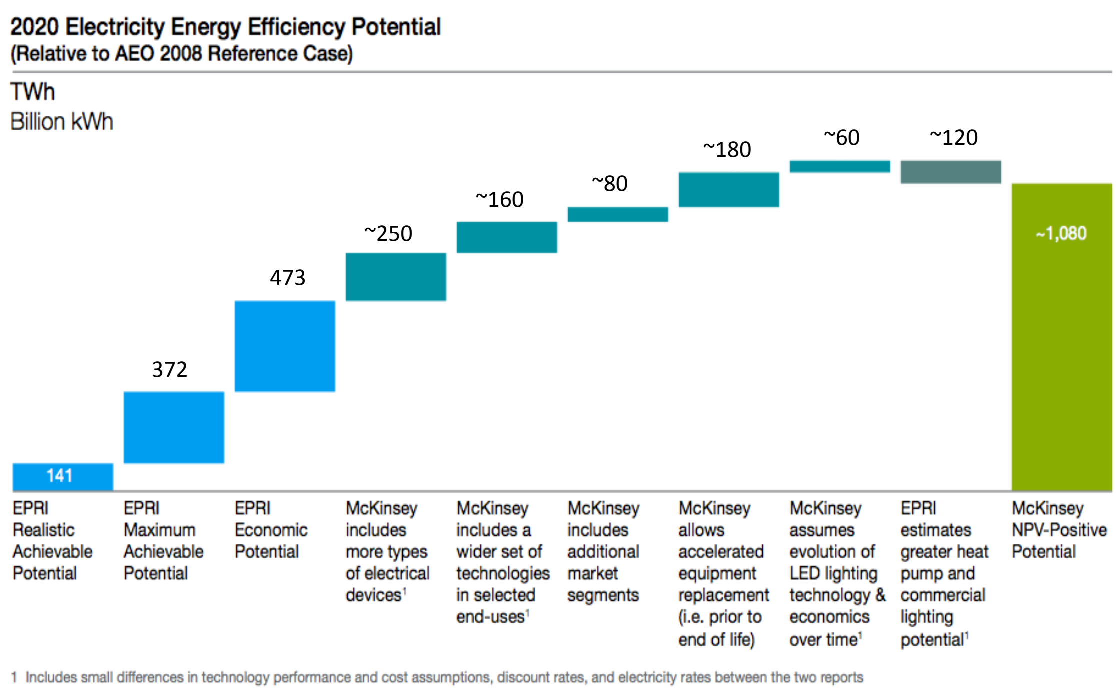


Figure 3. EPRI and McKinsey Results Comparison (McKinsey and Company 2009)

McKinsey does not disaggregate the costs of electrical energy efficiency implementation from natural gas efficiency costs so they cannot be compared directly. However, a recent study from the American Council for an Energy Efficient Economy (ACEEE) compiled data from existing utility efficiency programs in 14 states and found the average levelized cost of energy saved to be $0.025/kWh,[4] which is consistent with EPRI's more aggressive programmatic spending scenario (ACEEE 2009). In comparison, competitive renewable and conventional energy generation typically costs between $0.04/kWh and $0.15/kWh (Lazard Ltd. 2008).

Based on avoided marginal generation costs alone, energy efficiency programs are commonly attractive investments for utilities. This is to say nothing of ancillary benefits such as avoided climate change mitigation costs. If a carbon tax or cap and trade program is established in the U.S., energy efficiency will immediately become an even more appealing investment as a price on carbon would increase the cost of fossil fuel fired generation. McKinsey (2009) estimates that a realistic price of $30/ton of carbon dioxide equivalent (CO_2e) would increase the NPV-positive energy efficiency potential by almost 9%. They also estimate that if the full NPV-positive potential were captured, it would result in the abatement of 1.1 gigatons CO_2e/year by 2020 relative to the baseline. At $30/ton, this amounts to $33,000,000,000/year in avoided climate change mitigation costs in the US alone.

[4] Using a 5% discount rate.

Barriers to Energy Efficiency

Given the widespread agreement that energy efficiency is a high potential, low cost energy resource, the question arises as to why more of the potential has not been captured to date. A full discussion of the barriers and solutions to energy efficiency is beyond the scope of this thesis, but a brief overview is included here for context. Broadly speaking, there are three main factors that contribute to the difficulty of achieving an energy efficient economy. First, upfront investment costs in efficiency are substantial while benefits are realized in small increments spread out over the life of the measure. Second, energy efficiency potential is widely dispersed. It is comprised of billions of individual measures in millions of residential, commercial, and industrial buildings across the U.S. And third, evaluating, monitoring, and verifying the quantity of energy not consumed is inherently difficult. Within each of these broad categories, there are a number of individual barriers that are problematic on their own. When combined, they present a formidable challenge that must be addressed holistically through a number of complimentary solutions (McKinsey and Company 2009).

McKinsey presents four main categories of solutions to address these barriers:

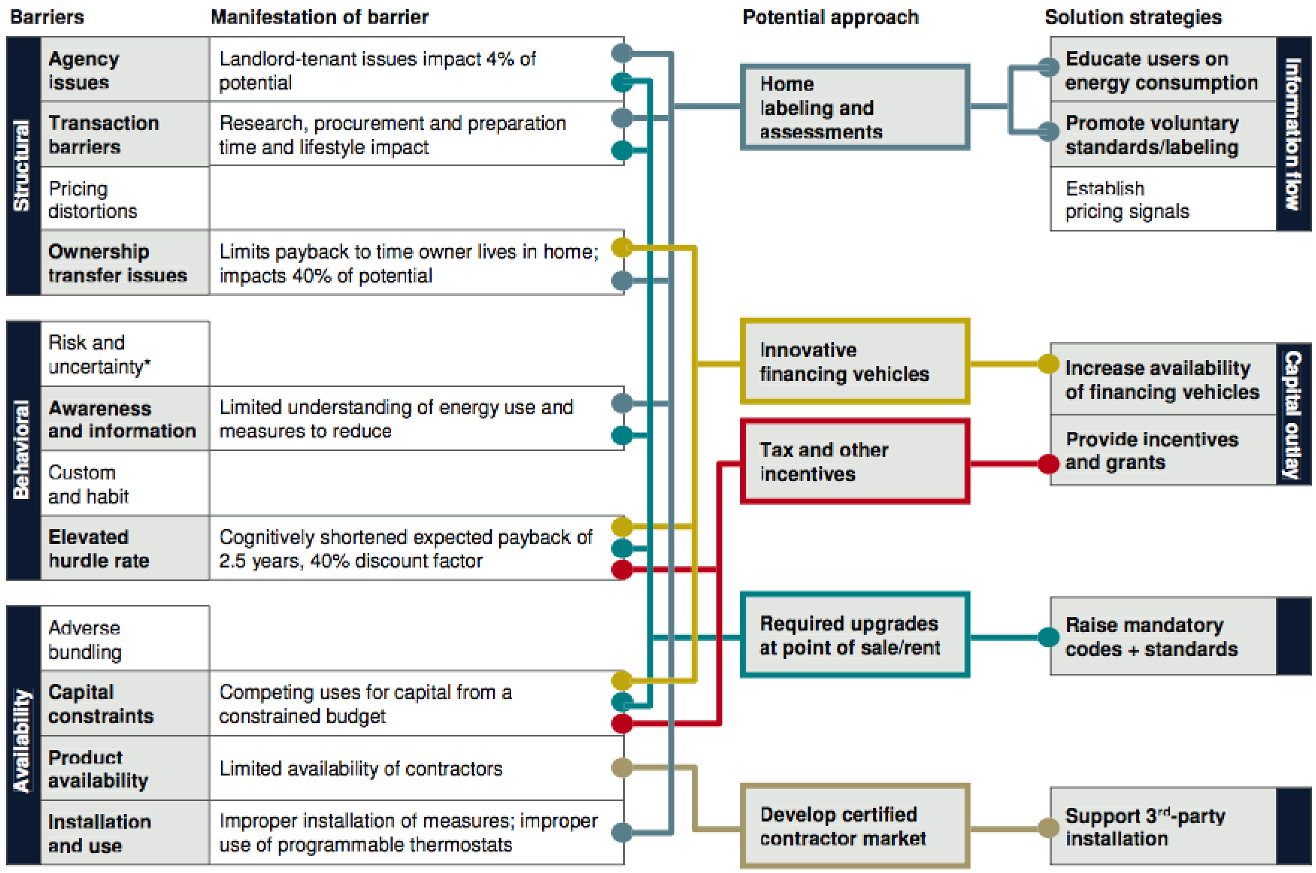
- Information and Education – Despite recent trends towards energy efficiency, overall customer awareness of its advantages remains low. A legitimate nationwide educational campaign on the financial benefits of investing in energy efficient measures coupled with subsidized energy audits, product energy use labels, and feedback mechanisms such as detailed billing or in-home displays would help address all three of the barrier categories previously mentioned.

- Incentives and Financing – Increasing utility incentives to cover the majority of a measure's incremental cost would alleviate the upfront consumer investment barrier for many measures while remaining profitable for utilities. For larger investments (such as windows or insulation), new and innovative financing mechanisms, tax credits, and on-bill financing should be considered.

- Codes and Standards – Updating building codes and appliance standards to be more stringent would capture savings in segments where customer awareness and / or willingness remain(s) low. This could include mandatory energy audits and increased enforcement of standards.

- Third-party Involvement – Third parties could specialize in energy efficiency retrofits. A specialized agent could put together and install packages of energy savings measures that meet the financial and energy service needs of the client, thereby removing much of the uncertainty in an emerging market.

Figure 4 demonstrates how the tactics above (boxes at right in Figure 4) can be used in concert to address a variety of common structural, behavioral, and availability barriers.



* Represents a minor barrier
Source: McKinsey analysis

Figure 4. Potential Solution Strategies to Energy Efficiency Barriers (McKinsey and Company 2009)

California as an Efficiency Leader

The State of California is often held up as an example of successful energy efficiency policy and practice. Partially in response to the Organization of Petroleum Exporting Countries (OPEC) 1973 oil embargo and the resulting increase in oil prices, California began pursuing energy efficiency improvements in 1974. That year, the California Energy Commission (CEC) was established with the passage of the Warren-Alquist Act (Public Resources Code 25000). The CEC was tasked with examining energy consumption trends, forecasting supply and demand, researching and developing alternative energy sources, and formulating plans for reducing energy consumption (CEC 2009). Shortly thereafter, the Department of Housing and Community Development created the first building energy standards for low-rise residential buildings in 1975, which were updated and expanded in 1978 to establish the Title 24 Energy Efficiency Standards for Residential and Nonresidential Buildings (CEC 2011a). Following a legislative mandate, Title 20 appliance standards were first established in 1976 (CEC 2011b). Since their initial establishment, California building codes and appliance standards have been updated every two to three years until the most recent adoptions in 2008 and 2009, respectively.(CEC 2011c).

Another important component of the state's energy efficiency efforts has been centered on the major investor owned utilities (IOUs). For decades, utilities have managed energy efficiency programs that include appliance rebates, direct installations, early appliance retirement, and low-income weatherization (Bernstein, et al. 2000).

California policy makers realized early on that these types of programs would be required to realize efficiency gains beyond the appliance and building standards already in place. However, because IOU revenue (and therefore profit) was based on electricity and natural gas sales, the utilities had a strong disincentive to invest in energy efficiency. To address this problem, the CEC, the California Public Utilities Commission (CPUC), and the Natural Resource Defense Council (NRDC) developed an innovative policy called decoupling. This mechanism disconnects the utility's electricity or natural gas sales from the incoming revenue stream. Instead, the CPUC issues period rate adjustments that allow utilities to recover their fixed costs of service regardless of unit sales (Cavanagh 2009). By 1982, decoupling was standard policy for the IOUs and energy efficiency investments became a low cost tactic for meeting growing demand. According to the CEC and CPUC (2006), aggressive energy efficiency policies have helped avoid the construction of 24 large (>500 MW) power plants by saving approximately 40,000 GWh of electricity and over 12,000 MW of peak demand (Figure 5).

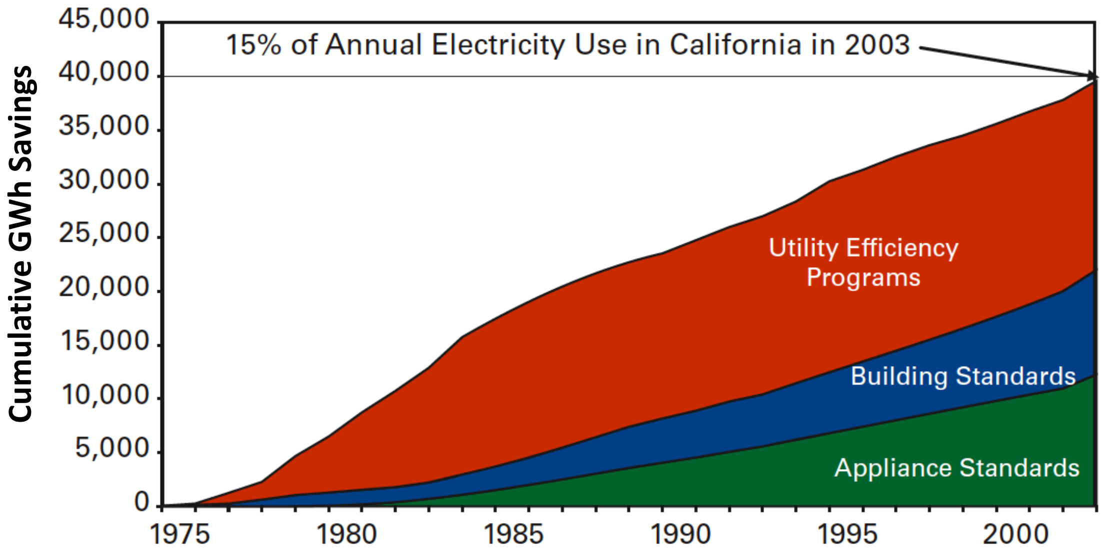


Figure 5. Cumulative Energy Savings Resulting from Energy Efficiency Programs and Policies in California Since 1975 (CEC 2005).

Partially due to California's investment in energy efficiency programs, the state has achieved a nearly constant per capita electricity use over the past three decades compared to a nationwide increase in electricity usage by almost 50% over the same time frame (Figure 6). There are, however, other factors at play. Figure 6 indicates that only about 25% of the per capita energy savings can be attributed to energy efficiency. Other possible factors include California's higher than average retail rates, a mild climate in large portions of the state, a larger than average household size, a large urban popluation, and a general conservation ethic among residents (Mitchell, Deumling and Court 2008).

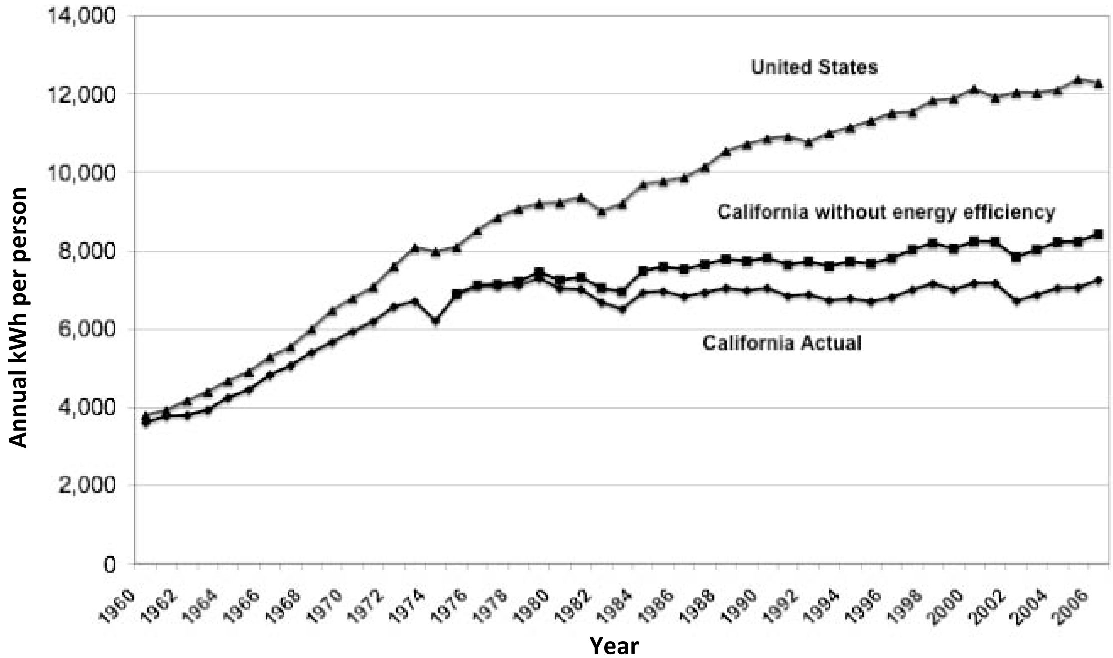


Figure 6. Annual Per Capita Electricity Consumption 1960-2006 (Rosenfeld and Poskanzer 2009)

More recent legislation has promoted energy efficiency as a means of meeting state Renewable Portfolio Standards (RPS) and carbon reduction goals of Assembly Bill (AB) 32. Dubbed the Global Warming Solution Act of 2006, AB32 was passed by the state Legislature and signed by Governor Schwarzenegger on September 27, 2006. It mandates the reduction of greenhouse gas emissions to 1990 levels by the year 2020. In the 2008 AB32 Climate Change Scoping Plan, the California Air Resources Board's (ARB) first two recommendations for meeting the 2020 CO_2 emissions limit were to:

- Expand and strengthen existing energy efficiency programs, as well as building and appliance standards;
- Achieve a statewide Renewable Portfolio Standard (RPS) of 33% renewable electricity production (ARB 2008).

It is unsurprising that energy efficiency programs fall first in this list as they have long been recognized as one of the largest, least costly, and immediately implementable zero carbon energy resources. The scoping plan establishes an annual goal of 32,000 GWh of electricity savings and 800 million therms of natural gas savings from efficiency measures by 2020 (ARB 2008). If this goal is met, over 25 million metric tons of greenhouse gases would be abated each year.

In 2003, the CPUC and the CEC adopted its first Energy Action Plan that listed energy efficiency as the highest priority resource, or first in the “loading order,” for meeting California’s future energy needs (CEC 2003). Since then, this recommendation has been backed up by legislation with the passing of California Senate Bill 1037 (Kehoe, Chapter 366, Statutes of 2005), followed in 2006 by AB 2021 (Levine, Chapter 734, Statutes of 2006). These directives dictate that electricity providers under CPUC’s regulation and publicly owned electricity utilities must first acquire their unrealized resource needs through all available energy efficiency and demand response resources that are cost effective, reliable and feasible.

Despite substantial efforts at improving energy efficiency, considerable opportunities for low cost energy savings remain. Over 50% of residential housing units and more than 20% of the non-residential building stock in California were built before building codes and appliance standards were established (CEC 2003). The savings potential in these building combined with additional energy upgrades in new buildings comprise a large efficiency resource that remains untapped. *The California Energy Efficiency Potential Study* (Itron 2008)estimates that from 2007-2016, approximately 14,000 GWh of electricity and 240 million therms could be saved cost effectively through utility programs in California.[5]

Current Efficiency Programs in Humboldt County

Several energy efficiency programs exist at the local level. The Redwood Community Action Agency (RCAA) is a local non-profit organization that works with low and moderate-income residents of Humboldt County to make their homes more energy efficient. They administer low-income weatherization assistance programs that provide at no cost home weatherization services and some equipment upgrades (furnaces and water heaters). The Redwood Coast Energy Authority (RCEA) is a Joint Powers Authority formed in 2003 to reduce energy demand, increase energy efficiency, and to promote clean energy development in the county. In 2006 RCEA partnered with PG&E

[5] Itron (2008) presents a range of potential savings estimates based on the utility incentive level and the types of measures that are included in the analysis. The estimates presented above correspond to full incentive level utility programs for measures that have a total resource cost test (TRC) ratio of ≥ 0.85. TRC test ratios and Itron incentive scenarios will be discussed more in Chapter 4.

to form the Redwood Coast Energy Watch (RCEW). This $1.6 million partnership allows RCEA to implement local energy efficiency programs with the PG&E public goods charge.[6] The RCEW programs include public outreach and education, public agency retrofits, small business direct install, single-family residential direct install, and local codes and standards. The direct install programs focus primarily on lighting and do not include more substantial, whole building retrofits. In all, these programs are expected to achieve a 783 kW peak demand reduction, an annual electricity consumption reduction of 5.2 GWh, and an annual natural gas consumption reduction of about 80,000 therms (RCEA 2011). While these are substantial savings, they only comprise about 0.4% of peak demand, 0.5% of electricity consumption, and about 0.2% of gas consumption countywide.[7]

This chapter has demonstrated that there is vast, nationwide potential for economically advantageous energy savings through energy efficiency. While there are a number of persistent market and institutional barriers that prevent the full economic potential from being realized, the savings that are realistically achievable through utility programs are substantial and available at a low cost. California's long history of energy efficiency efforts have shown that these programs can and do save energy effectively.

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[6] Assembly Bill (AB) 1890 (1996) created the public goods charge, which adds a small charge to all electrical utility bills to fund energy efficiency programs. A similar charge was added to natural gas sales with the passage of AB 1002 (1996). At the state level, both funds are administered by the CPUC.

[7] Humboldt County electricity and natural gas consumption statistics were obtained from the CEC searchable database: http://www.ecdms.energy.ca.gov/. Peak demand was taken from The Humboldt County Energy Element (Zoellick 2005).

The next chapter will review the literature on the economic benefits of energy efficiency investments.

CHAPTER 3. ECONOMIC IMPACTS OF ENERGY EFFICIENCY

Thus far, the arguments presented for energy efficiency have been framed as an attractive investment for utilities and as being a low-cost carbon mitigation strategy. Other benefits include reduced emissions of criteria pollutants that have associated human health and environmental damage costs and a decreased reliance on fossil-fuel imports. Often overlooked, however, are the jobs, income, and tax revenues created from the installation of the efficiency measures and the local economic stimulus resulting from increased cash flow from consumer utility bill savings. This chapter will review the economic impacts of energy efficiency and examine the economic modeling techniques used to estimate those impacts.

In recent years, industries associated with renewable energy and energy efficiency have experienced above-average growth (Hanke and Sauer 2009). The Pew Charitable Trust (2009) reports that jobs in the US "clean energy economy" grew by an average of 1 percent annually during the past decade. In comparison, total US employment grew by an average of 0.4 percent annually. Roland-Horst (2008) estimates that investments in energy efficiency have enabled California households to redirect their spending toward other goods and services, creating about 1.5 million full time equivalent (FTE)[8] jobs with a total payroll of $45 billion. These impacts were the result of well-documented household energy savings of $56 billion from 1972-2006. Throughout the US, the renewable energy and energy efficiency industries created more than nine million jobs

[8] One FTE job is equal to one person being employed full time for the duration of one year.

(both direct and indirect) in 2007 alone (Bezdek 2008a). Bezdek notes that growth in these clean energy industries creates high wage jobs in manufacturing, construction, accounting, and management, among other occupational sectors.

Because renewable energy and energy efficiency merely displace conventional energy, one may contend that net job creation would be zero. Kammen et al. (2006) and Wei et al. (2010) at UC-Berkeley's Renewable and Appropriate Energy Laboratory produced meta-analyses that synthesized the results of 13 independent reports and studies in 2006 and another 15 in 2010. These studies analyze the economic and employment impacts of the clean energy industry (renewable energy and energy efficiency) in the US and Europe. The central conclusion of this literature review and synthesis is that expanding the use of renewable energy and energy efficiency has a significant positive net impact on employment. To make intermittent renewable generation facilities (with low capacity factors) directly comparable to baseload fossil fuel-based generation facilities (with high capacity factors), these studies calculate an "average installed megawatt of power" (MWa) that is de-rated by the capacity factor of the technology. Their research indicates that every technology in the renewable industry generates more jobs per average installed megawatt of power in the construction, manufacturing, and installation sectors, as compared to the natural gas industry (Table 1 below). The results are less clear for operations and maintenance (O&M)—the range of estimates for wind and solar PV suggest that these generation sources may require more or fewer jobs than those required to fuel, operate, and maintain coal and gas plants. In their scenario analysis of various renewable energy portfolios displacing coal and gas plants, they found that in all cases the renewable energy portfolios produce more jobs in manufacturing, construction and installation, O&M, and fuel production and processing, than the corresponding fossil-fuel scenarios. Kammen et al. (2006) also noted that the construction and installation phase of renewable energy and energy efficiency development creates jobs in manufacturing and construction sectors of the economy that have suffered disproportionately high unemployment rates.

Table 1. Average Employment by Energy Technology Type

	Average Employment over Life of Facility (FTE Jobs/MWa)		
	Maufacturing, Construction, and Installation	**Operations, Maintenance, and Fuel Processing**	**Total**
Solar PV	1.43 – 7.4	0.60 – 5.00	2.03 – 12.40
Wind power	0.29 – 1.25	0.41 – 1.14	0.84 – 2.29
Biomass	0.13 – 0.25	1.42 – 1.80	1.67 – 1.93
Small hydro	0.26	2.07	2.33
Coal-fired	0.27	0.74	1.01
Natural gas-fired	0.03	0.91	0.94
Energy Efficiency*	-	-	0.17 – 0.59*

These data are based on findings from a range of studies published in 2001–09. Assumed capacity factor is 20 percent for solar PV, 35 percent for wind, 80 percent for coal, and 85 percent for biomass and natural gas. "MWa" refers to average installed megawatts de-rated by the capacity factor of the technology; for a 1 MW solar facility operating on average 21% of the time, the power output would be 0.21 MWa. The "total" range reflects totals from individual studies rather than the sum of minima and maxima in the row.
* Because energy efficiency measures have no capacity factor, average employment is reported in units of total job years/GWh.

Source: (Wei, Patadia and Kammen 2010)

While the energy efficiency job creation impacts in Table 1 are not directly comparable to impacts from natural gas and renewable energy generation (because impacts are reported in job years/GWh rather than job years/MWa), net positive job creation from energy efficiency programs has been well documented. The ACEEE estimates that in 2008, more than one million U.S. jobs were supported by energy efficiency improvements in the building sector (Ehrhardt-Martinez and Laitner 2008). The American Solar Energy Society (Bezdek 2007) estimates that by 2030 the energy efficiency industry will create 14.96 million jobs assuming no change in policy and no new major energy efficiency initiatives, 17.8 million new jobs assuming new moderate federal and state initiatives, and 32.2 million new jobs assuming aggressive new energy initiatives and policies at the state and federal levels. Kats, et al. (2009) estimates net job creation due to energy efficiency spending and finds that every million dollars invested in conventional energy generation would create approximately 2-4 jobs directly and indirectly while the same million dollars would create 8-12 direct and indirect jobs in the green building sector. One of the primary reasons that a given amount of energy efficiency spending creates more jobs than conventional generation has to do with the supply chain. When one dollar of spending is removed from the generation sector, it is removed from the relatively simple and capital-intensive variable cost supply chain that is mostly comprised of fuel extraction, transport, and generation. When that dollar is added to the efficiency sector, it becomes part of a much more labor-intensive supply chain that includes manufacturing, wholesalers, retailers, administrators, transport, and installation (Roland-Horst 2008).

Economic Modeling for Energy Efficiency

When examining the literature on economic modeling in the clean energy industry, two dominant approaches stand out: analytical modeling and input-output (I-O) analysis. Analytical models are typically spreadsheet based and are relatively simple compared to I-O models. For a given energy project, analytical models employ a bottom-up approach to evaluate direct job creation resulting from its construction/installation, management, and operation and maintenance (O&M). The methodology used in these studies is usually very transparent and key parameters can typically be modified easily (Wei, Patadia and Kammen 2010).

I-O models are usually much more complex and typically use a top-down approach to provide a more comprehensive picture of the entire economy. In addition to direct impacts, input-output analysis also evaluates indirect and induced impacts to an economy. The distinction between direct, indirect, and induced economic impacts is as follows:

- **Direct impacts:** As indicated above, direct effects include all on-site and immediate economic impacts resulting from the construction/installation, management, and O&M for a given energy project or projects.
- **Indirect impacts:** Indirect impacts are those associated with increased economic activity resulting from directly affected sectors making more purchases of goods or services that support their business. For instance, a new biomass power plant

would require increased economic activity in the logging industry to provide fuel for the plant. Other indirect impacts would include the bank that finances the project and the engineering firm that prepares the environmental impact statement.

- **Induced impacts:** Induced impacts result from increased household earnings and cash flow in a local economy due to the direct and indirect impacts. Those that are directly and indirectly employed as a result of the project spend their earnings on clothes, food, gas, medical services, taxes, etc. This increased spending induces job creation in these additional sectors.

Because I-O models examine the inter-industry interactions and interactions between industries and consumers, they provide a more complete picture of the effects of a given project whereas analytical models tend to underestimate economic impacts (Wei, Patadia and Kammen 2010). When modeling the economic impacts from energy efficiency programs, it is important to include indirect and induced effects because large-scale programs result in substantial consumer energy bill savings. Many of the jobs created from energy efficiency upgrades are supported by the spending of these savings in other sectors of the economy (Roland-Horst 2008; Geller and Goldberg 2009). Because these effects cannot be adequately captured with a simple analytical model, input-output analysis will be used to characterize economic impacts from energy efficiency programs in Humboldt County.

Input-Output (I-O) Analysis

Input-output analysis is a widely used tool for estimating economic impacts from clean energy development at regional to multinational levels (Allan, et al. 2008; Caldes, et al. 2009; Ciorba, Pauli and Menna 2004; ECOTEC Research & Consulting Ltd. 1999; Hillebrand, et al. 2006; Kulisic, et al. 2007; Lehr, et al. 2008; Madlener and Koller 2007; Geller and Goldberg 2009). It has its origins in 18th Century economics, when Francois Quesnay published the "Tableau Economique" in 1758 (Miller and Blair 1985; O'Connor and Henry 1975). Quesnay's Tableau Economique can be described as "…a diagrammatic representation of how expenditures can be traced through an economy in a systematic way" (Miller and Blair 1985). In 1874, Leon Walras further established a foundation for modern input-output economics with his use of Newtonian mechanics to develop a theory of general economic equilibrium (Miller and Blair 1985; O'Connor and Henry 1975). This work "…utilized a set of production coefficients that related the quantities of factors required to produce a unit of a particular product to levels of total production of that product…", which is a fundamental concept in modern input-output theory (Miller and Blair 1985). Despite these significant contributions by others, Wassily Leontief is viewed as the father of modern input-output analysis and was awarded a Nobel Prize in 1973 for his work on the topic.

Leontief first began developing an empirical model of the United States economy in 1931 and published "Quantitative Input-Output Relations in the Economic System of the United States" in August, 1936, in the journal *Review of Economics and Statistics*

(Miller and Blair 1985; O'Connor and Henry 1975). In an article published in 1951, Leontief argued that the field of economics had remained relatively static since the 18th century and remained "…largely a deductive system resting upon a static set of premises, most of which were familiar to Mill and some of which date back to Adam Smith's *The Wealth of Nations*" (Leontief 1986). Meanwhile, empirically based fields such as physics had "…moved on to entirely new premises" (Leontief 1986). Leontief's underlying argument was a call for the incorporation of empirically based economic models, including input-output analysis, into standard economic practice.

Leontief's justification for the adoption of input-output analysis into standard economic theory can be found in the following passage:

> "In recent years…the output of economic facts and figures by various public and private agencies has increased by leaps and bounds…As a result we have in economics today a high concentration of theory without fact on the one hand, and a mounting accumulation of fact without theory on the other. The task of filling the 'empty boxes of economic theory' with relevant empirical content becomes every day more urgent and challenging" (Leontief 1986).

Of course, Leontief's answer for filling the "empty box of economic theory" was through input-output analysis. Here, Leontief provides a succinct description of his newfound solution:

> "Essentially it is a method of analysis that takes advantage of the relatively stable pattern of the flow of goods and services among the elements of our economy to bring a much more detailed statistical picture of the system into the range of manipulation by economic theory" (Leontief 1986).

In input-output analysis, these flows of goods and services are referred to as inter-industry interactions, which are defined as either absorption (inputs) or production (outputs). These interactions, in terms of monetary value rather than actual goods or services, are derived from economic data that captures the absorption and production by industry sectors in a given economy over a given period of time (typically one year). Industry sectors can be defined on as highly aggregated or as specific of a level as required by the analysis in question.

All I-O models utilize the same fundamental theory, but the exact organization of the model and the specific multipliers used are dependent upon the economic system of interest. A given I-O analysis could be designed to model the entire world economy, a national economy, or even the economic system surrounding a specific local project (such as local utility energy efficiency programs). For any given system, the general approach involves collecting large amounts of purchase and sales cost information from each related industry, describing where inputs are bought and where outputs are sold, and evaluating how impacts from an exogenous shock to the economy (i.e. a final change in demand for an industry output) will ripple through the rest of the economic system. This process is illustrated below in Figure 7.

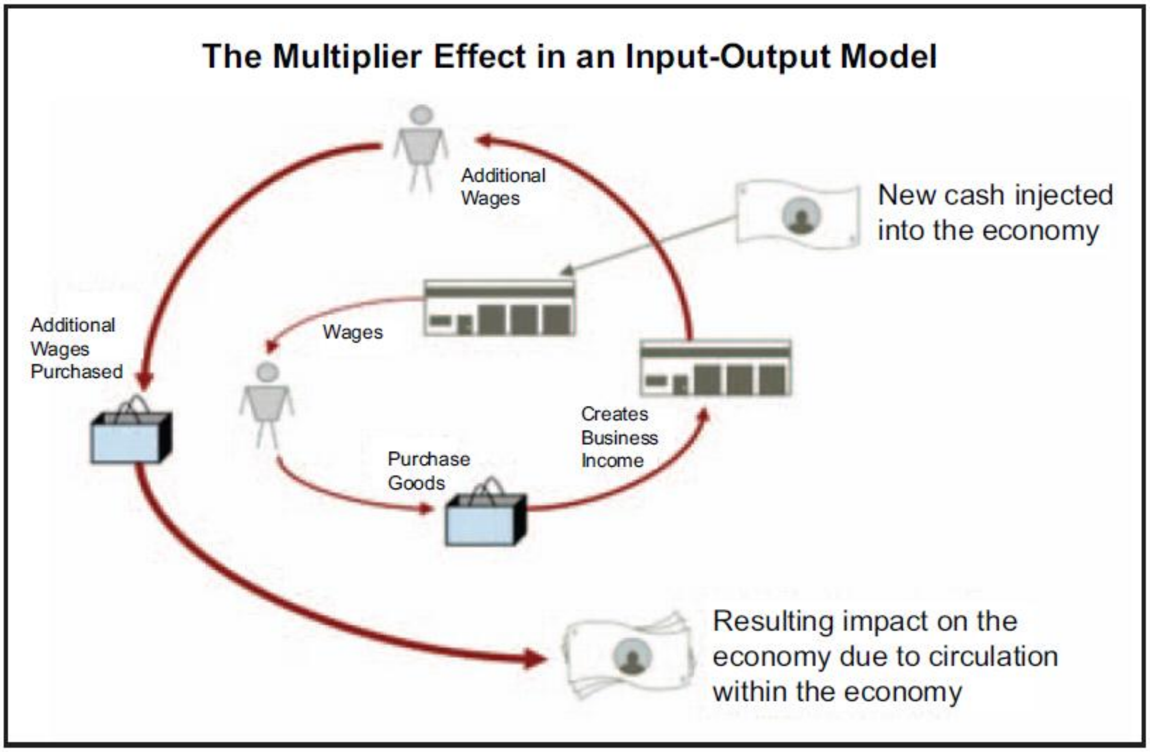


Figure 7. The Multiplier Effect in an Input-Output Model (Goldberg, Cliburn and Coughlin 2010)

To further examine this process imagine a simplified regional economy with three industrial sectors: industry A, industry B, and industry C.[9] Each industry interacts with the other industries and households in the region via purchases and sales. Each industry also exports some of its products out of the region and imports some of its raw materials into the region. The dollar values of these hypothetical transactions are described in Table 2, where a given row is reflective of the value of the goods and services sold to each sector and a given column represents the value of goods and services purchased from each sector.

[9] Much of this illustration is drawn from Hackett, et al. 2009.

Table 2. Illustrative Input-Output Transactions Table (in Millions of Dollars)

	Producing Sector (Buyers)			Consuming Sector (Buyers)		Total Sales
	Industry A	Industry B	Industry C	Exports	Households	
Supplying Sector (Sellers)						
Industry A	10	5	3	1	12	**31**
Industry B	3	9	8	1	4	**25**
Industry C	8	4	6	3	3	**24**
Primary Inputs						
Households	4	5	6	0	4	**19**
Imports	6	2	1	0	4	**13**
Total Inputs	**31**	**25**	**24**	**5**	**27**	**112**

Source: (Hackett, et al. 2009)

Looking more closely at industry B, the shaded row indicates that $3 million in goods and services were sold to companies in industry A, $9 million to other firms in industry B, and $8 million to industry C. Additional exports and household sales of $1 million and $4 million respectively bring industry B's total sales to $25 million. The shaded column shows purchases of $5 million, $9 million, and $4 million from industries A, B, and C and purchases of $5 million and $2 million from households and imports. These total purchases also sum to $25 million so total sales equal total purchases (inputs=outputs),[10] which is a key tenet of input-output economics.

Transaction tables like the one above are the first step in developing the predictive multipliers used in I-O analysis. Expressing the input costs from each industry row as a

[10] Due to the simplified structure of this example, it may not be immediately obvious why this is the case. Some of the $5 million purchased from households in this example include industry profits (payments to households owning businesses in industry B) as well as wages, rents, etc.

fraction of total input costs in each industry column yields a technical coefficients table; this is useful because it shows the direct dollar purchases from each supplying sector (rows) required to generate $1 of sales in the producing sector (columns). Continuing the above example, Table 2 shows technical coefficients for our simplified regional economy.

Table 2. Illustrative Inter-industry Technical Coefficients Table*

		Producing Sector (Buyers)		
		Industry A	Industry B	Industry C
Supplying Sector (Sellers)	Industry A	0.32	0.20	0.13
	Industry B	0.10	0.36	0.33
	Industry C	0.26	0.16	0.25

*Dollars of direct input purchases from each supplying sector listed in the rows by the producing sector listed in the column per dollar of output by the sector listed in the column. Source: (Hackett, et al. 2009).

Here we see that for industry A to generate $1 in final sales, it must purchase $0.32 of input products from other firms in industry A, $0.10 from industry B, and $0.26 from industry C. Assuming that the purchase costs of inputs to a given sector scale linearly with final sales of that sector, these technical coefficients can be used to estimate direct input-output requirements for related industries.

Calculating indirect impacts coefficients requires a bit more computational stamina, as it traces the supply chain linkages back towards primary inputs. Table 3 shows the interdependency coefficients table for our theoretical economy. These coefficients quantify the amount of direct and indirect sales stimulated in each row sector by $1 of sales in the column sector.

Table 3. Illustrative Total Inter-industry Requirements Table*

		Producing Sector (Buyers)		
		Industry A	**Industry B**	**Industry C**
Supplying Sector (Sellers)	**Industry A**	1.82	0.73	0.64
	Industry B	0.69	2.03	1.01
	Industry C	0.78	0.69	1.77
	Total Output	**3.29**	**3.45**	**3.42**

* Total local production required by each producing sector listed in the rows to satisfy each dollar of new demand from each producing sector listed in the columns. Source: (Hackett, et al. 2009)

Table 3 is derived from Table 2 by thinking past the first transaction. From Table 2, we know that to generate $1 more output, industry A must purchase $0.26 of goods from industry C. To generate $0.26 in goods, industry C must purchase $0.03 (0.26 x 0.13) of goods from industry A, $0.09 (0.26 x 0.33) from industry B, and $0.07 (0.26 x 0.25) from other firms in industry C. These indirect effects continue to ripple through the economy for multiple iterations so that the total impact coefficients in Table 3 are equal to the sum of direct production impacts and all subsequent indirect production impacts in the supply chain.[11] It is interesting to note that supply chain and income interactions often result in a $1 change in final demand for a given industry stimulating more than $1 of production in the same industry. For example, $1.82 of local production is required by all firms in industry A (row) to supply a $1 increase in final demand by a producing firm in industry A (column). The bottom row in Table 3 shows total output multipliers for each industry. To satisfy a $1 increase in final demand in industry A, we see that the

[11] In reality, the number of ripples it takes to reach the end of the supply chain (primary inputs) may vary considerably. Input-output economic theory uses the sum of an infinite series to approximate a solution to the economic model. For most cases, n=6 is enough to capture over 97% of the flows and n=8 approximates over 99% (Schaffer 1999).

total economic output of the region must increase by $3.29. With additional statistics on industry employment and wage rates, employment multipliers (ratio of employment to output) and income multiplier (ratio of income to output) can be formulated for each industry.

Many countries produce I-O tables on a national economy scale and include great sectoral detail. In the US, the Bureau of Economic Analysis (BEA) uses extensive surveys to collect benchmark data for 528 industry and commodity sectors every five years. Based on a snapshot of the economy at that time, interactions between industries are analyzed and used to create new national I-O tables (Listokin 2002). Computer programs take industry I-O tables and utilize matrix algebra to derive Type I and Type II multipliers. Type I multipliers predict direct and indirect effects on the total output of an economy from a change in final demand for a single or multiple industries. Type II multipliers are derived by expanding I-O tables to include household interactions with industry. Given a change in household income, Type II multipliers predict economic impacts resulting from changes in demand in relevant industries (induced effects).

At a regional or county level, economic impact assessment using input-output analysis can be a powerful tool for economic planning and policy making. Because local economies have their own unique inter-industry interactions, national level I-O tables must be modified accordingly when conducting a regional economic impact assessment. Multiple studies have shown that inaccurate and misleading multipliers can result from the regionalization of national I-O data (Jensen 1980; Kronenberg 2009; Richardson

1985; Tohmo 2004). One of the major sources of error when regionalizing data is not properly accounting for cross-hauling (i.e. the simultaneous import and export of a product over regional boundaries), which is particularly difficult to quantify (Kronenberg 2009). The most accurate way to establish regional I-O data would be through extensive industry surveys. However, this method is too expensive and time consuming for most research studies (Hewings 1985). This leaves researchers with little choice but to regionalize national data with available local economic data and appropriate extrapolation methods.

Fortunately, several software programs exist for conducting non-survey regional economic impact assessments including Impact Analysis for Planning (IMPLAN), Regional Economic Models, Inc. (REMI), and Regional Input-Output Modeling System (RIMS II). These programs use mathematical equations to calibrate national inter-industry I-O data to the state or county level based on the size of the region and its industrial characteristics. Geographical size is important because it relates to the amount of "leakage" that is likely to occur. Economic leakage takes place when new dollars entering the economy are not re-spent within the same economic system. This happens in every round of spending due to imports (the largest source of leakage), savings, and tax payments. This relates to geographic size because the larger the economy in question, the less likely that that economy will require imports from outside its boundaries. This generally results in larger regions having higher multipliers (Morgan 2010).

To regionalize data, IMPLAN and REMI use different variations of the regional purchase coefficient (RPC) method while the RIMS II model uses the location-quotient (LQ) method (Rickman and Schwer 1995). The RPC method accounts for cross-hauling in the region while the LQ method does not; therefore, IMPLAN and REMI inherently avoid a significant source of error in regionalization.

Each of the regionalization programs has its advantages and disadvantages that may make them particularly well (or poorly) suited for a given application. RIMS II was created by the U.S. BEA and modifies national I-O data by incorporating regional industrial structure and trading patterns (Poole, et al. 1999). It provides a list of industry specific (1) final demand multipliers for output, earnings, employment, and value-added and (2) direct effect multipliers for earnings and employment. If the initial value of business output or revenues is known for a given project, the final demand multipliers are used. Direct effects multipliers are appropriate if project information on direct employment and/or earnings is available. RIMS II is not an automated model like IMPLAN and REMI and does not have the functionality to estimate economic impacts. RIMS II only provides a table of multipliers that must be applied correctly to the project in question. This model provides accessible and affordable multipliers for a basic economic impact analysis but is the least robust of the three in terms of its methodology and functionality (Morgan 2010). For instance, it employs the location-quotient (LQ) method, which is a relatively simple method of regionalization (Rickman and Schwer 1995). This method quantifies the employment in each industrial sector as a fraction of total employment in both the regional economy and the base economy (i.e. the national economy). The location-quotient for each industry is the ratio of the region's sectoral employment fraction to the base sectoral employment fraction. The LQs are then applied to the national multipliers to arrive at regional multipliers. This method is somewhat rough and has no way of accounting for cross-hauling, which as noted above makes the RIMS II model particularly susceptible to regionalization error.

IMPLAN is an automated model that calculates regional multipliers that can be used directly by the user as with RIMS II. IMPLAN has the additional functionality to use those multipliers within the software package to estimate economic impacts. This model uses I-O data from 528 industry and commodity sectors from federal government sources including the U.S. Bureau of Labor Statistics and the Bureau of Economic Analysis. To regionalize national data, IMPLAN utilizes the regional purchase coefficient (RPC) method. Each commodity in each region has its own unique RPC, which estimates the fraction of final demand for that commodity that is sourced from local producers. The higher the RPC, the more of a commodity is purchased within the region and the higher the resulting I-O multipliers. The newest version of IMPLAN, version 3.0, uses a sophisticated gravity model. This model allows for multi-regional analysis that accounts for spatial variables like a region's place in the trade hierarchy and the proximity and size of alternative markets (Olson and Alward 2009). The term gravity model is applied because the calculation used is similar to Newton's Law of Gravity, in which the attraction between two masses is proportional to the size of the masses and inversely proportional to their distance apart. Likewise, the spatial interactions (import and export flows) between economic systems in IMPLAN's gravity model are proportional to the size of an economy and inversely proportional to the cost of moving commodities between them. The accounting for this type of model is complete and consistent, meaning that local supply and demand for all regions sums to the total supply and demand on the national level (Olson and Alward 2009). This allows the IMPLAN software to conduct regional or multiregional analysis while accounting for cross hauling. However, like most input-output models, IMPLAN is a static model based on a snapshot of the economy at the time of the most recent data collection. It assumes that wage levels, prices, property values, input costs, labor supply, productivity, and other key variables will remain constant and is thus ineffective at forecasting the economic effects of public policy modifications.

REMI is the most sophisticated of the three software packages. In addition to an I-O component that utilizes the RPC method (though not the same gravity model as IMPLAN), REMI includes three other modeling systems: general equilibrium, econometrics, and New Economic Geography. Combined, this modeling approach allows for dynamic changes in the economy over time and spatial interactions between regional economies. These characteristics make the REMI model the most effective (and most expensive) of the three for policy analysis and long term forecasting (10-20 years) (Elgar 2009).

Each of these programs uses different methods for regionalizing national data and different default values, which could result in substantial differences between multipliers for a given region (Duncombe and Wong 1998). However, researchers have created benchmarked versions of the three models to control for differences in estimation methods and data sources and found no statistically significant difference in the size of the multipliers generated by the three models (Rickman and Schwer 1995). IMPLAN, REMI, and RIMS II are well respected and widely used programs. The economic impact analysis in this thesis utilizes IMPLAN multipliers for Humboldt County. The basis for this decision as well as the methods used to quantify energy efficiency potential and cost will be elaborated on in the next chapter.

CHAPTER 4. METHODOLOGY

In Chapter 3, we learned that in addition to being a low cost energy resource, energy efficiency investments create positive net economic impacts. In this chapter, the methods used to estimate these economic impacts in Humboldt County will be described. First, however, it is necessary to quantify the Humboldt County efficiency resource and the cost of that resource.

Quantifying the Energy Efficiency Resource Potential in Humboldt County

When reviewing the literature on energy efficiency potential studies, two primary approaches are encountered: top down and bottom up. A top down approach is often utilized in large scale, national or international studies. This method is useful for relatively quick estimates of nationwide potential that may be used to influence public policy. However, top down approaches are typically quite sensitive to a few qualitative assumptions. Bottom up approaches are more quantitative as they are based on actual technology costs, energy savings, and estimated adoption rates. Most energy efficiency potential studies at state or regional levels use a bottom up methodology because this allows the most careful estimation of potential and costs by region, sector, and technology type, which can help inform efficiency program design. Because I-O analysis is based on inter-industry interactions, the level of granularity that a bottom up approach provides is necessary to accurately estimate economic impacts.

There have been no detailed Humboldt County specific quantifications of energy efficiency potential and associated costs, but there is a wealth of authoritative literature on the state level. The most recent and authoritative of these reports is the *California Energy Efficiency Potential Study* by Itron, Inc. (2008). This study was overseen by a Project Advisory Committee (PAC) consisting of representatives from Pacific Gas and Electric (PG&E), Southern California Edison Company (SCE), Southern California Gas Company (SCG), San Diego Gas & Electric Company (SDG&E), the California Public Utilities Commission (CPUC), and the California Energy Commission (CEC).

The Itron (2008) study quantifies yearly (2007-2026) energy savings potential and associated costs by IOU service territory, CEC climate zone (CZ), sector, building type, end-use category, fuel type (electricity or natural gas), and measure type. Itron performed this comprehensive analysis for use by the four California IOUs and their program planners to focus utility program offerings (Itron 2008). The sectors and end-use categories included in the analysis can be seen in Table 4 and the building types are presented in Table 5 below.[12] Each end-use category is comprised of a number of efficiency measures that provide energy savings above the most common base technology. The analysis considered 66 measures in the existing residential sector, 100 measures in the existing commercial sector, and two levels of residential and commercial

[12] Although the industrial sector is included in the Itron analysis, it is excluded from this study due to its relatively low contribution to energy consumption in Humboldt County.

new construction packages.[13] The measures were chosen to be comprehensive enough to provide reasonable estimates but general enough to be manageable and broadly applicable. The interested reader may obtain a more thorough discussion of how these measures were selected from Itron (2008).

Table 4. End Uses Included in the Analysis

End Use	Description
Residential Electric	
HVAC	High efficiency central and room air conditioners, whole house fans, windows, infiltration control and attic and wall insulation
Lighting	Compact fluorescent lamps and hardwired fixtures, LED exit signs, occupancy sensors, photocells, T8 linear fluorescents, and torchieres
Water Heating	Water heaters, low-flow showerheads, faucet aerators, high efficiency clothes washers, dishwashers, and pipe wrap
Miscellaneous	One-and two speed pool pumps, high efficiency refrigerators and refrigerator and freezer recycling
Residential Gas	
HVAC	High efficiency furnace, attic and window insulation, infiltration control, and duct repair
Water Heating	Water heaters, low-flow water fixtures, pipe wrap, clothes washers, and dishwashers
Commercial Electric	
HVAC	High efficiency air conditioning, chillers, chiller tune-up, motors, and DX tune-up
Lighting	Compact and efficient linear fluorescent lamps and hardwired fixtures, HIDs and metal halides, LED exist signs, time clocks, occupancy sensors, and photocells
Refrigeration	Controls, infiltration barriers, compressors, fan motors, and night covers
Food	Holding cabinet, steamer, high efficiency ovens
Miscellaneous	Copy machines, high efficiency computers, and vending machine controls.
Commercial Gas	
HVAC	Boilers and high efficiency furnaces
Food	High efficiency steamers, ovens and fryers
Water Heating	Water heaters, boilers, circulation pump time clocks, and clothes washers
Miscellaneous	High efficiency water heating boilers, water heaters, and pool heaters

Source: (Itron 2008)

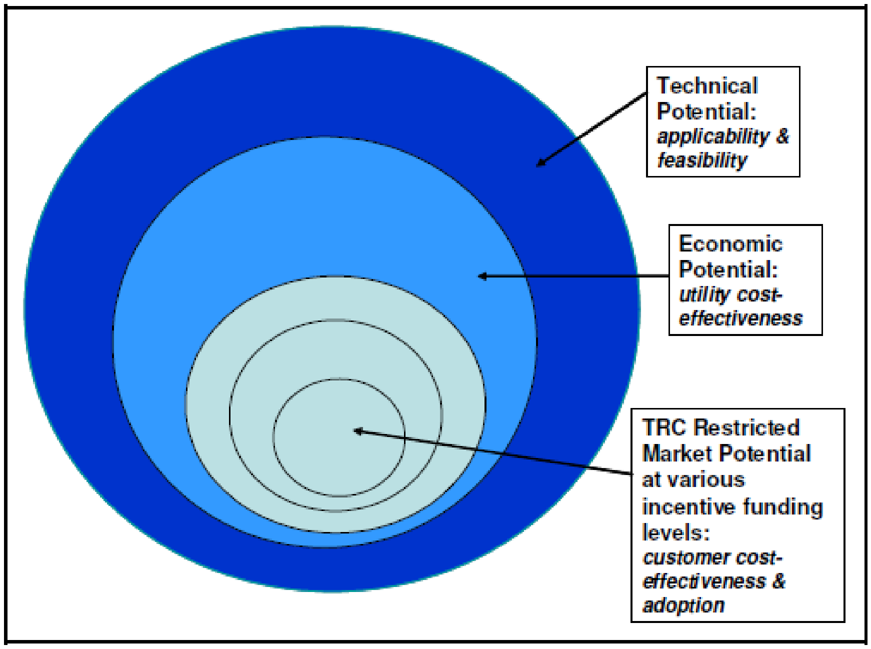
[13] The new construction packages are not included in this analysis because building turnover rate in Humboldt County is relatively low. Energy efficiency impacts in new buildings will thus be small as compared to the existing building stock.

Table 5. Building Types by Sector

	Sector	
	Residential	**Commercial**
Building Type	Single Family Multi-Family Mobile Home	Colleges Grocery Stores Health Lodging Large Office Small Office Refrigerated Retail Restaurants Schools Warehouses Miscellaneous

Source: (Itron 2008)

For each of the individual measures, three categories of savings potential are quantified by Itron: technical, economic, and market potential (Figure 7). Technical potential is the highest level of savings and refers to the savings that would be realized if all applicable and feasible measures were actually installed. Economic potential is a subset of technical potential that limits the applicable and feasible measures to those that are cost-effective. In this case, cost-effectiveness is determined using a total resource cost test (TRC), which is a ratio of the present value of avoided costs to incremental measure costs (neglecting programmatic costs). A measure with a TRC > 1 would be considered cost-effective. Market potential is a further subset that takes into account factors such as customer awareness, customer willingness to adopt the measure, and market barriers.



Source: (Itron 2008)

Figure 7. Categories of Savings Potential

The Itron study, as well as the current study, focuses primarily on market potential, as these are the measures that are most likely to be implemented. Because market potential is influenced by a number of uncertain factors, the Itron analysis considered nine scenarios. The scenario names and descriptions can be found in Table 6. Due to the limited scope of this energy efficiency analysis, only the base, mid, and full TRC restricted scenarios are considered here (shaded rows in Table 6). Note that the TRC restricted scenarios only require that the measure have a TRC ratio greater than or equal to 0.85. Utilities typically only incentivize portfolios of energy efficiency measures that are cost effective. Setting the TRC restriction at 0.85 allows measures that are nearly cost effective to be included in a portfolio of measures that is cost effective as a whole. In this way, nearly cost effective measures are in effect subsidized by the more cost effective measures, which may help push the market. Because the TRC restricted scenarios are limited to those measures that are cost effective (or nearly cost effective) as of 2008, the market potential energy savings estimates in these scenarios are likely conservatively low over the 20-year forecasting period.

Table 6. Market Potential Scenarios

Scenario Name	Scenario Description
Base Incentive	Includes measures incentivized in the 2004-2005 program cycle with incentive levels that were available in 2006.
Mid Incentive	Includes all measures analyzed in the study with incentives halfway between those that were available in 2006 and full incremental costs.
Full Incentive	Includes all measures analyzed with incentives set to full incremental costs.
Base Incentive TRC Restricted	Base Incentive scenario with measures restricted to those with a TRC ≥ 0.85.
Mid Incentive TRC Restricted	Mid Incentive scenario with measures restricted to those with a TRC ≥ 0.85.
Full Incentive TRC Restricted	Full Incentive scenario with measures restricted to those with a TRC ≥ 0.85.
Full Gradual	Includes all measures analyzed with incentives increasing from 2006 levels to full incremental costs in 2010.
Full Gradual TRC Restricted	Full Gradual scenario with measures restricted to those with a TRC ≥ 0.85.
Base TRC Restricted Higher Awareness	The Base Incentive TRC Restricted scenario with a higher level of awareness for both the program and the naturally occurring analysis.

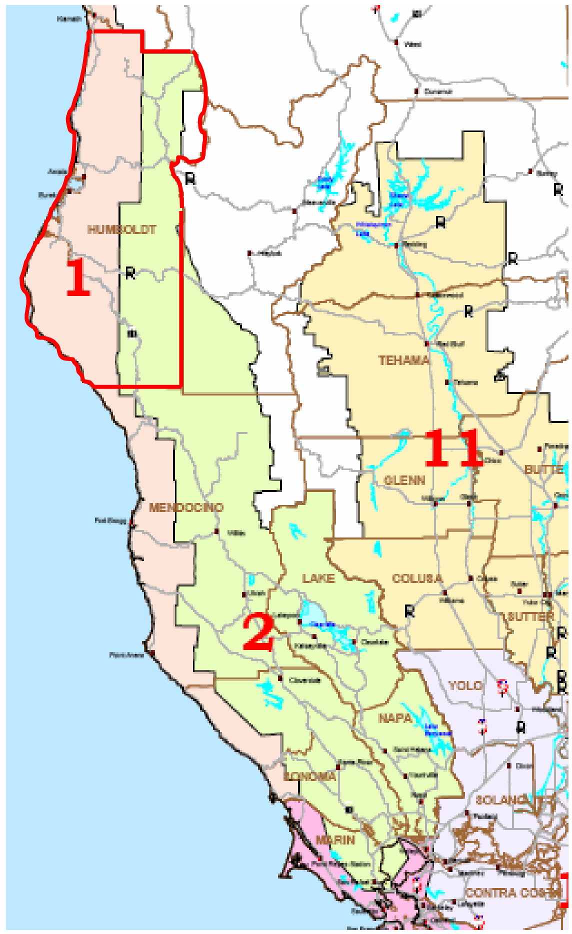
Source: (Itron 2008)

For each measure under consideration, the Itron databases provide estimates for measure, program, and incentive costs borne by the relevant IOU, as well as the associated energy savings (kWh or therms). The databases also provide estimates for the number of yearly installations of each measure from 2007-2026. The installations are further classified as device retrofit, equipment conversion, or replace-on-burnout. The distinction between conversion and retrofit is that a conversion is replacing existing equipment with an alternate technology (i.e. replacing a furnace with a heat pump) while a retrofit is upgrading existing equipment with a more efficient device of the same type. Replace-on-burnout means that once a unit reaches the end of its useful life, it is replaced with a more efficient device of the same type. Replace-on-burnout is included separately as it represents an event driven activity versus the discretionary nature of retrofits and conversions. These decision types have various cost implications and are therefore modeled differently in the Itron analysis (described in the Building an Economic Impact Assessment Model section below).

The Itron analysis was performed for each CEC climate forecasting zone because some measures, such as heating, ventilation, and air conditioning (HVAC), are largely weather dependent. In order to approximate energy savings potential for weather dependent measures in Humboldt County, this analysis focuses on the PG&E service territory in CEC climate zone 1. Geographically, Humboldt County is split approximately evenly between zones 1 and 2, with a small eastern portion in climate zone 16 (Figure 8). Approximately 94% of the county's population, however, lies in climate zone 1 so energy savings potential for this zone, scaled by climate zone 1 and Humboldt County's population, is used in this analysis.[14] In most cases, Itron's assumptions regarding the installation of measures appropriate for climate zone 1 are used. Though,

[14] It is assumed that this population distribution will remain relatively constant over the 20-year forecasting period.

due to common knowledge of energy end-uses in Humboldt County, measures involving residential air conditioning and pool pumps are excluded from this study.



Source: CEC, http://www.energy.ca.gov/maps/building_climate_zones.html

Figure 8. Humboldt County CEC Climate Zones

For weather insensitive measures, Itron reported costs and energy savings estimates for the entire PG&E service territory. Population could not be used to scale these results because of the difficulty in estimating the population of an IOU service territory. Instead, residential and commercial building electricity and natural gas consumption data were obtained from the CEC[15] and were used to scale costs and savings.

Appropriately scaled measure costs and energy savings estimates were then aggregated by end-use category and sector. The levelized cost of energy to the IOU was calculated for each end-use category in each sector over the 20-year study period using a real discount rate of 6%.[16] The LCOE is a useful measure that is typically employed to estimate the cost per unit of energy generated by an energy generation technology over its useful life. It is a natural extension of the life-cycle cost (LCC) analysis and provides a per-unit cost of energy (typically $/MWh) that incorporates all costs incurred by the project over its lifetime. The levelized lifetime cost per unit of energy generation is the ratio of total lifetime costs versus total expected energy outputs, expressed in terms of present value equivalent. Levelized cost is equivalent to the average price that would have to be paid by consumers to repay exactly the investor/operator for the capital, operation and maintenance and fuel expenses, with a rate of return equal to the discount rate. In general LCOE can be thought of as the total LCC divided by the total life-cycle quantity of energy (Figure 9). Note that Q_n is the energy produced by the project in year n, N is the project life in years, C_n is the project net cash flow in year n, and d is the discount rate.

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[15] 2008 consumption data from the entire PG&E service territory and for Humboldt County were obtained from: http://ecdms.energy.ca.gov/.

[16] Real discount rates in the range of 5-7% are often used in utility energy efficiency analysis. These rates reflect the relatively high cost of capital for utilities.

$$LCOE = \frac{\sum_{n=0}^{N} \frac{C_n}{(1+d)^n}}{\sum_{n=1}^{N} \frac{Q_n}{(1+d)^n}}$$

Figure 9. The Levelized Cost of Energy Calculation (Gilman, et al. 2008)

In the case of energy efficiency, the LCOE is essentially the same calculation where C_n is the total incentive and programmatic costs borne by the utility in each year and Q_n is the total energy savings in each year. The utility LCOE for energy efficiency programs can be directly compared to the LCOE of the utility's generation options.

In addition to IOU costs, consumer costs were also calculated. Direct consumer costs for each sector and end-use category are based on the difference between the aggregated measure costs and aggregated incentives provided by the utility. Consumer savings and payback were also calculated for each sector and end-use category using the user level energy savings[17] and average retail rates for each sector as reported by PG&E.[18]

[17] Itron provides estimates of energy savings at the system and user level. These two estimates differ by approximately 9% and account for line losses in transmission and distribution as reported by the IOU.
[18] The average retail rate for the residential sector is $0.18/kWh. This value reflects the consumption weighted average of rate schedules: E-1, EM, ES, ESR, ET (Jun. 1, 2010 - Nov. 2010) for the PG&E service territory. The average commercial rate is also $0.18/kWh and is based on the consumption weighted average of rate Schedules A-1 and A-1 TOU (Jun. 1, 2010 - Nov. 2010) for the PG&E service territory. As all measure costs in Itron (2008) are held constant over the 20-year forecasting period, electricity rates are assumed to be static as well. electricity rates are assumed to be static as well. Average PG&E rates can be found at: http://www.pge.com/nots/rates/tariffs/electric.shtml#RESELEC

Avoided Generation and Damage Costs

Investing in energy efficiency programs will allow PG&E to meet growing demand in Humboldt County without generating additional electricity at the new natural gas fired Humboldt Bay Generating Station (HBGS).[19] The cost of this avoided generation is equal to the difference between the levelized cost of energy efficiency program spending and the marginal cost of dispatch (or levelized average variable cost) of the HBGS.[20]

The marginal cost of dispatch is the incremental cost borne by the electricity generator when an additional unit of electricity is dispatched to serve load. The Energy Information Administration's electricity market module, a component of its national energy modeling system (NEMS), provides guidance on calculating the marginal cost of dispatch (EIA 1999). The marginal cost of dispatch in NEMS is equal to the sum of marginal fuel costs and marginal O&M costs. The marginal cost of dispatch for a particular power plant with an operating history can be calculated from past performance data. In this study, it is assumed that efficiency gains will offset additional generation at the Humboldt Bay Generating Station. Marginal O&M costs for the HBGS ($10/MWh) were obtained from the Application for Certification for the Humboldt Bay Repowering Project (CEC 2006). Marginal fuel costs were based on 1997-2009 prices from the EIA

[19] The HBGS consists of ten 16 MW internal combustion engines. This configuration is ideal for Humboldt County because it allows reliable and highly flexible base load electricity generation. Engines can be brought on-line or taken off-line as necessary to accommodate intermittent renewables or future energy efficiency investment.

[20] The avoided generation cost is not based on the LCOE for the HBGS because LCOE includes capital cost investment. Because the capital expenditure has already been made and energy efficiency gains merely displace a portion of the generation, avoided generation cost occurs at the margin.

for natural gas sold to California electric power generators (EIA 2011). While there is considerable year-to-year variability in prices, a general upward trend is observed. To account for this variation, a simple linear regression was performed for the 13-year period and was evaluated for 2008, giving a price of \$6.67/MMBtu (Appendix, Figure A.1).[21] The energy crisis circa 2001 created a natural gas price spike that appears to be an outlier. Excluding 2001 from the regression has a negligible impact on the estimate for 2008 price (~ -\$0.03/MMBtu). Using the heat rate of the Wartsila engines at the HBGS (7616 kJ/kWh), the fuel cost is anticipated to be approximately \$48/MWh. This gives a total levelized variable cost (or marginal cost of dispatch) of \$58/MWh.

Avoided climate change mitigation costs and avoided social damage costs were calculated based on the avoided generation cost. The avoided generation cost (\$/MWh) was divided by custom emissions factors (lb GHG or criteria pollutant/kWh) for the internal combustion engines at the HBGS to ultimately obtain the price per avoided ton of pollutant. Emissions data for the HBGS were obtained from the manufacturer (Wartsila 2011) and from the Application for Certification of the Humboldt Bay Repowering Project (CEC 2006).

[21] Because of the wide variability in year to year prices, no specific fuel escalation rate was applied. Fuel cost is assumed to increase at the same rate as general inflation. Given the long term rising trend in cost, this is considered to be a conservative assumption.

Building an Economic Impact Assessment Model

As mentioned in the introduction, this thesis developed from the author's work on the Humboldt County RESCO project at the Schatz Energy Research Center. A major deliverable of the RESCO project is a detailed analysis of the economic impacts of local renewable energy development. Dr. Steven Hackett, who directed the economic analysis, has had extensive experience with economic impact assessment using input-output analysis in the Humboldt County fishing industry (Hackett, et al. 2009). Dr. Hackett's previous work used IMPLAN multipliers for Humboldt County and modified them to be specific to the local fishing industry. A similar approach was to be taken for renewable energy development in the RESCO project. It was soon discovered that the National Renewable Energy Laboratory (NREL) has created a fully customizable suite of I-O models for various electricity generation technologies that utilize IMPLAN multipliers specific to the energy industry.

The NREL Jobs and Economic Development Impact (JEDI) Models

The NREL Jobs and Economic Development Impact (JEDI) models are user-friendly tools that are used to estimate the direct, indirect, and induced economic impacts for a variety of power generation technologies and biofuel plants at the regional (usually state) level. The first JEDI model was developed in 2002 to estimate economic impacts of wind power development and six more JEDI models have since been developed to assess the impacts of other energy technology development, including: cellulosic biofuel, corn ethanol, concentrating solar power (CSP), solar photovoltaic (PV), combined cycle natural gas, and pulverized coal. NREL is also currently developing JEDI models for biomass-to-electricity (biopower), conventional hydropower, and marine and hydrokinetic (MHK) power (NREL 2009). County and state planners and policy makers, public utility commissions, potential project owners, and researchers interested in economic impacts use these models to help make recommendations and decisions regarding potential energy development (NREL 2010).

The JEDI models are of significant benefit to the RESCO project because of the extensive research conducted by NREL to determine costs and inter-industry interactions associated with the development of each technology (e.g. purchases of steel for wind turbine manufacturing). The compilation of this data is crucial because the U.S. BEA does not currently track renewable energy industry input-output data. Therefore, without JEDI, a non-survey regional impact assessment of renewable energy would require collecting all of the cost data for each technology under study and manipulating an economic impact assessment software program to include these new industries. However, JEDI simply requires the input of corresponding IMPLAN regional multipliers at which point, "…changes in expenditures brought about by investments in developing power generation or biofuel plants are matched with their appropriate multipliers for each industry sector affected by the change in expenditure," (NREL 2009).

The development of JEDI makes renewable energy economic impact assessment more accessible and feasible for researchers who do not have direct access to renewable energy industry cost data. The JEDI models are particularly useful to the RESCO project because they are highly customizable. At the base level, they only require general inputs about the project such as the location, the installed project capacity, capacity factor, installed project cost, and operations and maintenance costs. But if the user knows more about the local economy and more about the given project, region specific modifications can be made for individual equipment component costs, labor costs, and the percentage of those costs are sourced locally. Financial and tax assumptions and many other project specifics are also customizable. This allowed for the integration of local cost information where it was available and to rely on NREL default values for California where Humboldt County information was lacking.

The JEDI model default setting is to run state-wide economic impact assessments. For users wishing to conduct county-level analysis, however, the JEDI suite also includes a "User Add-In Location" feature that allows for county level analysis. In order to utilize this feature, researchers must have access to an IMPLAN dataset for the county on which the analysis will be run. Professor Hackett and his research associates at SERC worked with the JEDI software developer, Marshall Goldberg of MRG & Associates, to derive the appropriate multipliers and personal consumption expenditures (PCE) [22] for use in the JEDI model from Humboldt County IMPLAN data. The most recent data available at the time of this collaboration was for the year 2008 and was formatted for use in IMPLAN version 3. Once the multipliers and PCEs are obtained for the appropriate industry

[22] Personal consumption expenditures (PCE) are I-O multipliers that estimate how individuals spend their income. Part of every dollar earned is spent on groceries, clothes, fuel, etc. These expenditures create induced economic impacts in the respective sectors.

aggregates used in the JEDI suite, these can simply be pasted into the User Add-In Location tab found on any JEDI model. For other users interested in performing county level analysis, NREL recommends the following steps for generating regional multipliers:

1. Purchase the desired county or state level data files from IMPLAN.
2. Using IMPLAN Pro Social Accounting & Impact Analysis Software, create a new model with the desired region (one county, group of counties or group of states).
3. Construct the model.
4. Aggregate the model. (This requires the user to create a new fourteen industry aggregation scheme and aggregate the new model. Once the model is aggregated, reconstruct the social accounts and multipliers.)
5. Open Reports, Study Area, and save Household Commodity Demand (personal consumption expenditures) to a spreadsheet file. Go to Multipliers, and save Employment, Employee Compensation and Output, each to a spreadsheet file.
6. The data contained in each of these files can then be formatted to easily input (i.e., cut and paste) into the respective location (MyCounty for a single county or MyRegion for a group of counties or states) in the User Add-in Location worksheet in JEDI.
7. Identify the location of the plant (in the project description section of the ProjectData worksheet) as MyCounty or MyRegion, depending on the area of analysis, and proceed with running the model (NREL 2010).

<u>The SERC Economic Impact Assessment Model Suite</u>

JEDI models for biomass, river hydroelectric, and wave power are currently under development by NREL contractors but were not available for customization to Humboldt County during the preparation of the RESCO project report. Consequently Dr. Hackett and his research assistants reverse-engineered the available JEDI models and used that knowledge to develop SERC impact assessment models for biomass (BIAM), riverine hydroelectric (RHIAM), and wave energy (WEIAM). Preliminary research on the economic impacts of energy efficiency during SERC impact model development led to the development of an additional model for energy efficiency (EEIAM). All of these SERC models incorporate the same Humboldt County multipliers that are used in the JEDI models. Moreover, the four SERC models were developed from research of the authoritative renewable energy literature and from interviews and other documented sources of local conditions that relate to SERC model components. The SERC models were used in conjunction with the JEDI models for solar PV, wind, and natural gas to perform a full portfolio analysis of clean energy development within the county. As the energy efficiency model is the focus of this thesis, a full description of its development is included in the next section.

The SERC Energy Efficiency Impact Assessment Model (EEIAM)

While the JEDI models are complex and powerful tools, NREL made their methodology quite transparent. The models were developed in Microsoft Excel and all calculations are visible to the user (though they are locked for editing). The only proprietary information in the models is the state level multipliers derived from IMPLAN. The basic organization of the JEDI models is shown in Figure 10.

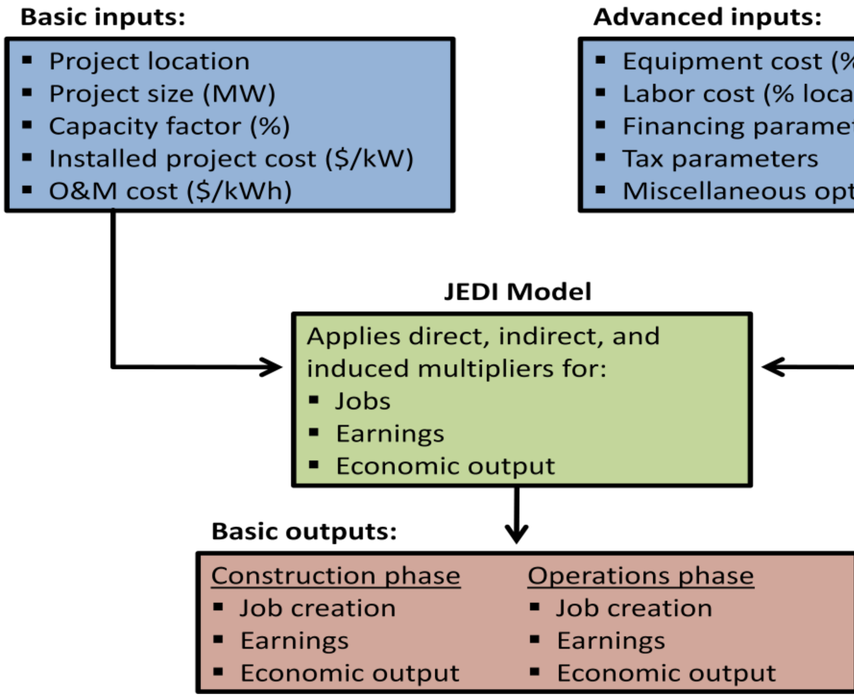

Figure 10. Basic Structure of the JEDI Models

In order to describe this structure in more detail, the JEDI Wind model will be used as an example. Besides obtaining regional multipliers, the most important and labor intensive component of building an economic impact assessment model is determining an accurate and detailed life-cycle cost breakdown and establishing the percentage of each of those costs spent locally. The construction phase cost allocations for a hypothetical 50 MW wind farm are displayed below (Figure 11).

Project Cost Data				
Construction Costs	**Cost**	**Cost Per**	**% of Total**	**Local Share**
Equipment Costs				
Turbines (excluding blades and towers)	$45,673,219	$913	43.3%	0%
Blades	$10,692,727	$214	10.1%	0%
Towers	$11,838,376	$237	11.2%	0%
Transportation	$8,172,298	$163	7.7%	0%
Equipment Total	$76,376,620	$1,528	72.4%	
Balance of Plant				
Materials				
Construction (concrete, rebar, equip, roads	$11,036,422	$221	10.5%	23%
Transformer	$1,248,448	$25	1.2%	0%
Electrical (drop cable, wire,)	$1,315,949	$26	1.2%	0%
HV line extension	$2,403,799	$48	2.3%	0%
Materials Subtotal	$16,004,618	$320	15.2%	
Labor				
Foundation	$1,349,110	$27	1.3%	12%
Erection	$1,528,059	$31	1.4%	3%
Electrical	$2,226,842	$45	2.1%	6%
Management/Supervision	$1,155,512	$23	1.1%	0%
Misc.	$4,003,023	$80	3.8%	0%
Labor Subtotal	$10,262,546	$205	9.7%	
Development/Other Costs				
HV Sub/Interconnection				
Materials	$758,491	$15	0.7%	0%
Labor	$232,341	$5	0.2%	0%
Engineering	$1,032,116	$21	1.0%	0%
Legal Services	$562,503	$11	0.5%	0%
Land Easements	$0	$0	0.0%	100%
Site Certificate/Permitting	$263,190	$5	0.2%	100%
Development/Other Subtotal	$2,848,641	$57	2.7%	
Balance of Plant Total	$29,115,805	$582	27.6%	
Total	$105,492,424	$2,110	100.0%	

Figure 11. Construction phase cost breakdown for a hypothetical 50 MW wind farm (NREL 2011)

Establishing such a detailed cost breakdown requires a great deal of research and an in-depth knowledge of the project specifics. Establishing local percentages requires a similar amount of research into the structure of the local economy. Once the local costs are established, they are then allocated to one of the 14 JEDI industry aggregates (Table 7). From here, it is a relatively straightforward exercise to apply the appropriate multipliers to arrive at direct, indirect, and induced jobs, earnings, and economic output.

It should be noted that in some cases, the JEDI models do not use I-O analysis to calculate direct job creation. Instead, when information is available on wage rates, JEDI employs a hybrid approach where direct jobs are calculated analytically, and all other impacts are calculated using multipliers.

Table 7. JEDI Industry Aggregates

Industrial Sectors	
Agriculture	TCPU*
Mining	Wholesale Trade
Construction	Retail Trade
Manufacturing	FIRE*
Fabricated Metals	Misc. Services
Machinery	Professional Services
Electrical Equipment	Government

*TCPU stands for transportation, communication, and public utilities. FIRE stands for financing, insurance, and real estate.

The energy efficiency impact assessment model was developed using the same basic structure as the JEDI models. The main distinction between the EEIAM and other SERC and JEDI models is that instead of construction phase and operating phase impacts, the EEIAM estimates economic impacts for the measure installation phase and for the consumer energy bill savings phase over a 20-year forecasting period.

The EEIAM is designed to require a minimal amount of user defined inputs but is customizable to allow for future updates or for use outside Humboldt County. At the base level, the user only needs to specify sector (residential and/or commercial), end-use category, incentive scenario, and energy savings type (natural gas and/or electricity). For instance a user could examine job creation from a residential lighting program at full incentive level spending. The model calculates economic impacts specific to Humboldt County based on the assumptions described below. Future users with data specific to their region (or with updated information for Humboldt County) could import their data and may choose to modify developer assumptions to more accurately reflect their needs.

Estimating Installation Phase Impacts

For the installation phase, measure level cost information was drawn from Itron (2008) as detailed above. However, for discretionary measures (retrofit and conversion), the total incremental cost reported by Itron includes the installation labor component whereas event driven measures (replace on burnout) include only incremental material costs to avoid double counting. To disaggregate labor costs from materials cost, the DEER database was used. For hundreds of common energy efficiency measures, DEER reports installation man hours, wage rates (by climate zone), and materials costs (CPUC 2008). For each measure included in this analysis, the corresponding measure from DEER was used to establish the percentage of the total cost allocated to labor. This percentage was then applied to discretionary measure costs to extract labor costs. The net present value (NPV) of labor costs, materials costs, and utility program costs (administration and marketing) for the 20-year forecasting period were aggregated by end use category. These costs form the basis for the installation phase impacts.

The percentage of each of these costs sourced locally was determined primarily through interviews with the Redwood Coast Energy Authority as well as with local contractors, retailers, and wholesalers. The default local share for each sector and cost category and the justifications are displayed in Table 8. Due to the large number of potential contractors and vendors, these estimates are relatively rough (± 10% to 20%). Where local interviews indicated a range of values, the low end of the range was used to ensure that economic impact results are conservatively low.

Table 8. Local Percentage of Total Energy Efficiency Costs

Cost Category	Purchased Local (%)	Justification
Residential Sector Electrical Measures		
Materials Costs		
Lighting	10%	RCEA indicated in a personal communication on 10/27/2010 that they obtain ~10% of their residential lighting materials from local distributors
HVAC Water Heat Appliances	10% 10% 10%	Interviews with several local contractors indicated that they source 10-20% of their residential materials locally.
Labor Costs		
Lighting HVAC Water Heat Appliances	90% 90% 90% 90%	Because Humboldt County is geographically isolated and because this analysis is focused on individual upgrades rather than whole building retrofits, it is assumed that nearly all labor will be sourced locally.
Gas Measures		
Materials Costs		
HVAC Water Heat	10% 10%	Interviews with several local contractors indicated that they source 10-20% of their residential materials locally.
Labor Costs		
HVAC Water Heat	90% 90%	Because Humboldt County is geographically isolated and because this analysis is focused on individual upgrades rather than whole building retrofits, it is assumed that nearly all labor will be sourced locally.

Table 9 (continued)

Cost Category	Purchased Local (%)	Justification
Commercial Sector Electrical Measures		
Materials Costs		
Lighting	90%	RCEA indicated in a personal communication on 10/27/2010 that they obtain ~90% of their commercial lighting materials from local distributors.
HVAC Refrigeration Food Appliances	5% 5% 5% 5%	Interviews with several local contractors indicated that there are no local distributors for commercial equipment in these end use categories. However, they do obtain a small portion (<10%) of their miscellaneous materials from local sources.
Labor Costs		
Lighting HVAC Refrigeration Food Appliances	90% 90% 90% 90% 90%	Because Humboldt County is geographically isolated and because this analysis is focused on individual upgrades rather than whole building retrofits, it is assumed that nearly all labor will be sourced locally.
Gas Measures		
Materials Costs		
Food HVAC Water Heat Appliances	5% 5% 5% 5%	Interviews with several local contractors indicated that there are no local distributors for commercial equipment in these end use categories. However, they do obtain a small portion (<10%) of their miscellaneous materials from local sources.
Labor Costs		
Food HVAC Water Heat Appliances	90% 90% 90% 90%	Because Humboldt County is geographically isolated and because this analysis is focused on individual upgrades rather than whole building retrofits, it is assumed that nearly all labor will be sourced locally.
Additional Costs		
Admin. and Marketing	100%	Here it is assumed that more aggressive efficiency programs would be administered locally through RCEA. Although some portion of programmatic costs would still occur outside the county, the local percentage is set at 100% to account for economy of scale effects (i.e. A small local program would have higher admin costs as a fraction of total costs than a program for the entire service territory).

After establishing local costs, the same general approach used in the JEDI models was applied to establish economic impacts from energy efficiency. Direct jobs were calculated analytically by using total labor expenditures and a weighted average wage rate from each labor category.[23] All other economic impacts are estimated using the appropriate multipliers. In addition to direct jobs, labor expenditures have a number of indirect and induced impacts because total labor expenses and wage rates include payroll costs (FICA tax, worker's compensation, insurance, etc.). Per JEDI methodology, 7.1% of total payroll costs is allocated to the government sector for payroll taxes and 30.5% is allocated to the professional services sector for employee benefits. The remainder is take home pay for the workers. PCE multipliers are applied to these employee wages to estimate indirect and induced impacts from employee spending.

The last component of installation phase impacts is from the sale of energy efficiency materials. Because these materials are not manufactured locally, the only two industrial sectors that are affected by the sale of efficiency materials are wholesale trade and government. 9% of total materials spending is allocated to the government sector for local sales tax, and 36% of total materials spending is allocated to wholesale trade. Only 36% of the total cost is used here because this represents a common wholesale markup for efficiency materials (DOE 2010). This wholesale margin is used to estimate direct,

[23] DEER database wage rates for climate zone 1 were used for each end use category. Administration labor rates are based on the average fully loaded wage rate as reported by RCEA in a personal communication on 11/5/10.

indirect, and induced impacts because it is the portion of materials spending that is most likely to remain in the local economy.

Estimating Energy Bill Savings Phase Impacts

As previously indicated, gross consumer energy bill savings were estimated based on user level energy savings (kWh or therms) from the measure level and average retail rates charged by PG&E. Consumer costs (the portion of total measure costs not covered by utility incentives) were subtracted from gross dollar savings to arrive at net savings to the consumer. The NPV of net consumer savings over the 20-year forecasting period was used to determine local economic impacts during the energy bill savings phase. Not all of these savings, however, will be spent locally. Local share default values for the spending of energy bill savings were assumed to be 60% in both the residential and commercial sectors. This value was established based on Dr. Hackett's in-depth knowledge of the Humboldt County economy as well as an NREL study on the economic impacts of energy efficiency in Boulder County, CO (Goldberg, Cliburn and Coughlin 2010). Nationwide, a variety of sources indicate that consumers spend about 80-90% of their disposable income in their local community. Thus, the default values in the EEIAM likely produce conservatively low impact estimates.

CHAPTER 5. RESULTS AND DISCUSSION

In this chapter, the methods described above will be used to assess the costs and benefits of more aggressive utility energy efficiency programs in Humboldt County. The first broad area of analysis focuses on the realistically achievable energy efficiency potential and the cost of that resource as compared to generation at the Humboldt Bay Generating Station. Additionally, efficiency will be examined as a carbon mitigation strategy and as a means of reducing the negative externalities associated with criteria pollutant emissions. Finally, the economic impacts of each level of programmatic spending are analyzed in order to highlight benefits to the Humboldt County community.

Humboldt County Energy Efficiency Potential and Costs

As with all energy efficiency potential studies, it is important to clearly and firmly establish a baseline. The Itron (2008) baseline includes all efficiency codes and standards that were in place in 2006 as well as an estimate of naturally occurring market uptake but excludes existing utility sponsored efficiency programs. The BaseRestrict scenario is based on the market potential for measures incentivized in the 2004-2005 program cycle with incentive levels available in 2006. This serves as a close approximation for expected energy savings through 2026 under business as usual (BAU).

The LCOE borne by the IOU was calculated for each end-use category at three incentive levels (BaseRestrict, MidRestrict, and FullRestrict) over the 20-year study period using a real discount rate of 6%. This discount rate is consistent with the authoritative literature (EPRI, 2009a; Itron, 2008; McKinsey, 2009) and is justifiable because for profit organizations such as IOUs have a high opportunity cost in forgone profitable investment options. The 20-year cumulative electricity and natural gas portfolio-wide savings potential and associated utility costs under each incentive scenario are displayed for the residential sector in Figure 12 and Figure 13.

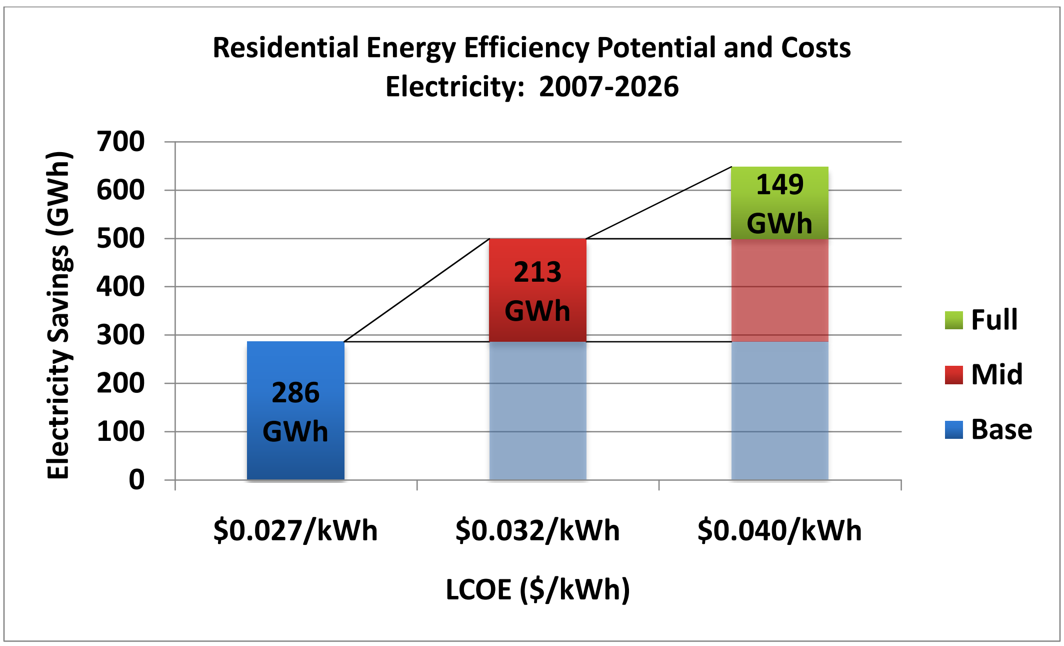

Figure 12. Humboldt County Cumulative Residential Electrical Efficiency Potential and Costs

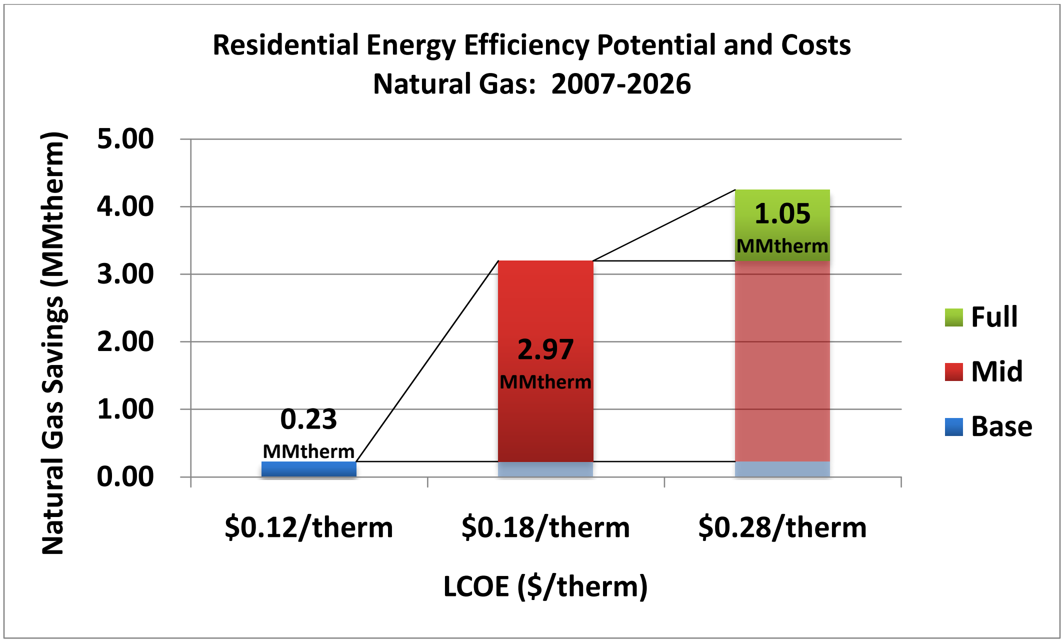

Figure 13. Humboldt County Cumulative Residential Natural Gas Efficiency Potential and Costs

Figure 12 shows that at current incentive levels (Base), approximately 286 GWh would be saved by 2026 at a levelized cost of $0.027/kWh. With increasing incentive levels, we see additional energy savings, though there are diminishing marginal returns. Full incentive level programmatic spending for the residential electricity sector is anticipated to achieve almost 650 GWh over the 20-year forecasting period. Annualized, this amounts to 32.4 GWh/year, or 7.2% of residential electricity consumption.[24] The cost of these savings is estimated at $0.04/kWh, which is $0.018/kWh less than the marginal cost of generation at the HBGS.

[24] Based on 2008 residential electricity consumption for Humboldt County of 448.2 GWh as reported by the CEC (CEC 2011a).

Figure 13 shows that current incentive levels are expected to achieve 0.23 million therms by 2026. At the full incentive level, 4.25 million therms could be saved for a cost of $0.28/therm. While these savings are considerable, the yearly savings only represent about 1% of 2008 residential consumption. The cost of these savings, however, is substantially less than PG&E's acquisition costs of $0.67/therm (EIA 2011).

In the commercial sector, savings estimates for both electricity and natural gas are more modest than the residential sector and come at a higher cost (Figure 14 and Figure 15). Full incentive level savings of 181 GWh and 0.31 MMtherm could be achieved for $0.08/kWh and $1.19/therm, respectively. This amounts to 3.8% of yearly commercial electricity demand and about 0.25% if yearly gas demand (CEC 2011a). The costs associated with full incentive level programs are more expensive than marginal generation costs and gas acquisition costs. However, a future price on carbon may still make these programs low cost abatement strategies.

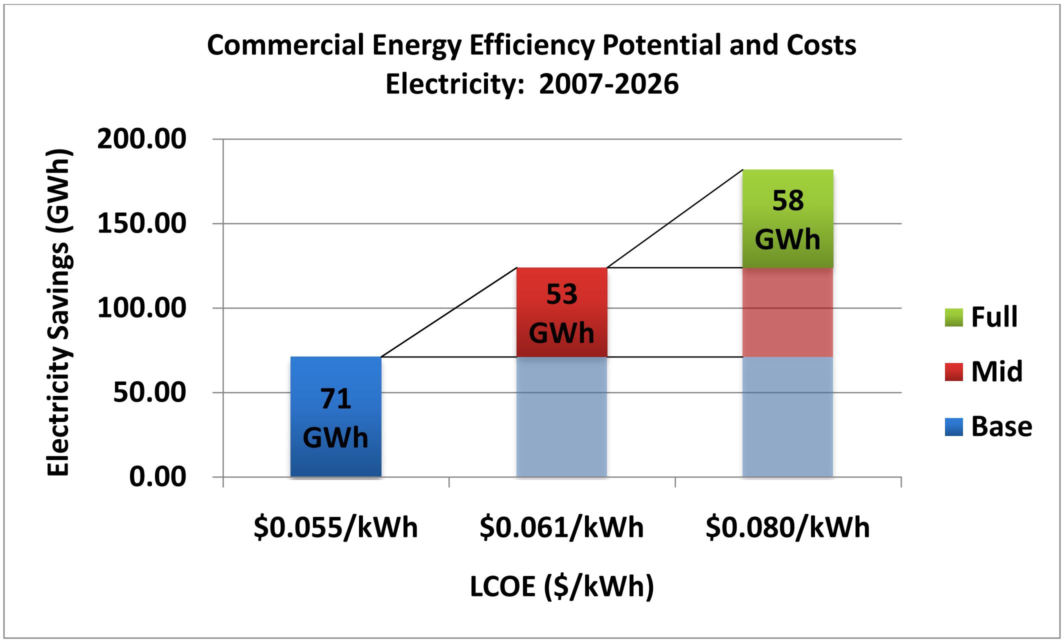

Figure 14. Humboldt County Cumulative Commercial Electrical Efficiency Potential and Costs

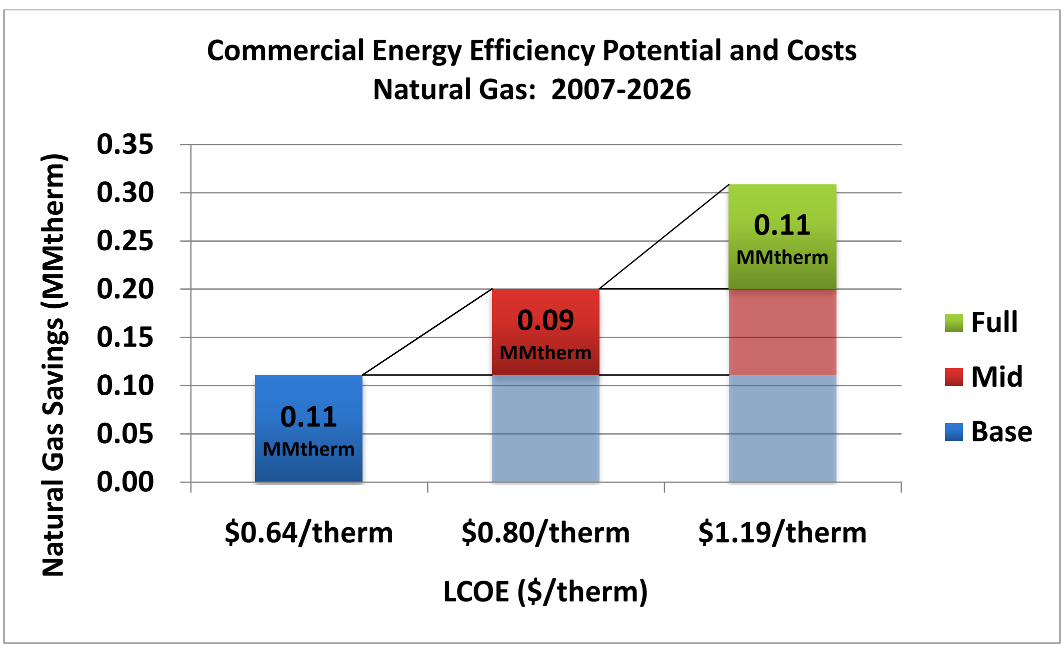

Figure 15. Humboldt County Cumulative Commercial Natural Gas Efficiency Potential and Costs

In order to examine residential and commercial savings more closely, market potential supply curves were developed by end use category and are presented in Figures 17 through 20 below.

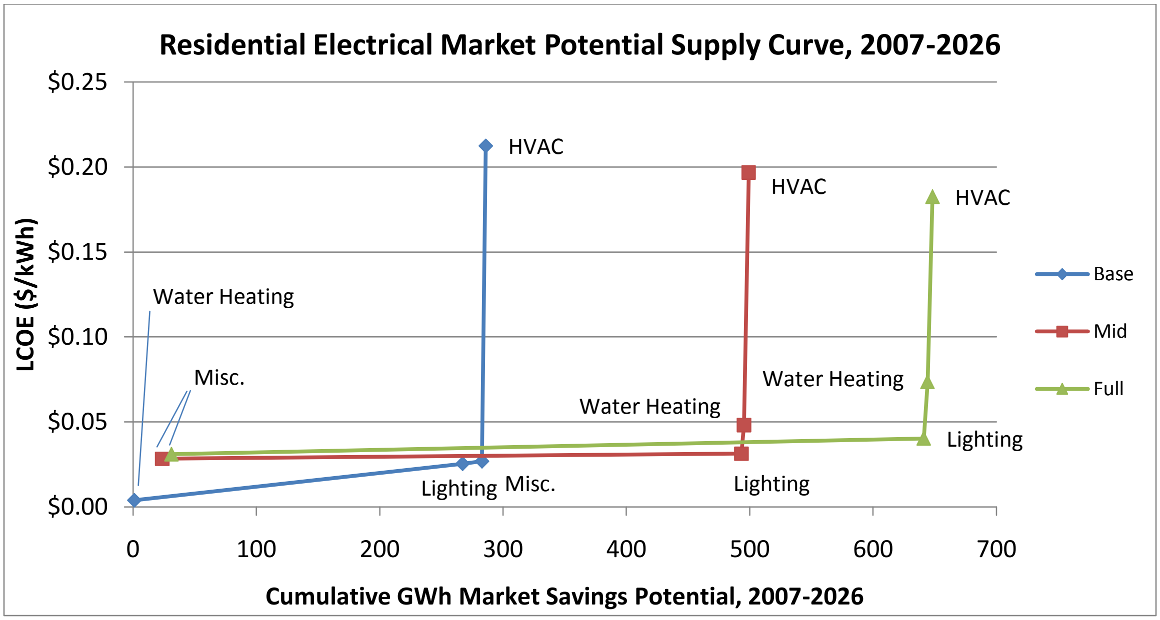

Figure 16. Humboldt County Residential Electrical Efficiency Supply Curve

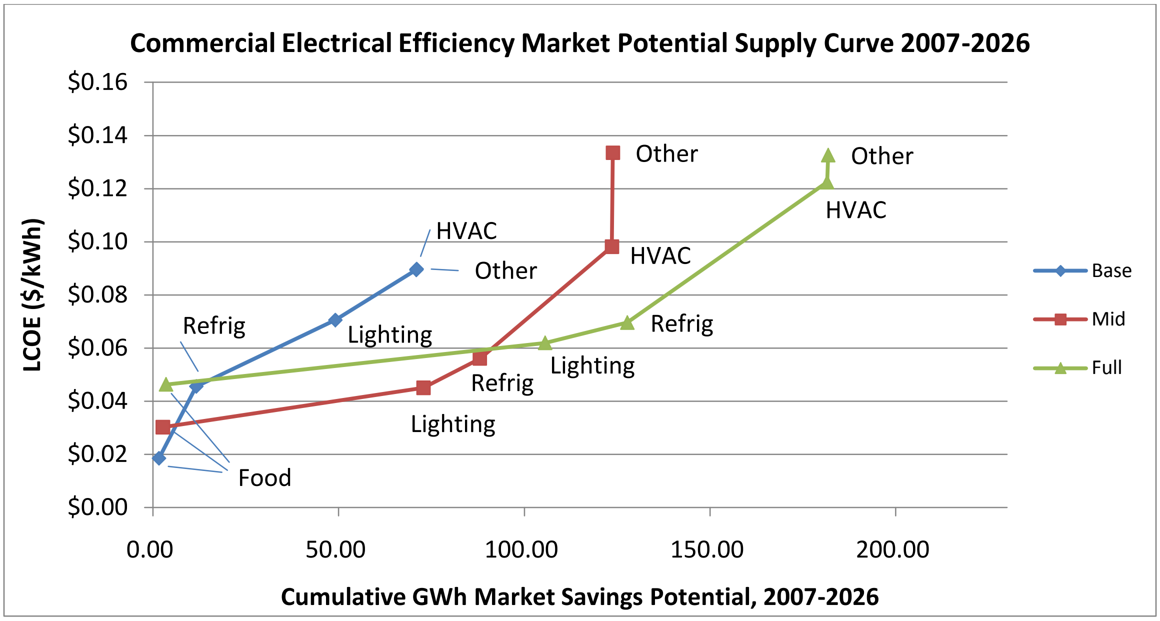

Figure 17. Humboldt County Commercial Electrical Efficiency Supply Curve

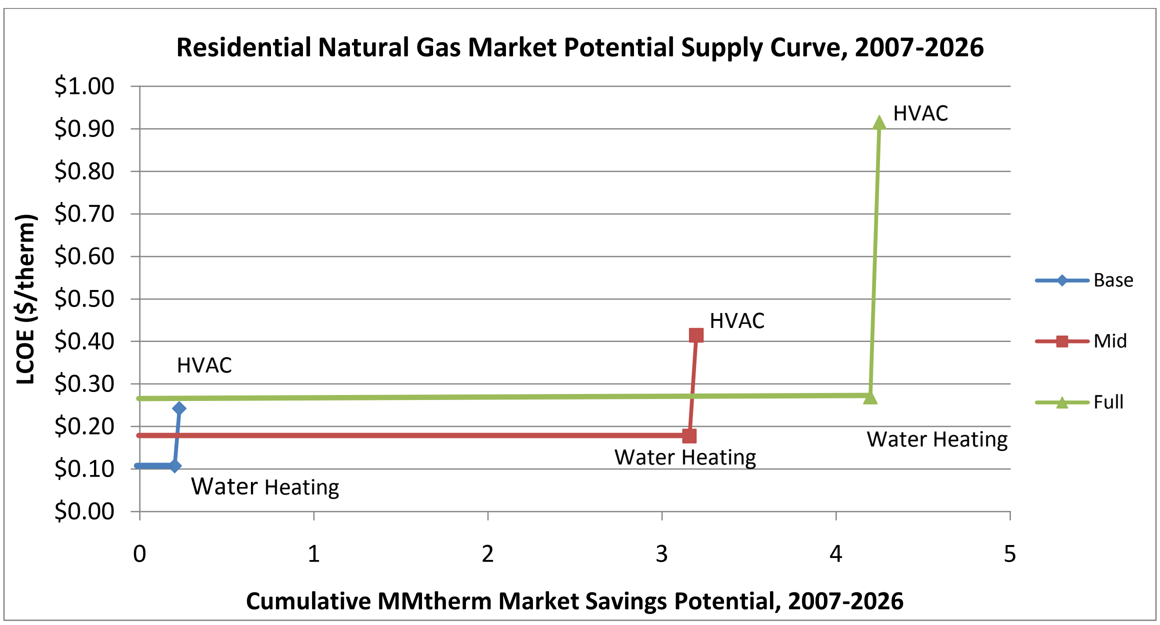

Figure 18. Humboldt County Residential Natural Gas Efficiency Supply Curve

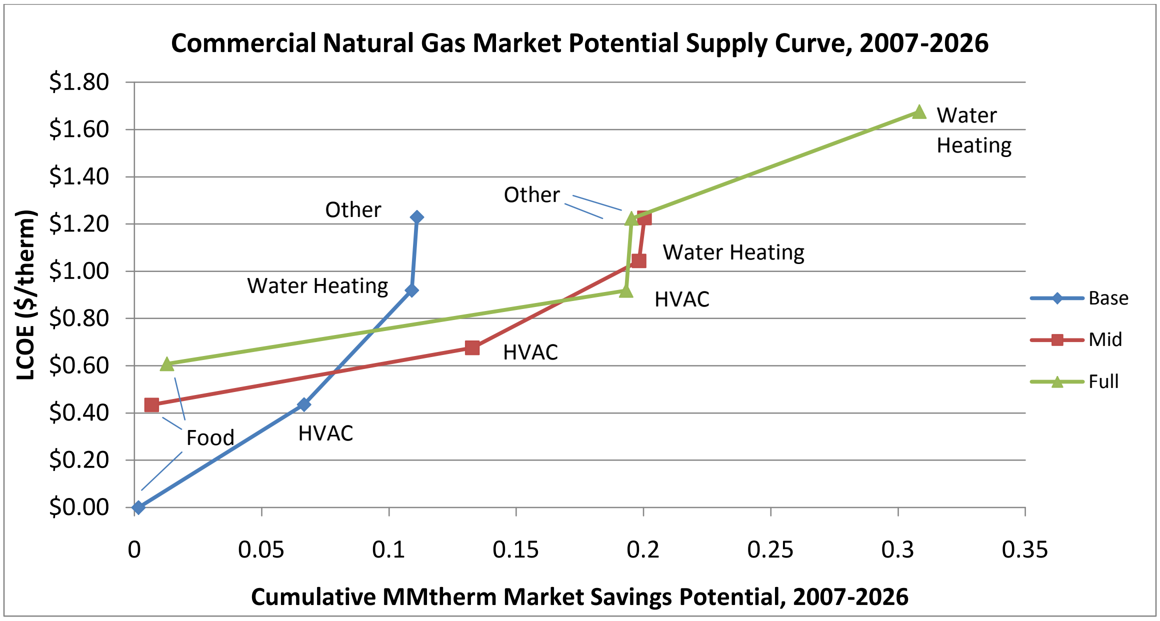

Figure 19. Humboldt County Commercial Natural Gas Efficiency Supply Curve

These figures indicate that the residential sector dominates Humboldt County energy savings potential for both electricity and natural gas. Lighting measures make up the majority of electrical savings potential in both the residential and commercial sectors (~94% and ~56%, respectively) with significant contributions also coming from refrigeration and HVAC measures in commercial buildings.[25] Residential natural gas savings result almost entirely from water heating measures while commercial savings are split mainly between water heating and HVAC measures. These results demonstrate that there is considerable potential for energy savings through increased energy efficiency efforts in Humboldt County available at a low cost.

[25] The Redwood Coast Energy Authority (RCEA) estimates that their efforts to promote lighting efficiency as well as natural market uptake had achieved an ~36% market penetration as of 2009. This suggests that the estimated savings due to lighting upgrades may be achieved before 2026. Though it is not addressed in this analysis, cost competitive LED lighting could potentially be on the market within 5-10 years, creating additional savings opportunities.

Avoided Generation, Climate Change Mitigation, and Social Damage Costs

If it costs less to implement efficiency programs and save a megawatt hour of electricity than it does to generate that same megawatt hour, that program is probably a sound investment for the utility. Additionally, not generating that MWh abates a certain amount of carbon. If the cost of avoided generation is negative, then the cost of removing a ton of carbon from the atmosphere is also negative. With AB32 moving forward, there will be some market mechanism that establishes a price on carbon. This means that it will become increasingly important for PG&E to capitalize on all low and negative cost carbon abatement strategies.

Table 10 shows the avoided generation cost for each sector and incentive scenario and the corresponding cost per avoided ton of CO_2e. As a point of comparison, these same metrics are presented for the most prominent renewable energy technologies.

Table 10. Cost of Avoided Generation and Avoided CO_2e

Incentive Scenario / Technology Type	LCOE ($/MWh)	Displaced Levelized Variable Cost at HBGS ($/MWh)	Avoided Generation Cost ($/MWh)	Avoided CO_2e ($/ton)
Residential Efficiency				
BaseRestrict	$28	$58	-$30	-$63
MidRestrict	$34	$58	-$24	-$51
FullRestrict	$42	$58	-$16	-$33
Commercial Efficiency				
BaseRestrict	$55	$58	-$3	-$7
MidRestrict	$61	$58	$3	$6
FullRestrict	$80	$58	$22	$46
Residential and Commercial Efficiency Combined				
BaseRestrict	$34	$58	-$25	-$52
MidRestrict	$39	$58	-$19	-$40
FullRestrict	$51	$58	-$8	-$16
Renewable Technologies				
Hydro	$121	$58	$63	$133
Biomass	$127	$58	$69	$145
Wind	$90	$58	$32	$67
Solar	$370	$58	$142	$657
Wave	$187	$58	$129	$272

Here it is seen that for the residential sector, all three incentive scenarios are less costly on a per megawatt hour basis than the marginal cost of dispatch for the HBGS.

For the commercial sector, only the BaseRestrict scenario has a negative cost while the Mid- and FullRestrict scenarios have additional costs of \$3/MWh and \$22/MWh, respectively. However, when the residential and commercial sectors are combined, all three scenarios have lower costs than generation at the margin. In comparison, average LCOE values for prominent renewable technologies taken from the literature (Black and Veatch 2010, E3 2008; EIA 2009; KEMA 2009; Klein and Rednam 2007; Klein 2010; Lazard 2008; and PIER 2007) suggest that displacing generation at the HBGS with renewable energy would cost an incremental \$32/MWh to \$142/MWh.

The cost of avoided carbon emissions is based on the avoided generation cost so that all efficiency scenarios with a negative displaced generation cost also have a negative climate change mitigation cost. Although the Mid and FullRestrict scenarios in the commercial sector have costs of \$6/ton and \$46/ton CO_2e, these costs are still considerably lower than the \$67-\$657/ton CO_2e range observed for renewables (Hackett, Scheidler and Garcia Jr. 2011).

Table 11 shows the avoided cost of criteria pollutant emissions for the pollutants emitted by the internal combustion engines at the HBGS. These calculations utilize the same LCOE and displaced levelized variable costs as Table 10 above. Here again, with the exception of the Mid and FullRestrict scenarios in the commercial sector, avoiding criteria pollutant emissions through efficiency spending has a negative cost.

Table 11. Avoided Cost of Criteria Pollutant Emissions

Incentive Scenario / Technology Type	Avoided NO_x (\$/ton)	Avoided VOC (\$/ton)	Avoided SO_2 (\$/ton)	Avoided PM_{10} (\$/ton)
Residential Efficiency				
BaseRestrict	-$374	-$235	-$2,935	-$957
MidRestrict	-$306	-$192	-$2,402	-$783
FullRestrict	-$199	-$125	-$1,563	-$510
Commercial Efficiency				
BaseRestrict	-$41	-$26	-$324	-$106
MidRestrict	$36	$23	$284	$93
FullRestrict	$273	$172	$2,147	$700
Residential and Commercial Efficiency Combined				
BaseRestrict	-$309	-$194	-$2,425	-$791
MidRestrict	-$238	-$149	-$1,867	-$609
FullRestrict	-$95	-$60	-$746	-$243
Renewable Technologies				
Hydro	$792	$498	$6,220	$2,029
Biomass	$867	$545	$6,813	$2,222
Wind	$401	$252	$3,154	$1,029
Solar	$1,786	$1,123	$14,033	$4,577
Wave	$1,622	$1,020	$12,747	$4,158

Source: (Hackett, Scheidler and Garcia Jr. 2011)

Based on avoided generation costs alone, pursuing more aggressive energy efficiency programs in Humboldt County would be cost effective. An estimated market potential of 830 GWh could be achieved by 2026 in the residential and commercial sectors for a combined average cost of \$0.05/kWh. This is 13 percent lower than the current marginal generation cost at the HBGS (see Cost Effectiveness of Energy Efficiency Programs in Humboldt County section below).

This is to say nothing of the potential global warming damage costs associated with GHG emissions from natural gas fired generation. The National Research Council (2009) estimates that these damage costs may be in the range of \$3-\$100/ton CO_2e.[26] Assuming a damage cost of \$50/ton (\$24/MWh), the marginal cost of dispatch for the HBGS becomes \$82/MWh. This increases the avoided cost of generation to -\$40/MWh for the residential FullRestrict scenario, -\$2/MWh for the commercial FullRestrict scenario, and -\$31/MWh for the residential and commercial sectors combined. These savings are substantial and present a strong argument for more aggressive energy efficiency spending as a means of complying with AB32 mandates.

Social damage costs from criteria pollutant emissions are another important consideration. Criteria pollutants have deleterious effects on human health, agriculture, and the environment that are most commonly borne by individuals and are not factored in to the cost of electricity. Muller and Mendelsohn (2009) use the Air Pollution Emission Experiments and Policy (APEEP) model (Muller and Mendelsohn 2007) to estimate the marginal damage costs associated with NH_3, NO_x, PM_{10}, VOC, $PM_{2.5}$, and SO_2 emissions

[26] The low end of this range is based on a discount rate of 3% and a 1-2% reduction in global GDP due to global warming. The high end assumes a 1.5% discount rate and a 7-11% reduction in global GDP. Given the magnitude of the potential consequences of global warming, marginal damage costs in the range of \$50-\$100/ton CO_2e are not unreasonable.

from electricity generation nationwide. Humboldt County specific marginal damage cost estimates (2008$/ton) from this model can be seen in Table 9 below. Note that damage cost estimates vary based on where they are emitted relative to the ground (i.e. stack height). Muller and Mendelsohn (2009) explain that this is especially relevant in urban areas with high population density and that the correlation between stack height and damage cost is less clear in rural areas such as Humboldt County.

Table 9. Humboldt County Marginal Damage Costs (2008$/ton)

Criteria Pollutant	**Ground level**	**Low Point Sources***	**High Point Sources***
Ammonia (NH_3)	$608	$515	$309
Particulate Matter (2.5)	$393	$337	$249
Nitrogen Oxides (NO_x)	$139	$57	$153
Sulfur Dioxide (SO_2)	$527	$468	$378
Volatile Organic Compounds (VOC)	$51	$50	$74
Particulate Matter (10)	$129	$112	$69

* Note: Low point sources are sources with effective heights <250 m; high point sources have effective heights of >250 m and <500 m. Although Muller and Mendelsohn (2009) report marginal damage cost estimates for high point sources, a personal communication with Winslow Condon of the North Coast Unified Air Quality Management District on 14 July 2010 indicated that there are no point sources that high in Humboldt County. General note: All damage cost estimates were adjusted from 2000$ to 2008$ using inflators derived from data contained in the Budget of the United States Government: Historical Tables Fiscal Year 2011. http://www.gpoaccess.gov/usbudget/fy11/hist.html

Source: (Muller and Mendelsohn 2009)

Due to the rural nature of Humboldt County, these social damage costs are relatively low. However, they should still technically be added to the cost of generation at the HBGS. Efficiency spending represents a low to negative cost option for avoiding these damages (as shown in Table 11 above).

Consumer Costs and Savings

Despite being attractive investments for PG&E at all incentive levels, Base and Mid incentive level programs require a substantial upfront investment by customers. This initial capital outlay is often cited as one of the main barriers to consumers making energy efficiency investments. When compared to the net present value of energy bill savings in the same time period, however, the costs are quite low. Figures 21 and 22 present the net present value of these costs and savings for each sector and incentive level.[27]

[27] Using a 6% real discount rate. Consumer savings are net of upfront cost.

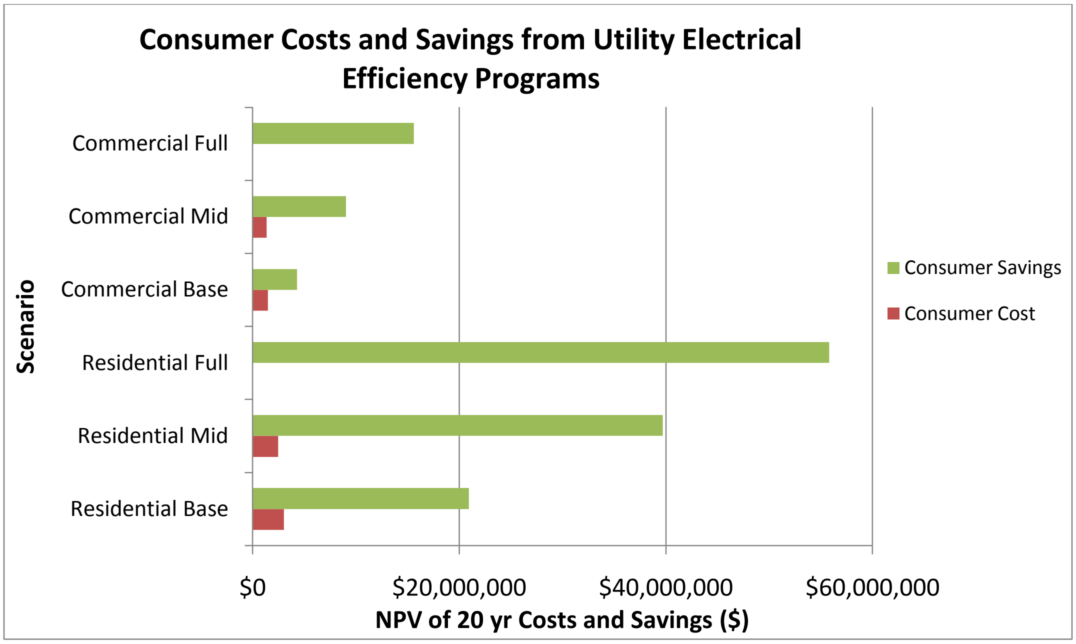

Figure 20. Costs and Savings from Utility Electrical Efficiency Programs

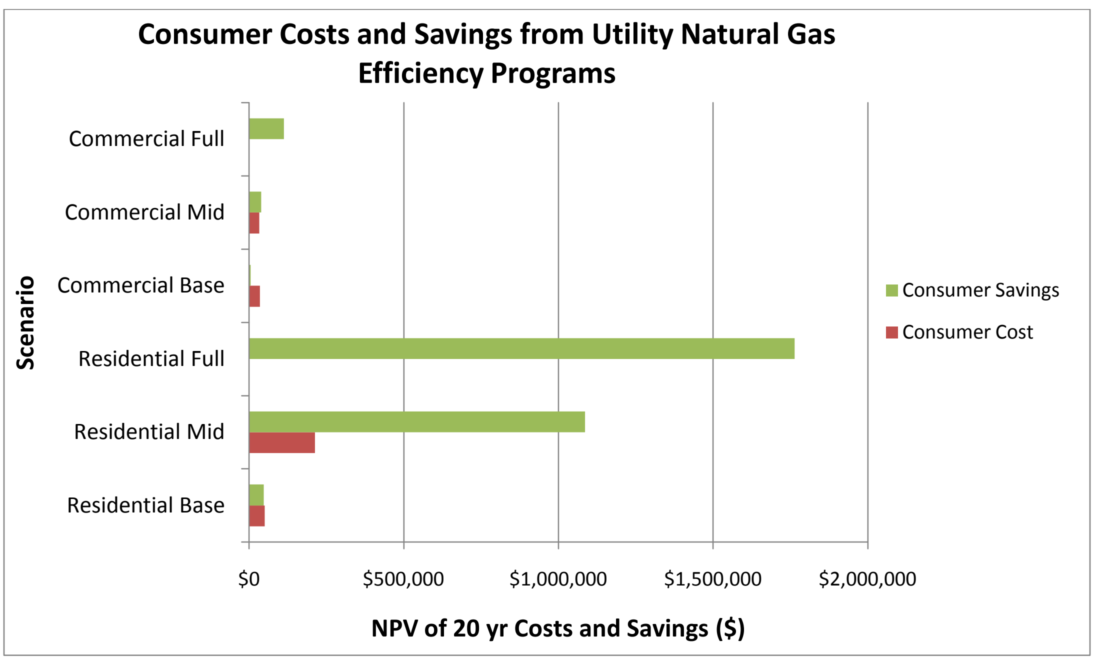

Figure 21. Costs and Savings from Utility Natural Gas Efficiency Programs

For each sector and end-use category, consumer savings exceed consumer costs several fold over the 20-year forecasting period. For nearly all sectors and end-use categories, energy bill savings exceed the consumer cost after the fourth year of the program at the latest. In most cases, savings exceed costs within the first year because high savings, low incremental costs measures like CFL light bulbs dominate many of the end-use portfolios.

Although this analysis has shown that consumer payback on efficiency investments typically pay back within 1 to 4 years (at the end-use category level), upfront consumer cost could still be a barrier to energy efficiency upgrades. If PG&E pursued programmatic spending at or near the full incentive level, this barrier would largely be removed and would result in mean NPV energy bill savings of $3.7 million annually.

Cost Effectiveness of Energy Efficiency Programs in Humboldt County

Previously mentioned Senate Bill 1037 and Assembly Bill 2021 require that electricity corporations under CPUC's regulation must first acquire their unrealized resource needs through all available energy efficiency and demand response resources that are cost effective, reliable and feasible. All of the measures included in this analysis are existing and mature technologies so they are known to be reliable. PG&E currently has well performing programs in place that demonstrate the feasibility of utility incentive programs. The cost effectiveness of each efficiency program is determined primarily through the TRC test. While some end uses (such as residential lighting) dominate the lowest cost savings potential, it is important from a policy perspective to pursue energy savings in all sectors and end use categories. Doing so will push the market towards more efficient devices and ultimately bring the cost of savings in all end use categories down and maximize efficiency gains.

Recall that all measures in this analysis are restricted to a TRC value of 0.85 or greater. This means that some efficiency measures are not cost effective in their own right, but programs planners can cross subsidize less cost effective measures (such as HVAC) with more cost effective measures (such as lighting) to arrive at a portfolio of measures that is cost effective as a whole (TRC > 1). If LCOE is calculated for all end uses in the residential and commercial sectors combined in this analysis, the full market potential could be captured for $0.05/kWh and $0.34/therm (TRC values of approximately 1.16 and 2.0, respectively). Table 13 displays the LCOE and total savings potential through 2026 at the sector level and with the residential and commercial sectors combined for each incentive level.

Table 13. LCOE and Cumulative Savings Potential at the Sector Level

Incentive Level	Electricity LCOE ($/kWh)	2026 Savings Potential (GWh)	Natural Gas LCOE ($/therm)	2026 Savings Potential (MMtherm)
Residential				
Base	$0.03	286	$0.12	0.23
Mid	$0.03	499	$0.18	3.20
Full	$0.04	648	$0.28	4.25
Commercial				
Base	$0.05	71	$0.64	0.11
Mid	$0.06	123	$0.80	0.20
Full	$0.08	181	$1.19	0.31
Residential and Commercial Combined				
Base	$0.03	357	$0.29	0.34
Mid	$0.04	623	$0.22	3.40
Full	$0.05	830	$0.34	4.56

Source: (Hackett, Scheidler and Garcia Jr. 2011)

Sensitivity Analysis

A sensitivity analysis was performed to examine the influence of discount rate on the LCOE of each sector and incentive level (Figure 22). Over a wide range of discount rates (1%-15%), residential programs at all incentive levels remain low cost options for reducing energy consumption. The solid horizontal line represents the marginal generation cost at the Humboldt Bay Generating Station ($0.058/kWh). We see here that even at a discount rate of 15%, the full incentive level LCOE is approximately $0.01/kWh less than the marginal cost of generation. In the commercial sector, the mid and full incentive levels are more expensive than generation at the margin at any discount rate; all three incentive levels become more expensive than the marginal cost of generation at discount rates above 9% (Figure 24).

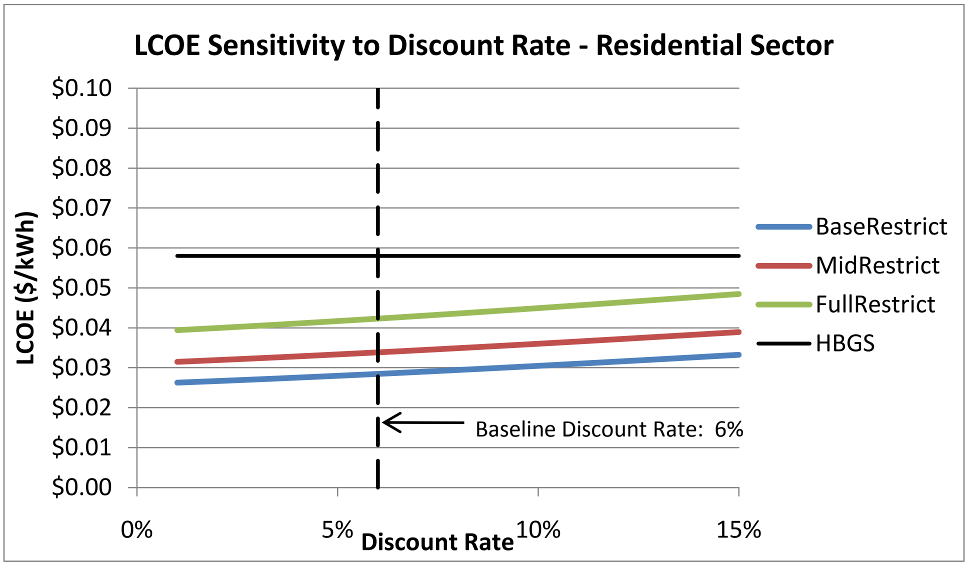

Figure 22. Residential Sector LCOE Sensitivity to Discount Rate

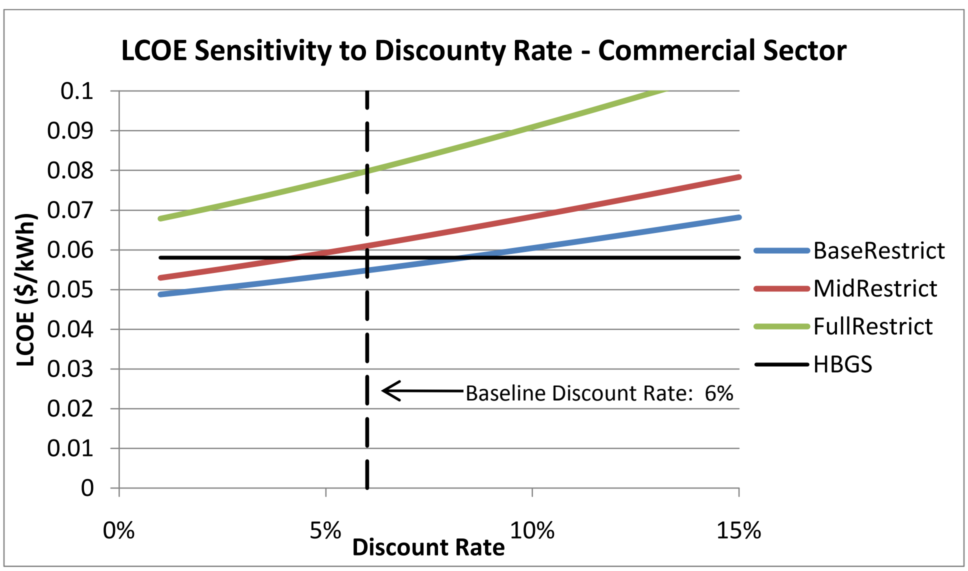

Figure 23. Commercial Sector LCOE Sensitivity to Discount Rate

When the residential and commercial sectors are combined, however, all three incentive levels are less expensive than the marginal cost of generation at discount rates below 13% (Figure 24). The CEC (2010) reports a range of discount rates for IOUs from 6.78% - 10.65% with an average of 7.70%. This analysis suggests that full incentive level efficiency programs in Humboldt remain less costly than marginal generation for PG&E over the full range of reasonable discount rates.

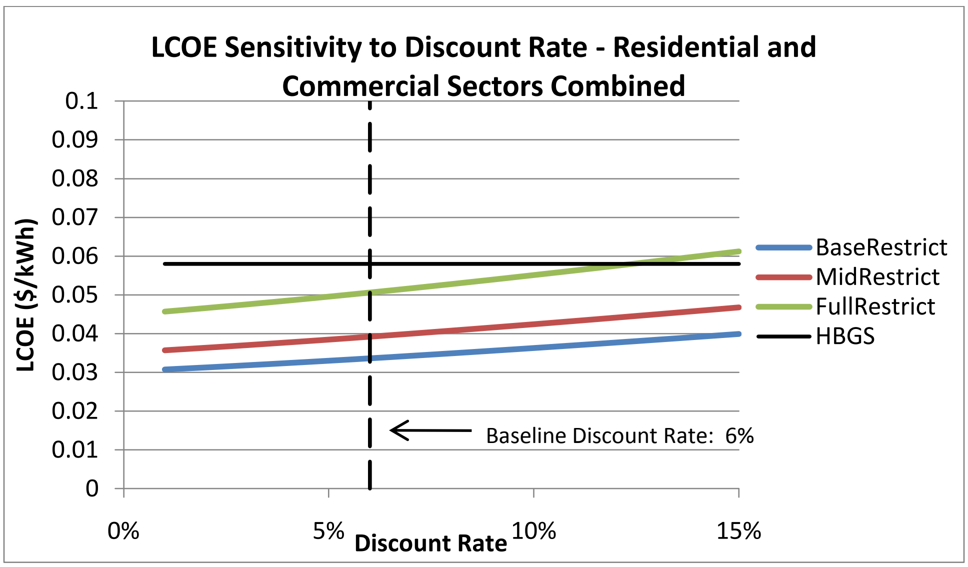

Figure 24. LCOE Sensitivity to Discount Rate for the Residential and Commercial Sectors Combined

This analysis has shown that full incentive level energy efficiency programs in Humboldt County are less expensive than marginal generation when evaluated for the residential and commercial sectors combined. This is true even in the absence of a price on carbon or criteria pollutant emissions. The analysis has also shown that consumer energy bill savings vastly outweigh their upfront capital costs at all incentive levels. If full incentive level programs in Humboldt County are cost-effective, reliable, and feasible, why are they not being implemented in accordance with Senate Bill 1037 and Assembly Bill 2021?

There are several potential factors at play. First, cost effectiveness in this analysis is calculated for residential measures, all commercial measures, and all residential and commercial measures combined in comparison to the marginal cost of supply at the HBGS and PG&E's natural gas acquisition costs. In reality, the cost effectiveness of utility energy efficiency programs is not calculated for all measures combined or on a county by county basis. Instead PG&E evaluates cost effectiveness on a program by program basis in comparison to their system wide avoided costs. As of 2009, PG&E had 73 distinct energy efficiency programs (CPUC 2009), each including some subset of efficiency measures that targets a consumer group (e.g. schools and colleges). Each efficiency program is evaluated using the TRC test, which weighs the net present value of avoided costs of non-renewable energy supply-side resources avoided or deferred for the entire service territory (i.e. the benefits) against the NPV of lifecycle participant and program administrator costs. If the system wide ratio of benefits to costs is greater than 1, the program is considered cost effective (CPUC 2008). So while the lifecycle avoided-cost benefits of reduced generation at the HBGS outweigh the estimated costs of implementing *all* measures at the full incentive level in Humboldt County, the criterion for cost effectiveness may not be satisfied on a program by program basis as compared to PG&E system-wide avoided costs.

Another factor may be the political sensitivity to increased electricity bill rates. Under decoupling, utilities recover their fixed costs of service regardless of unit sales through periodic rate adjustments issued by the CPUC. It is possible, therefore, that aggressive efficiency programs could reduce unit sales enough to substantially increase electricity bill rates. If this is the case, efficiency programs deemed cost effective by the TRC test may still not be implemented.

Ultimately, the level of programmatic energy efficiency spending in Humboldt County is dependent on PG&E's system-wide efficiency targets (as set by the CPUC) as well as the system-wide cost of generation. PG&E, as a regulated for-profit entity, has an obligation to meet the efficiency goals established by the CPUC while maintaining electricity rates that are conducive to profit maximization. This means that PG&E has an incentive to implement efficiency programs to meet but not exceed CPUC directives. As AB32 is implemented, it is possible that the future price on carbon will increase PG&E's system-wide cost of generation enough to make many more full incentive programs cost effective. If this is the case, Humboldt County may realize the energy savings estimates presented above through PG&E programs. If not, and the county still wishes to pursue more aggressive efficiency savings, it would have to do so either through a non-ratepayer based financing mechanism (such as PACE programs) or by taking direct control of their electricity service and incentive programs through a municipal utility district or Community Choice Aggregation.

Humboldt County Economic Impacts

The economic impacts from energy efficiency vary from year to year due to anticipated changes in consumer awareness and willingness to adopt measures in response to utility efficiency programs. Because of this variation, the present value of economic impacts were estimated for the entire forecasting period (2007-2026) and are reported as mean impact/year for each incentive level (Table 14). While the EEIAM has the capacity to estimate impacts for each sector, end-use category, and energy type (electricity or natural gas) separately, the results presented below are the total estimated impacts for electricity and natural gas efficiency programs in the residential and commercial sectors combined for all end-use categories. A full breakdown of impacts can be found in Appendix A, Tables A.1 and A.2.

Table 14. Economic Impacts from Energy Efficiency Programs (2007-2026)

Incentive Level	Earnings ($/Yr)	Economic Output ($/Yr)	Annual Jobs Created (FTE/yr)
Installation Impacts			
Base	$117,000	$427,000	2.6
Mid	$186,000	$677,000	4.1
Full	$247,000	$895,000	5.4
Gross Energy Bill Savings Impacts			
Base	$98,000	$406,000	3.6
Mid	$193,000	$800,000	7.0
Full	$283,000	$1,176,000	10.3
Net Energy Bill Savings Impacts			
Base	$64,800	$261,000	3.0
Mid	$160,000	$655,000	6.4
Full	$214,000	$872,000	9.0

Note: The net energy bill savings impacts account for the fact that more aggressive energy efficiency programs would result in the natural gas fired Humboldt Bay Generating Station running less. There are some variable operations and maintenance jobs that will be lost as a result. The reduced operation (capacity factor) of the HBGS was calculated using the SERC Regional Energy Planning Optimization (REPOP) model customized for Humboldt County. The reduction in economic impacts (1.3 FTE jobs/yr at the full incentive level) was calculated using the NREL JEDI model for natural gas customized for Humboldt County (SERC 2011).

These results indicate that investment in energy efficiency is likely to have a small but positive impact on the Humboldt County economy. Over the 20-year forecasting period, total gross mean job creation from full incentive level programs is anticipated to be 15.7 FTE jobs/yr (full incentive level installation impacts plus full incentive level gross energy bill savings impacts). As noted in Table 14, at the full incentive level only 1.3 jobs/yr are expected to be lost due to reduced operation of the HBGS which results in net positive job creation of 14.4 jobs/yr. This amounts to approximately 0.35 FTE jobs/GWh, which falls in the middle of the range (0.17-0.59 FTE jobs/yr) of economic impact estimates presented by Kammen et al.(2006) and Wei et al. (2010) (Table 1).[28] A common finding among energy efficiency studies is that the majority of the impacts resulting from efficiency programs stem from additional household consumer spending generated by consumer energy bill savings (Geller and Goldberg 2009; Roland-Horst 2008). As consumers save money on their energy bills, a portion of that savings is spent on goods and services within the community resulting in more jobs, higher earnings, and more economic output. This analysis suggests energy bill savings create nearly twice the number of jobs as installation, driven by mean NPV savings of $3.7 million annually.

As demonstrated above, the majority of the energy savings potential from utility energy efficiency programs lies in the residential sector. Furthermore, lighting measures dominate energy savings potential in both the residential and commercial sectors. It follows, therefore, that the majority of the economic impacts in both the installation and energy bill savings phases are from lighting measures, especially residential lighting. Figure 26 shows how the full incentive level efficiency job impacts from Table 14 are

[28] The present value job creation from electrical energy efficiency programs is estimated at 288 job years (net) over the 20-year forecasting period, with an associated energy savings of 830 GWh.

distributed between the residential and commercial sectors and between electricity and natural gas.

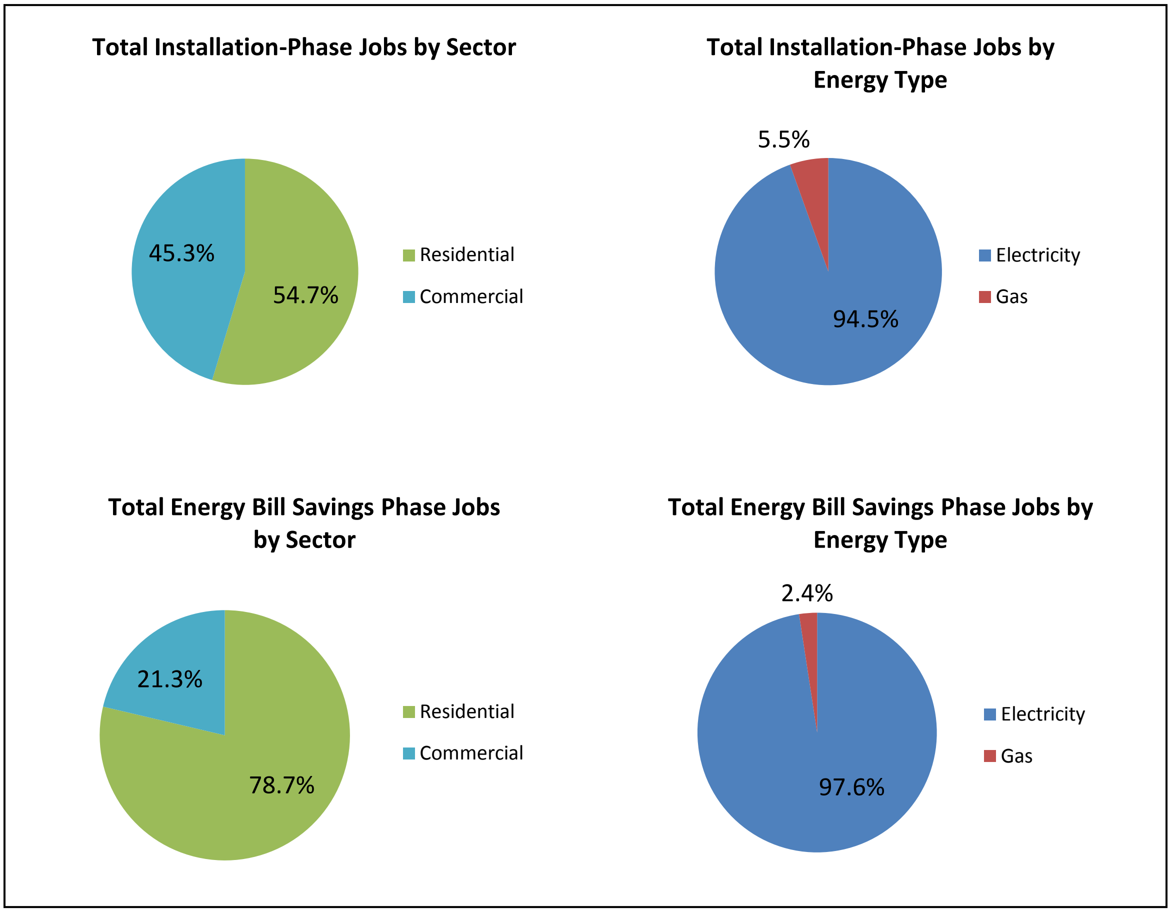

Figure 25. Full Incentive Level EE Job Impact Distribution by End Use

Looking at the residential and commercial sectors more closely, we see that the majority of job creation impacts are, as expected, from lighting upgrades (Figure 27). This is especially true in the residential sector, where 75% of installation job creation and 92% of energy bill savings job creation are due to lighting. In the commercial sector, job creation impacts are distributed more widely across electricity end uses, but lighting still accounts for more than half of total job creation. Plots of earnings and economic output are not included here, but the distribution of these impacts is approximately the same as job creation.[29]

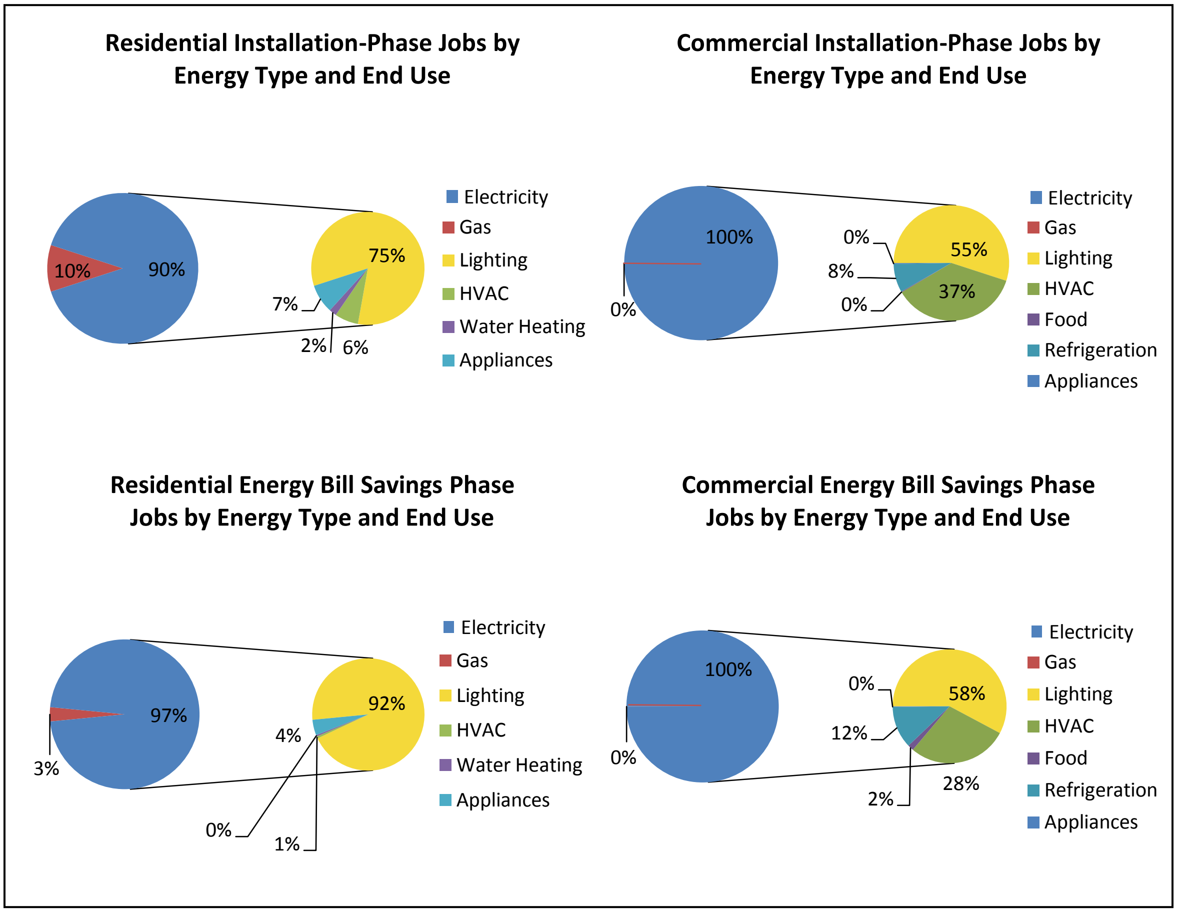

Figure 26. Full Incentive Level EE Job Impact Distribution by End Use
Note: The smaller pies demonstrate how electricity savings are distributed among end use categories.

This analysis has demonstrated that there is enormous potential for energy savings from residential and commercial lighting upgrades in Humboldt County. This energy savings is available at a negative cost for both consumers and the utility and provides a

[29] Full economic impact results by end use category can be found in Appendix A.

negative cost carbon abatement option for PG&E. Additionally, lighting upgrades account for the majority of net economic development potential from efficiency programs. While this analysis has focused on Humboldt County, it is widely recognized that efficiency improvements in lighting represent some of the "lowest hanging fruit" nationwide. Given the low cost and high benefits, it is unsuprising that there has been some effort to incorporate common lighting upgrades into appliance standards so the benefits are realized. The Huffman Bill in California (AB 1109) and the Energy Independence and Security Act of 2007 at the federal level both include provisions to phase out the sale of incandescent lightbulbs over coming years. However, recent outcry about the alleged overreach of big government has led to the introduction of the Better Use of Light Bulb (BULB) Act. This act would repeal the federal ban on incandescents and inhibit an enormous amount of energy savings from being realized nationwide. While restricting the availability of common products on the market is a very visible form of governmental control, the energy savings and carbon mitigation potential of adopting lighting standards is substantial. Concerns over energy security and potentially catestropic damages from climate change require a transition to renewable energy and more efficient and sustainable practices, which will take time and considerable investment. It is important, therefore, from a public policy prospective to take full advantage of the near term low cost / high benefit options for reducing our energy consumption and carbon emissions where they exist. State or national studies like the county level analysis in this thesis that highlight the economic development potential from lighting could further strengthen the argument for a ban on incandescent bulbs.

Scenario Analysis

Assumptions on the percentage of spending done locally in both the installation phase and the energy bill savings phase were established with as much certainty as possible. The default assumptions were consistently chosen to under-estimate economic impacts. Economic impacts in both the installation phase and the energy bill savings phase, however, are directly influenced by the percentage of spending done locally. Because of this, a scenario analysis was performed to examine the sensitivity of the model results to three categories of parameters: the percentage of materials sourced locally, the percentage of labor sourced locally, and the percentage of energy bill savings spent locally. The first two of these parameters affect the impacts in the installation phase while the third affects the energy bill savings impacts. For each parameter category, a low local percentage and a high local percentage scenario were examined in relation to the base case. Based on literature research and local interviews, these scenarios represent the estimated maximum and minimum amount of energy efficiency-related spending done locally. For the installation phase, the percentage of local materials was varied from 0% to 30% (base case of 10% in the residential sector and 5% in the commercial sector) and the percentage of local labor was varied from 70% to 100% (base case of 90%). The only exception to this is commercial lighting. A personal communication with Dana Boudreau of the Redwood Coast Energy Authority indicated that they source approximately 90% of their commercial lighting materials from a local distributor. Thus, the local materials percentage in this end use category was varied from

70% to 100%. For the energy bill savings phase, the base case local spending of 60% was varied from 40% to 80%.

Figures 28 through 30 present the results of the scenario analysis for the percentage of materials purchased locally. At the full incentive level, job creation varies from 5.1 to 5.7 FTE jobs/yr (base case = 5.3 FTE jobs/yr), earnings vary from $239,000 to $256,000/yr (base case = $247,000/yr), and economic output ranges from $804,000 to $998,000/yr (base case = $896,000/yr). Every 10% change in the percentage of materials purchased locally changes economic impacts by approximately 0.2 FTE jobs/yr, $5600 in earnings/yr, and $65,000 in output/yr. The relatively low sensitivity to local materials is due to several factors. First, the percentage of materials purchased locally was only varied from 0%-30%. This is because there are no large scale manufacturers or distributors of efficiency materials locally, and contractors only source a small amount of their materials from local retailers. For the materials that are purchased locally, only a small fraction of those costs remain in the local economy. This is due to the fact that local materials providers source the majority of their goods from distributors outside of the county, which means that only the wholesale margin (36%) remains local (EERE 2011). Because of this, there are minimal local supply chain impacts from the sale of efficiency materials. If there were a more robust manufacturing sector locally, a larger percentage of materials could be purchased locally, and the majority of costs associated with efficiency materials would be allocated to the manufacturing and wholesale trade sectors. Because Humboldt County is geographically remote, however, it will not likely attract substantial additional manufacturing. Thus, economic impacts from the purchase of efficiency materials will remain low.

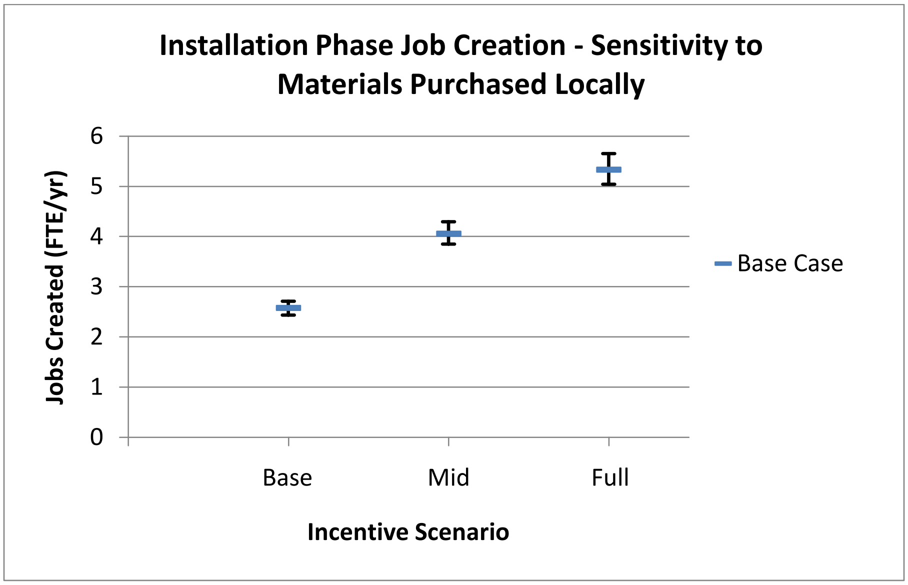

Figure 27. Installation Phase Job Creation Sensitivity to Materials Purchased Locally

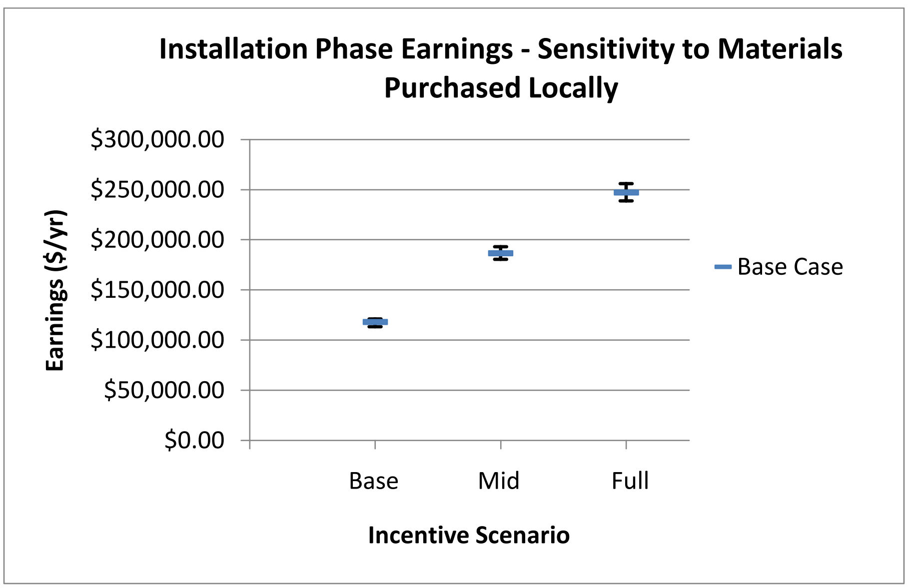

Figure 28. Installation Phase Earnings Sensitivity to Materials Purchased Locally

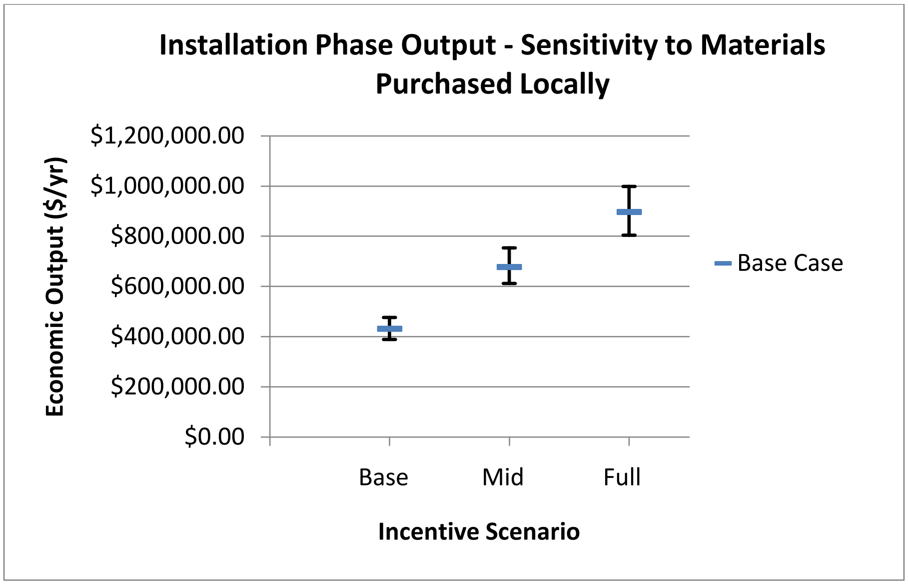

Figure 29. Installation Phase Output Sensitivity to Materials Purchased Locally

Figures 31 through 33 demonstrate the sensitivity of installation phase economic impacts to the percentage of labor sourced locally. At the full incentive level, job creation varies from 4.0 to 5.6 FTE jobs/yr (base case = 5.3 FTE jobs/yr), earnings vary from $185,000 to $261,000/yr (base case = $247,000/yr), and economic output ranges from $683,000 to $937,000/yr (base case = $896,000/yr). In this scenario analysis, the total variation in percentage of labor sourced locally is the same as the total variation in percentage of materials sourced locally (30%). Changing the percentage of local labor, however, results in a larger variation in economic impacts. Every 10% change in the percentage of labor sourced locally changes economic impacts by approximately 0.5 FTE jobs/yr, $26,000 in earnings/yr, and $86,000 in output/yr. Because the base case assumes that 90% of the labor associated with energy efficiency upgrades is sourced locally, most of the potential variation in economic impacts results in lower impacts than the base case.

However, there are many skilled contractors within the county, many of which are taking advantage of RCEA grant opportunities to become Building Performance Institute (BPI) certified contractors.[30] Due to the geographic isolation of Humboldt County, it is unlikely that a substantial portion of labor would be sourced externally. Transportation overhead would make it difficult for out-of-county contractors to compete with local providers. It is unlikely, therefore, that the base case assumption of 90 percent local labor is an overestimate.

One might expect that full incentive level programs that result in the substantial energy savings demonstrated in this analysis would require more installation jobs than estimated here. This scenario analysis suggests that it is unlikely that substantially higher economic impacts would result from either an increase in the percentage of materials or labor sourced locally. The low impacts during the installation phase result partially from the fact that efficiency materials are not manufactured or distributed by local companies. More significantly, many of the most commonnly installed measures modeled in the Itron analysis are classified as replace-on-burnout. As indicated in Chapter 4, replace-on-burnout measures do not include labor costs and only include incremental materials cost. This results in low direct job creation and a only small amount of indirect and induced job creation from the highest volume measures that have the highest associated energy savings.

[30] BPI certification is required by the CEC for contractors to perform efficiency upgrades as part of the new Energy Upgrade California program. Energy Upgrade California is discussed in the conclusion of this document. A list of certified contractors can be found at: http://energyupgradeca.org/county/humboldt/overview

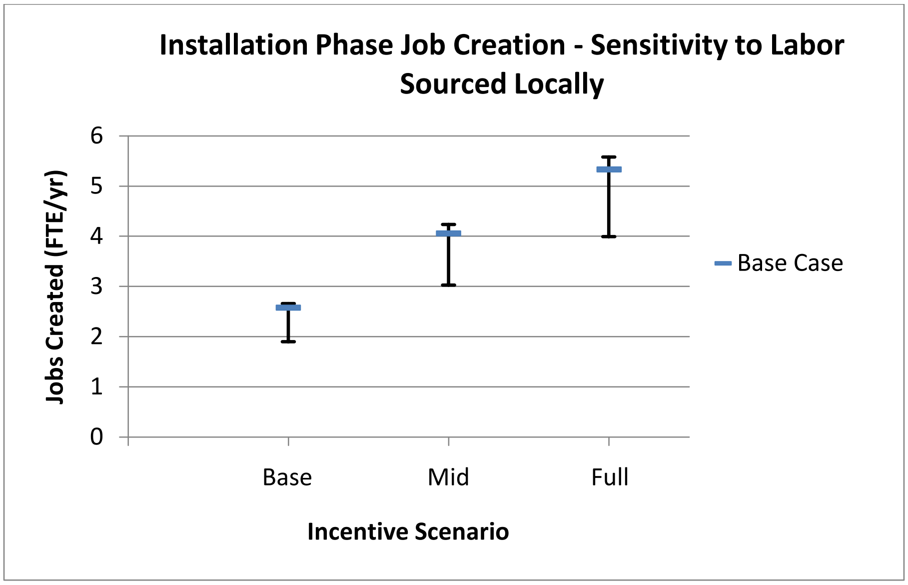

Figure 30. Installation Phase Job Creation Sensitivity to Labor Sourced Locally

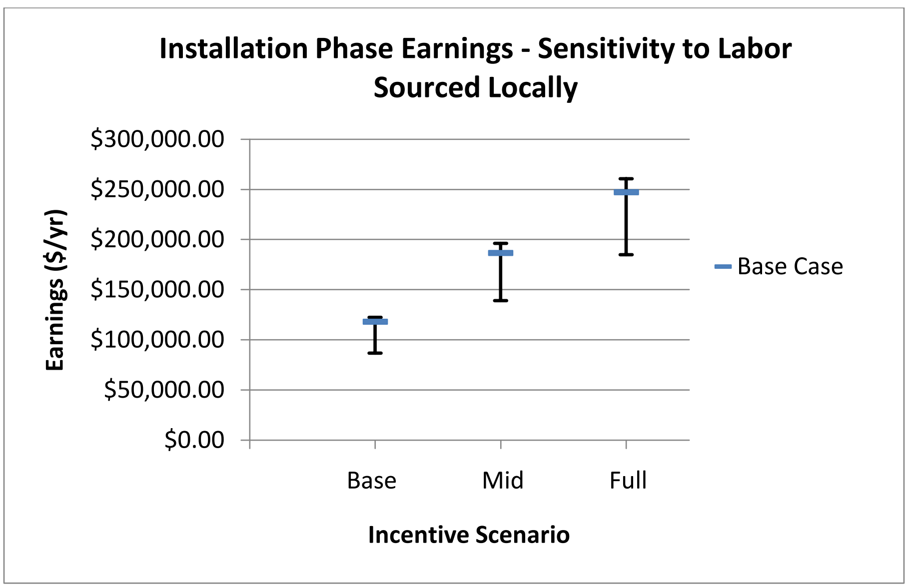

Figure 31. Installation Phase Earnings Sensitivity to Labor Sourced Locally

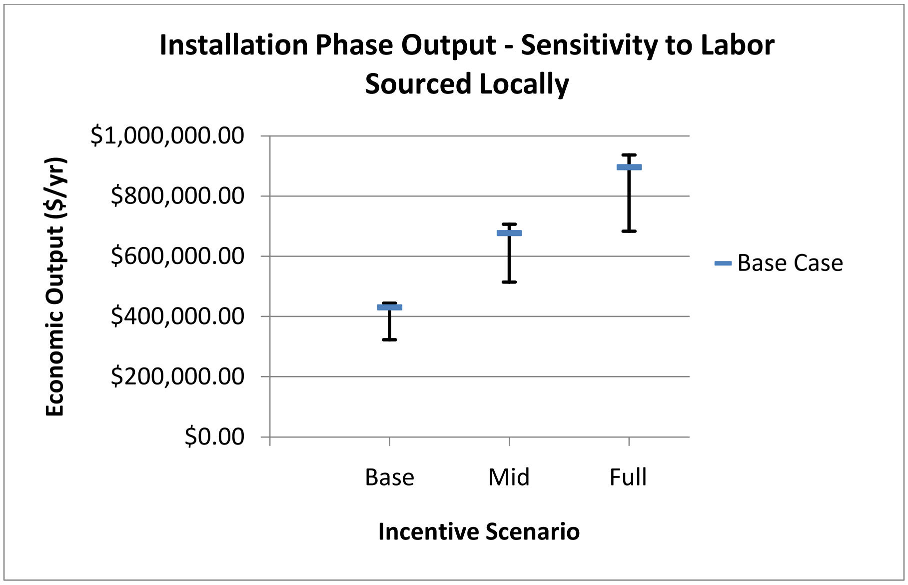

Figure 32. Installation Phase Output Sensitivity to Labor Sourced Locally

Figures 34 through 36 demonstrate the sensitivity of energy bill savings phase economic impacts to the percentage of labor sourced locally. At the full incentive level, job creation varies from 6.9 to 13.8 FTE jobs/yr (base case = 10.3 FTE jobs/yr), earnings vary from $189,000 to $378,000/yr (base case = $283,000/yr), and economic output ranges from $785,000 to $1.6 million/yr (base case = $1.2 million/yr). Every 10% change in the percentage of energy bill savings spent locally changes economic impacts by approximately 1.7 FTE jobs/yr, $47,000 in earnings/yr, and $196,000 in output/yr. Energy bill savings impacts are more sensitive to the amount of spending done locally simply because the dollar value of energy efficiency savings is over three times the dollar value of installation phase investment. Accordingly, a 10% change in local spending of energy bill savings corresponds to a much larger injection of cash into the local economy. While considerable variation in impacts is demonstrated in this scenario analysis, the base case impacts are considered to be conservative. The 60% local spending of energy bill savings is based on an NREL study of the economic impacts of energy efficiency in Boulder County, CO (Goldberg, Cliburn and Coughlin 2010). While Boulder County is more densely populated, it is less than 1/5th the geographical size of Humboldt County and is located in close proximity to Denver, CO. Because of its small size and proximity to a major city center, it is likely that more economic leakage occurs in Boulder County than in Humboldt County.

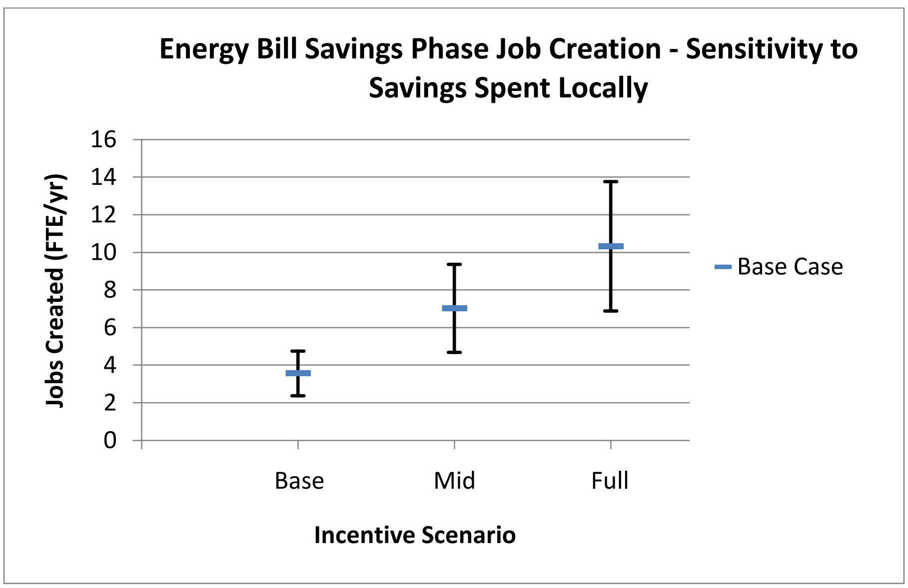

Figure 33. Energy Bill Savings Phase Job Creation Sensitivity to Savings Spent Locally

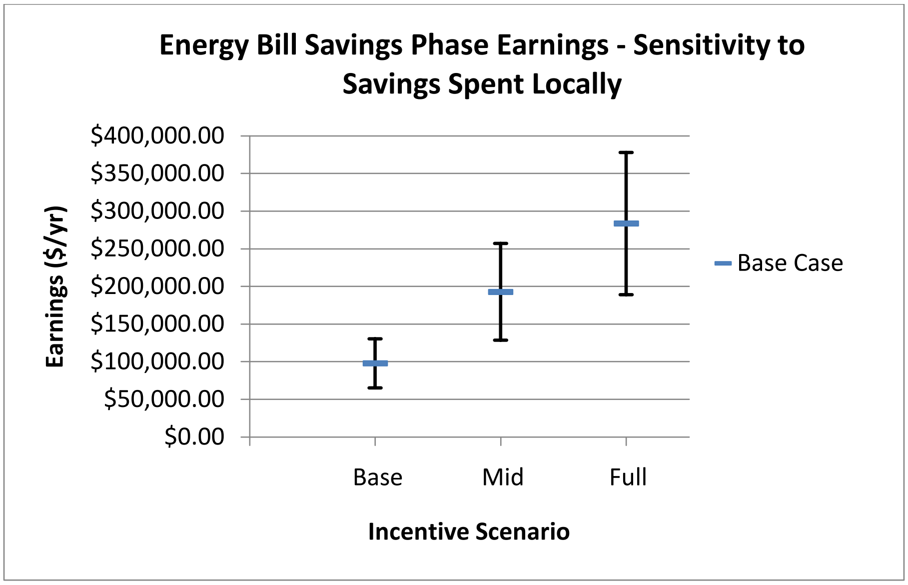

Figure 34. Energy Bill Savings Phase Earnings Sensitivity to Savings Spent Locally

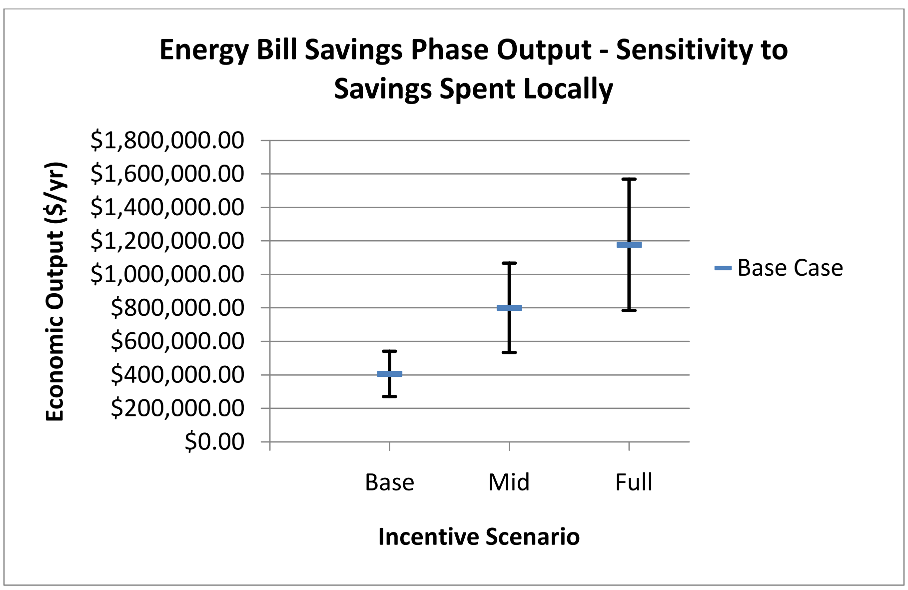

Figure 35. Energy Bill Savings Phase Output Sensitivity to Savings Spent Locally

This scenario analysis suggests that even with full incentive level programs, installation phase economic impacts in Humboldt County are likely to remain low. This is due to a combination of factors. First, many of the most common measures modeled in the Itron (2008) analysis are classified as replace-on-burnout which do not include a labor component. Despite the assumption that the majority of installation labor would be sourced locally, a relatively small fraction of measures actually have incremental labor costs. Second, because efficiency materials are neither manufactured or distributed locally, there are negligible local indirect and induced impacts from the efficiency materials supply chain. Each of these factors is discussed in turn below.

It is important to remember that the economic impacts estimated in this analysis are only as accurate as the input data from Itron. While the Itron study is the most recent and authoritative estimate of energy efficiency potential in California and has been used by the four major utilities for their program planning, actual energy efficiency implementation may follow a somewhat different path. The Itron study was conducted from 2006-2008 and the model utilized in that study was calibrated to forcast efficiency measure penetration based on 2004-2005 program activity. During that time, IOU efficiency program offerings included energy audits, individual measure rebates, and consumer education. Since then, the CPUC has released the *California Long Term Energy Efficiency Strategic Plan* (CPUC 2008). This plan calls for a transition from an individual measure "widget" based approach to a "whole-building" retrofit approach in both the residential and commercial sectors that would include comprehensive packages of audits, demand side management options and tools, rebates and financing options, and installation services. An important component of this transition is the widespread adoption and application of building energy rating systems such as BPI and the Home Energy Rating System (HERS) approved by the CEC in 2008 (CPUC 2008). In conjunction with these rating systems, local governments are encouraged to enact Residential Energy Conservation Ordinances (RECO) and Commercial Energy Conservation Ordinances (CECO) for energy ratings and possible improvements at the time of sale. Comprehensive energy assessments and whole-building retrofit packages at the time of sale may also help to overcome financing hurdles by including retrofit costs in the home mortgage. There are already a number of BPI and HERS certified contractors within Humboldt County. If local government leaders were to implement RECO's and CECO's, whole-building retrofits may become more common, which would result in higher energy savings and greater installation and energy bill savings impacts from efficiency upgrades than suggested by the analysis above.

As for the manufacturing and distribution supply chain impacts, it is not likely that these indirect impacts will increase in the near term. In order to attract manufacturers and distributors of efficiency products, Humboldt County would have to provide some clear benefit that would outweigh the costs of locating in a geographically remote county. If Humboldt County follows through with it's renewable energy goals (at least 75% of electricity demand met with renewables), and had some mechanism for providing that green energy to local customers (such as a Community Choice Aggregation or direct access), some green industries may be convinced to relocate to within the county. Though, there are existing mechanisms by which industries may acquire green energy without physical relocation (such as renewable energy credits) so local renewable electricity would have to be offered at very competitive rates to attract new business.

In the energy bill savings phase, economic impacts are quite sensitive to the percentage of spending done locally. Because the amount of local spending is largely a function of the structure of the local economy, there is not a clear application of public policy that would increase these impacts. It is possible that a public education campaign could increase local support and the amount of spending within the county. While a successful campaign could promote economic development in general, it would not be specific to energy bill savings.

Another potential way to increase energy bill savings impacts would be to develop a community finance program for energy efficiency. If local banks were to provide loans for whole-building efficiency upgrades and those loans were repaid with energy bill savings, it would redirect a large portion of the savings slated as cash outflows to PG&E into the local community over the term of the loan. A well designed community finance mechanism in conjunction with building energy ratings and local energy conservation ordinances (RECOs and CECOs) could greatly enhance energy savings and economic impacts from both installation and energy bill savings.

The results of the analysis indicate that there is a substaintial energy efficiency resource available in Humboldt County at a low cost and that investing in more aggressive energy efficiency programs would have net positive economic development impacts. The next chapter will distill the results above into a set of conclusions and recommendations while highlighting the caveats of the study.

CHAPTER 6. CONCLUSIONS

If Humboldt County is serious about meeting 75 percent of their electricity needs and a significant portion of their heating and transportation needs with local renewable energy, it should pursue more aggressive energy efficiency policies and programs. Doing so can cost-effectively reduce electricity demand and limit the amount of expensive renewable energy infrastructure that must be installed while creating greater economic development benefits than the natural gas fired generation it displaces.

This thesis has shown that, over a 20-year forecasting period, full incentive level utility efficiency programs could save 830 GWh and 4.56 MMtherms in the existing residential and commercial sectors. These savings represent a 4 percent annual reduction in electricity use and a 1 percent annual reduction in natural gas use relative to 2008 county-wide consumption (CEC 2011a). The LCOE for energy saved is estimated at $0.05/kWh and $0.34/therm, which is 14 percent lower than the marginal cost of generation at the Humboldt Bay Generating Station and 49 percent less than PG&E's natural gas acquisition costs.

Despite the apparent attractiveness of this investment for PG&E in Humboldt County, utilities do not calculate cost effectiveness on a county-by-county basis. Instead, they have detailed methodologies for how to design and implement efficiency programs most cost-effectively across their entire service territory. The full incentive level energy savings estimates presented above will only be achieved through PG&E programs if their system wide avoided cost of supply side options increases enough to make more programs cost effective at higher incentive levels. This may happen when a price on carbon is established in accordance with AB32.

If more aggressive programs are put in place and the energy savings estimates presented in this thesis are achieved, the local community has much to gain. Over a 20-year time horizon, consumers are estimated to save a NPV of $3.7 million annually on their energy bills (assuming the measures were distributed evenly across the approximately 60,000 households in Humboldt County, this would amount to ~$60 per household per year). This injection of cash into the local economy would result in substantial net economic development benefits. The energy bill savings would induce approximately 9.0 FTE jobs/yr with associated earnings of $214,000/yr and an increase in the county's economic output of $872,000/yr. Additionally, the administration of local efficiency programs and the installation of efficiency measures are anticipated to create 5.4 FTE jobs/yr with associated earnings of $247,000/yr and $895,000/yr in increased economic output.

It is important to recognize that the energy savings potential and economic impacts presented herein are based on traditional utility incentive programs targeting individual measure upgrades in the existing residential and commercial sectors. The data utilized in this study are the most recent and authoritative estimates of 20-year energy efficiency potential and cost for current programs. Efficiency potential studies, however, are inherently difficult because efficiency savings are realized over a long time line (i.e.

individual measures may have energy savings benefits lasting for 10 years or more). Energy efficiency policies and program design are constantly being updated and improved. It is likely that this trend will continue as the cost of fossil based generation increases and efficiency becomes even more practical and profitable. Accordingly, a 20-year forecast that is based on today's policies and programs may not accurately reflect the trajectory of actual efficiency implementation.

For instance, if the previously mentioned Huffman Bill is successful in the phase-out of incandescent light bulbs in California by 2018, much of the energy savings and economic benefits estimated in this analysis would be realized irrespective of more aggressive PG&E programs. Additionally, in the *California Long Term Energy Efficiency Strategic Plan* (CPUC 2008), the CPUC laid out goals for efficiency programs to take on a "whole-building" retrofit approach that would include comprehensive packages of audits, demand side management options and tools, rebates and financing options, and installation services. During the preparation of this thesis, a new statewide program pursuing energy savings from whole-building retrofits called Energy Upgrade California was launched. This program is an exciting collaboration between the CEC, the CPUC, utilities, local governments, non-governmental agencies, and the private sector to promote and finance energy efficiency and renewable energy projects for homes and businesses. Using the program's "web portal,"[31] property owners can enter their zip code and receive information about available programs, rebates, financing options, and

[31] http://www.energyupgradeca.org

participating local contractors. Well designed whole-building programs such as this would overcome many of the barriers to energy efficiency described in Chapter 2 and could potentially result in even greater energy savings (and greater energy bill savings phase economic impacts) than suggested by this thesis. Whole-building retrofits would also be much more labor intensive, which would increase installation phase economic impacts.

Beyond the uncertainty implicit in a 20-year efficiency potential study, another important caveat of this study is that input-output analysis is based on a snapshot of the economy at a given time. While the inter-industry relationships in a regional economy are fairly stable, multipliers are considered most accurate for analysis periods of 3-5 years. The economic impact analysis in this thesis was based on the NPV of efficiency costs and energy bill savings over a 20-year forecasting period. If there were substantial changes in the structure of the Humboldt County economy over the next 20 years, the 2008 IMPLAN multipliers used in the EEIAM would not adequately characterize inter-industry interactions and would generate misleading economic impact estimates. Using IO analysis for estimating energy efficiency impacts will always encounter this issue because investments are made in year one and energy savings are realized over the course of many years. Other regional multiplier software programs such as REMI have the capability to forecast structural changes to the economy and generate dynamic multipliers that are geared toward long-term analyses. Of course, any attempt to forecast structural changes in the economy using modeling will introduce its own error.

Despite being based on a static model of the economy, I-O analysis is the best tool for estimating economic impacts from efficiency programs. There is no other method that would as adequately capture the induced effects from energy bill savings. The uncertainty introduced through long-term forecasting does mean that the results of the economic analysis should be viewed with caution. But the bigger message is that, given the current structure of the economy, efficiency spending generates greater economic impacts than the high-efficiency natural gas fired generation it displaces.

Regardless of how PG&E proceeds with their efficiency program design and implementation, Humboldt County should begin looking for ways to reduce energy consumption. One of the near-term next steps should be to enact residential and commercial energy conservation ordinances (RECOs and CECOs). These ordinances should include mandatory building energy audits at the time of sale paid for by the buyer. Mandatory time of sale audits would serve the dual purpose of increasing consumer awareness of opportunities to save energy and money as well as providing the opportunity to bundle retrofit financing with the existing mortgage. Full energy audits and detailed energy savings estimates for whole-building retrofits (time of sale or without ownership change) may also encourage local lenders to participate in community finance programs.

Humboldt County has ambitious goals for its energy future. Fortunately, the county has a wealth of energy resources like biomass, wind, and wave that make these goals seem possible. There is no other resource, however, that matches energy efficiency in terms of cost and accessibility. Pursuing aggressive energy efficiency savings will not only result in net economic development but will also be critical to achieving a high penetration of renewable energy at a reasonable cost.

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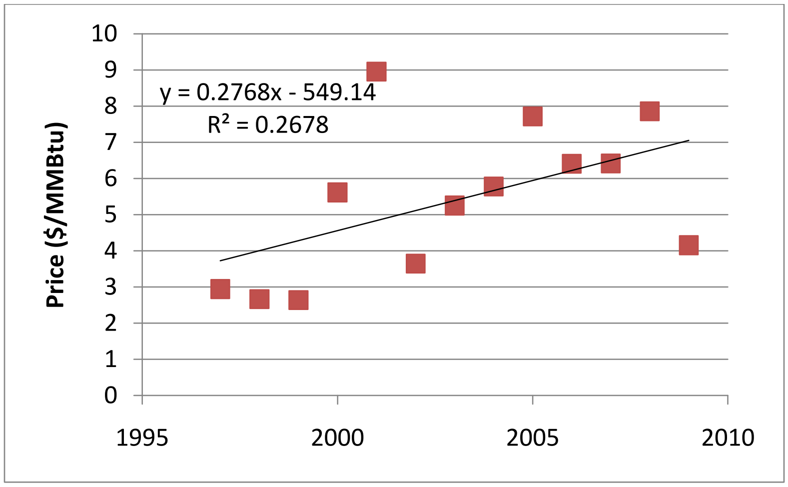
APPENDIX A

Figure A.1. California Natural Gas Price Sold to Electric Utilities (EIA 2011)



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.51750532
R Square	0.267811757
Adjusted R Square	0.201249189
Standard Error	1.861981969
Observations	13

ANOVA

	df	*SS*	*MS*	*F*	*Sig. F*
Regression	1	13.94923896	13.94923896	4.023459	0.0700968
Residual	11	38.1367454	3.466976855		
Total	12	52.08598437			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-549.1378142	276.4531127	-1.986368715	0.072476	-1157.61	59.33
X Variable 1	0.276846835	0.138019286	2.005856157	0.070097	-0.027	0.581

Table A.1. Gross Residential Sector Economic Impacts By End Use – NPV over 20 yr forecasting period

				Installation Phase			Energy Bill Savings Phase		
Sector	**End Use**	**Incentive Scenario**	**Energy Type**	**Earnings ($)**	**Output ($)**	**Jobs**	**Earnings ($)**	**Output ($)**	**Jobs**
Residential	Lighting	Base	Electricity	$918,272	$3,657,569	22.82	$1,512,415	$6,280,675	55.08
Residential	HVAC	Base	Electricity	$187,480	$566,628	3.45	$14,744	$61,227	0.54
Residential	Water Heating	Base	Electricity	$1,123	$3,750	0.02	$5,442	$22,600	0.20
Residential	Appliances	Base	Electricity	$150,864	$498,719	3.13	$86,703	$360,057	3.16
Residential	Lighting	Mid	Electricity	$1,393,725	$5,573,816	34.69	$2,900,847	$12,046,483	105.65
Residential	HVAC	Mid	Electricity	$192,618	$582,486	3.55	$20,567	$85,411	0.75
Residential	Water Heating	Mid	Electricity	$50,598	$154,706	1.03	$9,421	$39,123	0.34
Residential	Appliances	Mid	Electricity	$182,610	$603,419	3.79	$139,375	$578,789	5.08
Residential	Lighting	Full	Electricity	$1,769,447	$7,081,765	43.94	$4,080,719	$16,946,193	148.62
Residential	HVAC	Full	Electricity	$195,161	$589,970	3.59	$25,558	$106,135	0.93
Residential	Water Heating	Full	Electricity	$55,222	$169,279	1.13	$17,888	$74,283	0.65
Residential	Appliances	Full	Electricity	$211,324	$698,376	4.39	$193,046	$801,673	7.03
Residential	HVAC	Base	Gas	$53	$344	0.00	$775	$3,220	0.03
Residential	Water Heating	Base	Gas	$18,817	$59,458	0.39	$2,907	$12,070	0.11
Residential	HVAC	Mid	Gas	$127	$830	0.00	$1,162	$4,824	0.04
Residential	Water Heating	Mid	Gas	$268,992	$815,871	5.45	$82,789	$343,802	3.02
Residential	HVAC	Full	Gas	$313	$2,073	0.01	$1,609	$6,682	0.06
Residential	Water Heating	Full	Gas	$290,288	$880,941	5.88	$134,771	$559,671	4.91

Table A.2. Gross Commercial Sector Economic Impacts By End Use - NPV over 20 yr forecasting period

				Installation Phase			Energy Bill Savings Phase		
Sector	**End Use**	**Incentive Scenario**	**Energy Type**	**Earnings ($)**	**Output ($)**	**Jobs**	**Earnings ($)**	**Output ($)**	**Jobs**
Commercial	Lighting	Base	Electricity	$574,275	$2,178,831	12.29	$182,543	$758,054	6.65
Commercial	HVAC	Base	Electricity	$346,981	$1,109,379	6.75	$91,737	$380,959	3.34
Commercial	Food	Base	Electricity	$2,152	$8,899	0.05	$7,065	$29,338	0.26
Commercial	Refrigeration	Base	Electricity	$131,099	$446,877	2.76	$49,562	$205,819	1.81
Commercial	Appliances	Base	Electricity	$1,062	$3,560	0.02	$536	$2,227	0.02
Commercial	Lighting	Mid	Electricity	$888,421	$3,386,373	18.82	$411,514	$1,708,913	14.99
Commercial	HVAC	Mid	Electricity	$579,323	$1,831,673	11.15	$181,525	$753,827	6.61
Commercial	Food	Mid	Electricity	$3,136	$12,970	0.08	$13,683	$56,823	0.50
Commercial	Refrigeration	Mid	Electricity	$156,917	$537,034	3.31	$90,436	$375,559	3.29
Commercial	Appliances	Mid	Electricity	$4,472	$16,524	0.11	$1,582	$6,571	0.06
Commercial	Lighting	Full	Electricity	$1,282,275	$4,856,558	26.86	$697,380	$2,896,043	25.40
Commercial	HVAC	Full	Electricity	$931,821	$2,922,473	17.82	$342,493	$1,422,286	12.47
Commercial	Food	Full	Electricity	$4,187	$17,317	0.11	$20,267	$84,164	0.74
Commercial	Refrigeration	Full	Electricity	$183,687	$635,801	3.91	$144,288	$599,190	5.25
Commercial	Appliances	Full	Electricity	$4,956	$18,320	0.12	$1,869	$7,760	0.07
Commercial	HVAC	Base	Gas	$71	$285	0.00	$0	$0	0.00
Commercial	Food	Base	Gas	$0	$0	0	$42	$174	0.00
Commercial	Appliances	Base	Gas	$326	$1,247	0.01	$64	$264	0.00
Commercial	HVAC	Mid	Gas	$101	$414	0.00	$51	$213	0.00
Commercial	Food	Mid	Gas	$192	$761	0.00	$134	$556	0.00
Commercial	Appliances	Mid	Gas	$337	$1,288	0.01	$66	$274	0.00
Commercial	HVAC	Full	Gas	$128	$526	0.00	$134	$558	0.00
Commercial	Food	Full	Gas	$315	$1,258	0.01	$352	$1,461	0.01
Commercial	Appliances	Full	Gas	$343	$1,311	0.01	$67	$279	0.00