Public Interest Energy Research (PIER) Program

INTERIM PROJECT REPORT

HUMBOLDT COUNTY AS A RENEWABLE ENERGY SECURE COMMUNITY

Economic Analysis Report

DRAFT

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Prepared by: Schatz Energy Research Center

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PREFACE

The California Energy Commission Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

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- Renewable Energy Technologies
- Transportation

The *Humboldt County as a Renewable Energy Secure Community: Economic Analysis Report* is an interim report for the Humboldt County RESCO project (PIR-08-034) conducted the Schatz Energy Research Center. The information from this project contributes to PIER's Renewable Energy Technologies Program.

For more information about the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-654-4878.

ABSTRACT

This document reports on the economic analysis conducted for the Humboldt Renewable Energy Secure Community project. Broadly speaking, the task was to generate cost and economic impact estimates associated with investments in renewable energy and energy efficiency. Energy efficiency supply curves and levelized cost of energy estimates are developed. A transportation cost analysis examines the costs and benefits associated with electric vehicles. To estimate economic impacts, the research team customized available Jobs and Economic Development Impact models from the National Renewable Energy Laboratory for the Humboldt County, California economy, and where not available developed their own impact assessment models. The renewable energy industry cluster is characterized and jobs, earnings and economic outputs are estimated. These cost and impact estimates are used as criteria for selecting feasible and appropriate portfolios of renewable energy and energy efficiency that have the potential of being implemented in Humboldt County. Ultimately, the economic and engineering technical analyses will inform the development of a viable strategic plan to guide clean energy investments in Humboldt County.

Keywords: economic impacts, RESCO, renewable, energy, secure, community, Humboldt County, efficiency, jobs, research, levelized, cost, electric, vehicles, JEDI, industry, cluster

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EXECUTIVE SUMMARY

Background

The Humboldt County Renewable Energy Secure Community (RESCO) study is focused on formulating a strategic plan for the efficient development of local renewable energy resources in Humboldt County, California. Broadly speaking, the goal of the study is to examine the feasibility of meeting 75 percent of the county's electricity needs, as well as a substantial portion of heating and transportation needs with renewable energy. Key elements of the study include a resource and technology assessment, an economic analysis, and the development of a strategic plan. Results from the resource and technology assessment and the economic analysis will be used to inform the stakeholder-guided formulation of a strategic plan that best aligns with Humboldt County's development goals.

Purpose

This document reports on the economic analysis component of the study. It describes the costs and economic impacts associated with a clean energy development plan for Humboldt County. The cost analysis examines the construction, operations, and maintenance costs associated with each renewable energy category (biomass, wind, wave, small hydroelectric, and solar photovoltaic) as compared to the costs of natural gas fired generation at the Humboldt Bay Generating Station. Additionally, the costs of more aggressive energy efficiency programs and a transition from conventional heating and transportation to heat pumps and electric vehicles are estimated. The results of this cost analysis are used by Schatz Energy Research Center researchers as inputs to a Regional Energy Planning Optimization Model in order to identify preferred scenarios of renewable energy generation, energy efficiency, heat pumps and electric vehicles for Humboldt County.

For each of the preferred scenarios, a suite of economic impact assessment models are employed to estimate the local jobs, income, and economic output created by construction and operation of proposed renewable energy generation plants. An energy efficiency impact model is used to estimate the local jobs, income, and economic output created by the installation of efficiency measures, and more significantly, by the additional household expenditures made possible through energy bill savings. Together, the economic analysis and the resource and technology assessment provide a broad look at the costs and benefits of a variety of energy development scenarios in Humboldt County.

Methods

Cost estimates for natural gas generation, renewable energy generation, energy efficiency, heating, and transportation were first drawn from the most current and authoritative literature. In addition to technology costs, the analysis included estimates of the cost per unit of avoided pollution emissions implied by renewable energy, energy efficiency, and electric vehicle investments. Based on the research team's knowledge of local conditions and extensive local interviews, cost estimates were modified to reflect unique conditions in Humboldt County.

To evaluate economic development potential, the research team utilized highly specialized economic impact assessment models for each of the major renewable energy categories and for energy efficiency. The authors identified no other such studies done for northwestern California. For natural gas, wind, and solar photovoltaic generation, the research team customized available Jobs and Economic Development Impact models developed by the National Renewable Energy Laboratory. Models were unavailable, however, for biomass, wave, small hydroelectric, and energy efficiency. Consequently, the research team reverse engineered the available Jobs and Economic Development Impact models and used that knowledge to develop their own impact assessment models for these technologies. By utilizing this full suite of models, the research team was able to estimate net economic impacts for each preferred scenario.

Results and Conclusions

- Humboldt County energy demand can be met with a large fraction of locally generated renewable energy at moderate cost increases relative to business as usual through a variety of development scenarios.
- Small hydro, wind, and investing in full incentive-level efficiency programs would be cost effective on an avoided cost of generation basis alone, and therefore do not entail any positive cost per ton of avoided CO_2e.
- All of the clean energy scenarios have considerable positive *net* economic impacts in terms of county jobs, income, and economic output.
- Many of these scenarios feature substantial greenhouse-gas reductions with modest increases in cost. Biomass, hydro, and to a lesser extent wind play a central role in the preferred scenarios identified by the research team.
- Biomass-fired energy generation has the largest potential to be a driver of the local economy because Humboldt County has a substantial forest biomass resource. Jobs associated with gathering, transporting, and processing biomass fuel results in biomass energy having proportionately larger economic impacts in the operations phase relative to other forms of electricity generation evaluated in this report.
- The economic benefits of having a high proportion of biomass-fired energy generation must be weighed against the need for a diverse energy portfolio, concerns about environmental impacts associated with deforestation, questions about the carbon neutrality of biomass power, and the specific economic development goals of Humboldt County.
- A benefit-cost analysis for the year 2020 indicates that the average lifecycle cost of electric vehicles will be $5000 more than for conventional vehicles. Of the five types of electric vehicles considered, only the plug-in hybrid electric vehicle with an all-electric range of 10 miles (PHEV10) is cost competitive, costing $200 less than a conventional vehicle.
- Lifecycle electric vehicle operation and maintenance costs are on average about $7,400 less than conventional vehicles. This is due to reduced gasoline consumption and less frequent maintenance required by electric vehicles. However, capital costs for electric vehicles are substantially higher, resulting in higher overall lifecycle costs.
- Over the lifetime of an electric vehicle, an average of 47.3 tCO_2e (or 252 g CO_2e/mi) are avoided through the replacement of gasoline consumption with electricity use. If more renewables are added to the electric mix in Humboldt County the carbon reduction will be even greater.

Benefits to California

- NREL JEDI models were customized for Humboldt County and additional JEDI-like models were developed. The approach used can serve as a starting point for studies in other counties. It should also be noted that this modeling approach could be scaled up to multi-county regions or even states. In fact, larger geographical scales tend to have more coherent regional economies that feature fewer leakages and therefore have larger economic impacts for a given expenditure in construction or operation of a generating facility.

- A JEDI-like model was developed for estimating the economic impacts associated with energy efficiency investments. This “first-of-its-kind” model offers a new development for assessing the benefits of energy efficiency.
- As the focus shifts from planning to implementation, the economic analysis tools developed here can be useful to planners, developers and policy makers as they seek to understand the economic impacts associated with specific renewable energy project proposals or energy efficiency incentive programs.

CHAPTER 1: Introduction

The Humboldt County Renewable Energy Secure Community (RESCO) study is focused on developing a strategic plan for the efficient development of local renewable energy resources in Humboldt County, California. The goal of the study is to examine the feasibility of meeting 75 percent of the county's electricity needs, as well as a substantial portion of heating and transportation needs, with local renewable energy. Key elements of the study include a resource and technology assessment (see: *Humboldt County as a Renewable Energy Secure Community: Resource and Technology Assessment Report*, May 2011), an economic analysis, and the development of a strategic plan. Results from the resource and technology assessment and the economic analysis will be used to inform the stakeholder-guided development of a strategic plan.

This document reports on the economic analysis and is focused on three broad areas: cost estimation, benefit-cost analysis of electric transportation options, and local economic development opportunities.

The first area of analysis addresses cost estimation. Elements of the cost analysis include modeling and estimating the instant capital cost, levelized cost, and marginal cost of supply for each renewable energy category, as well as the existing gas-fired Humboldt Bay Generating Station (HBGS) facility. These cost estimates serve as the economic foundation to identifying least-cost energy supply portfolios. The research team also evaluated the costs and savings associated with energy efficiency programs, which reduce the net load that must be served by the energy generation portfolios. In addition to renewable energy and energy efficiency costs, the analysis includes estimates of the cost per unit of avoided pollution emissions implied by renewable energy and energy efficiency investments. All cost estimates are first drawn from the most current and authoritative literature, and are then modified to reflect idiosyncratic economic conditions in Humboldt County. These cost estimates are then used in the resource and technology assessment in an effort to identify optimal resource scenarios.

The second broad area of analysis involves a benefit/cost analysis of using electricity derived from renewable energy as a transportation fuel. Electricity can be used to charge and power electric vehicles and to generate hydrogen to power fuel cell vehicles. Elements of the transportation energy analysis include technical and economic cost assessments of electric vehicles and hydrogen powered buses and the necessary infrastructure to support vehicle usage. Electric vehicle market penetration and diffusion is also assessed to determine the likely adoption and impacts of electric vehicles in Humboldt County. Avoided fossil fuel usage and greenhouse (GHG) emissions are also quantified. From this set of estimations the research team was able to evaluate the net present value of lifecycle net benefits. The results of this analysis are also utilized in the resource and technology assessment and provide insight into the feasibility of integrating transportation energy into the renewable energy generation plan as a cost effective GHG reduction mechanism for Humboldt County.

The third area of analysis assesses the county-level economic development consequences of implementing the renewable energy generation portfolios and energy efficiency investments developed by the engineering team. Elements of the economic development analysis include developing economic impact assessment models for each renewable energy technology and energy efficiency measure category, each of which is customized for the Humboldt County economy. These models are then applied to estimate the local jobs, income, and economic output created by construction and operation of the renewable energy generation plants implied by each portfolio. The energy efficiency impact model estimates the local jobs, income, and economic output created by efficiency investments (net of reduced conventional generation activity), and more significantly, by household expenditure of energy bill savings created through efficiency upgrades. Another component of the economic development analysis characterizes the clean energy industry cluster, including key input suppliers and the skilled occupational workforce required to support the cluster. The results of this analysis indicate the extent to which the Humboldt County economy would benefit from implementation of various energy portfolios being considered in the resource and technology assessment.

CHAPTER 2: Cost Analysis

2.1 Renewable Energy Cost Analysis

An extensive review of the most recent and authoritative literature was performed on the cost of renewable energy development. A wide range of costs were observed for several of the generation technologies. This is due to the fact that, among other variables, there are various technologies within each broad renewable energy category, variations in tax benefits and financing options, and varied geographic locations. The literature costs are reflective of assumptions for a representative project in each energy category. In some cases, however, these assumptions do no pertain to the types of projects or conditions in Humboldt County. Where additional local cost information was available, literature cost estimates were modified accordingly. The reader should note that all cost estimates presented in this report are in real 2010$. These values are projected from the study year using the Producer Price Index for intermediate materials, supplies, and components.[1]

2.1.1 Life-cycle Cost Components for Renewable Energy Supply Portfolios

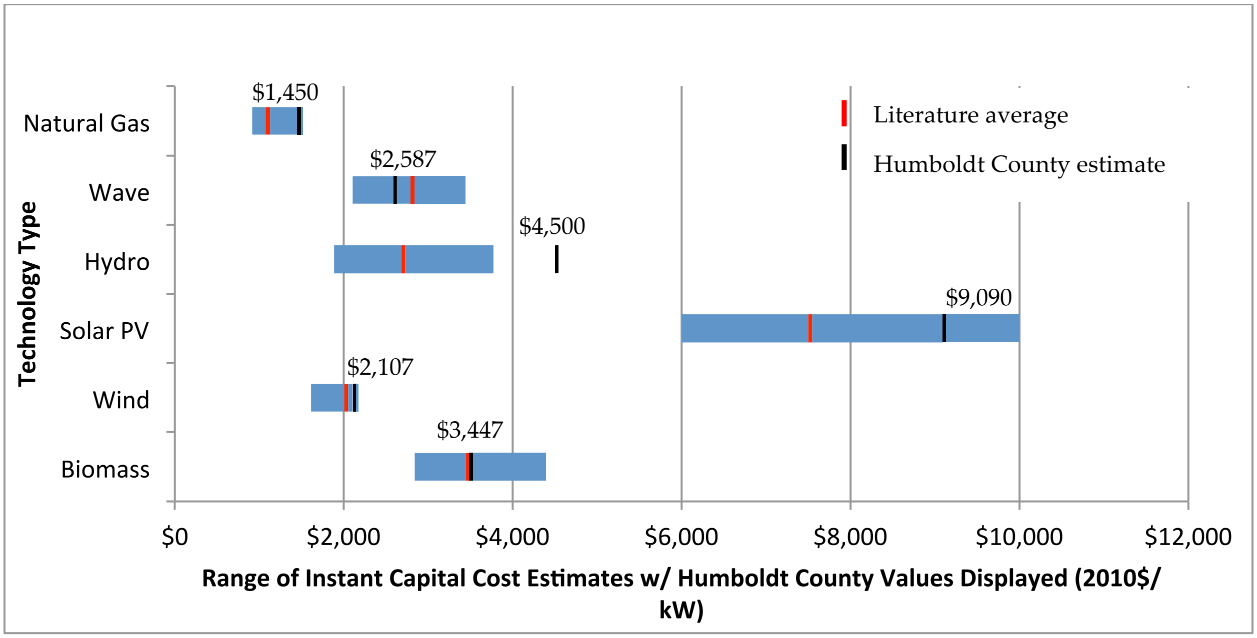
Three main indicators of cost were examined for each energy generation technology: instant capital cost, the marginal cost of energy supply, and the levelized cost of energy (LCOE). The instant capital cost of a project is a standard economic method of estimating the up-front cost of a project. Instant capital cost is based on the assumption that the project was completed overnight, and therefore no interest-based financial carrying costs on construction loans are incurred in the construction period. Instant capital cost estimates were obtained from a number of sources and averaged for each technology type. Figure 1 shows the range (in blue) of cost estimates as well as averages (in red) for each technology. The values used in the Humboldt RESCO analysis are marked in black and displayed above each bar.[2] Natural gas has a considerably lower upfront cost on a per-kilowatt basis than any of the renewable technologies.[3] Wind, at one and a half times the cost of natural gas, has the lowest instant capital cost of the renewables, while solar PV is by far the most expensive technology.

1 Yearly inflation index values taken from the month of April. April 2010 = 100. Available from: www.bls.gov/ppi/.

2 All cost assumptions used in this analysis as well as their justifications can be found in Appendix B.4.

3 Literature ranges for natural gas instant capital cost presented here and levelized cost of energy estimates presented below are reflective of conventional combined cycle gas turbines, not the internal combustion engines at the Humboldt Bay Generating Station.

Figure 1: Instant Capital Cost Estimates



Source: SERC staff analysis[4]

The marginal cost of energy supply was calculated for each viable technology based on the total levelized variable costs (fuel + variable operations and maintenance (O&M)) used in the National Renewable Energy Laboratory (NREL) Jobs and Economic Development Impact (JEDI) models for natural gas, wind, and solar PV and Schatz Energy Research Center (SERC) models for small hydro, wave, and biomass.[5,6,7] For more information on these models and costs, see section 3.2: Economic Impact Analysis and Appendix C below. Figure 2 is illustrative of one potentially feasible scenario for total installed capacity of each technology and shows that solar PV, wind, small hydro, and wave energy have the lowest marginal cost of supply. This is expected because these technologies are not subject to high and escalating fuel prices. Marginal cost of energy supply estimates for biomass and the PG&E internal combustion engines at the Humboldt Bay Generating Station (HBGS) are considerably higher, with natural gas reaching nearly $60/megawatt hour (MWh). The figure below illustrates the fact that after the capital investments in infrastructure are made, renewable technologies are considerably cheaper to operate and maintain.

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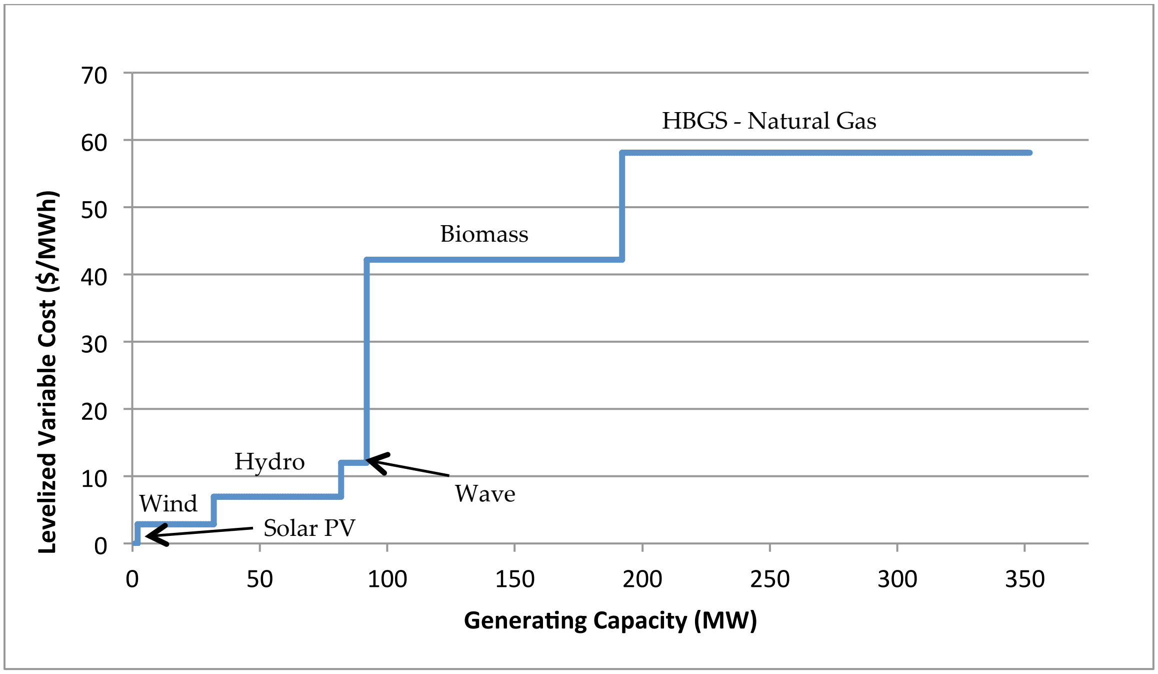
4 Instant capital cost estimates were obtained from: E3, 2008; EERE, 2009; EIA, 2009; EPRI, 2009; KEMA, 2009; Klein, et al., 2007; Klein, 2010; Lazard, 2008; McKinsey, 2007; O'Donnell et al., 2009; PIER, 2007; and Wiser, et al., 2009.

5 Given the uncertainty of future biomass and natural gas fuel prices, the levelized variable cost is calculated under the assumption that fuel prices increase at a rate equal to general inflation.

6 The NREL JEDI model for wind does not include a variable O&M component. Variable O&M for wind included here is based on *Comparative Costs of California Central Station Electricity Generation* (Klein, 2010).

7 We use the term marginal cost of energy supply to reflect the incremental cost of supplying an additional megawatt-hour of energy. Note that intermittent renewable energy resources such as wind, wave, and solar PV are not dispatchable.

Figure 2: Humboldt County Marginal Cost of Supply



Source: SERC staff analysis

Levelized cost of energy is a metric that estimates the cost per unit of energy generated by a given technology over its useful life.[8] LCOE is the most inclusive of the cost terms as it includes capital costs as well as fixed and variable O&M costs. Levelized cost of energy values in this report, however, do not include environmental, system diversity, or risk factors that may influence cost. Estimates for LCOE borne by the developer were obtained from a number of sources for each renewable technology type and for energy efficiency.[9,10] Literature ranges, average values, and Humboldt County LCOE estimates are displayed in Figure 3. Comparing Humboldt County estimates across technologies, energy efficiency immediately stands out as the lowest cost energy option. LCOE estimates for natural gas, wind, hydro, and biomass are all within the $90-$116/MWh range, which indicates that a cost competitive portfolio of energy options exist in Humboldt County. Wave energy is not a mature technology, and cost estimates are therefore preliminary. Solar PV is estimated to be, by far, the most expensive energy option in Humboldt County ($685/MWh). This estimate is well outside the range of values in the literature for two primary reasons. First, this analysis assumes that most of the PV development in the county will be small, distributed residential installations which are inherently more expensive on a MWh basis than larger PV systems. Second, a more significant

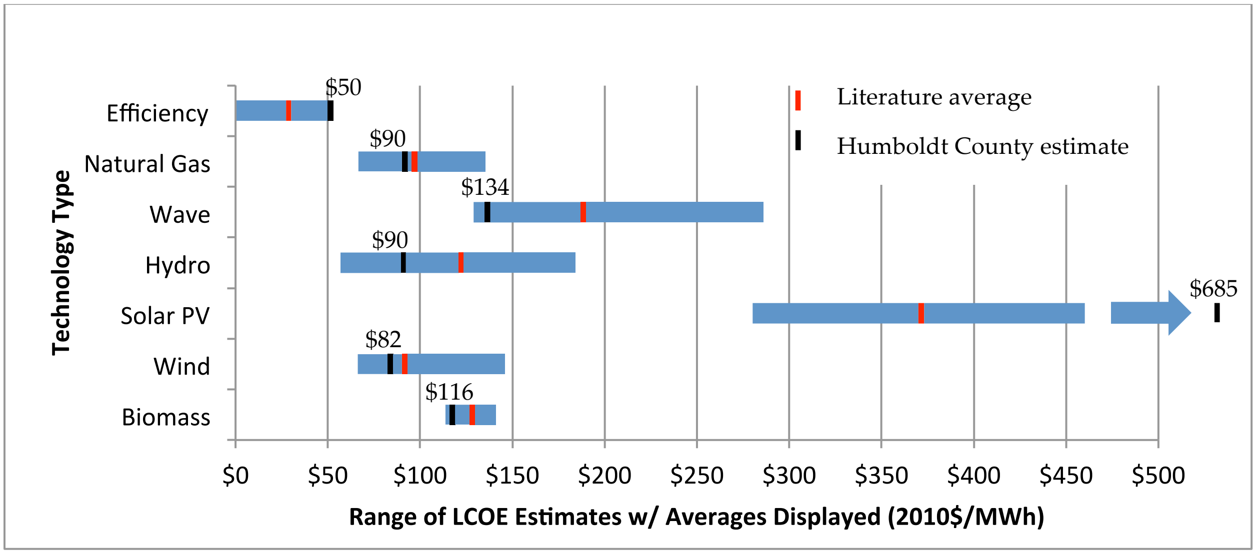
8 See Appendix B.2 for a more thorough description of the levelized cost of energy.

9 Levelized cost of energy estimates were obtained from: ACEEE, 2009; Black & Veatch, 2010; E3, 2008; EIA, 2009; EPRI, 2009; KEMA, 2009; Klein et al., 2007; Klein, 2010; Lazard, 2008; PIER, 2007; and Price, et al., 2010.

10 Note that saved energy is not a physical "source" of energy but rather a way of displacing additional generation. As 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. A full description of energy efficiency potential in Humboldt County and associated costs can be found in Section 2.2 below.

factor is the less abundant solar resource in Humboldt County. This cost estimate assumes a capacity factor of 13.5 percent, whereas the authoritative literature assumes values in the 20 percent to 27 percent range.

Figure 3: Levelized Cost of Energy Estimates



Source: SERC staff analysis

Note that this analysis does not address biogas resources and technologies. Zoellick (2005) ranked biogas potential in Humboldt County as "low" from a resource perspective. Potential biogas resources such as landfills and agricultural waste are relatively small, which (due to fixed costs related to factors such as gas scrubbing and power purchase contracts) reduces the economic feasibility of integrating biogas either into the electrical generation system or the natural gas distribution system. While it is not expected that biogas projects will have a big impact, there are some important community-based, small-scale projects that show promise as near-term RESCO next steps.

2.1.2 Learning Curve Effects

In developing projected future costs for energy generation, one sometimes encounters "learning curve" cost estimates that show a downward cost trajectory as installed capacities of a given generation category increase. These learning curves are sometimes drawn from observed past trajectories in actual cost experienced for wind and solar technologies. While there is a productive role for learning curve cost projections, they remain conjectural in nature and display a potentially wide variation reflecting different underlying economic assumptions regarding future input and production costs (NREL, 2011). For example, while technological advances in manufacturing may drive down the unit cost of production, bottlenecks in non-substitutable inputs could drive up cost as manufacturing scales up. Moreover, the economic analysis cannot pinpoint exactly when in the time period under analysis particular renewable energy investments will occur. Therefore this analysis makes the simplifying (and conservative) assumption that real (inflation-adjusted) costs are constant over the analysis period. This is most likely to affect solar PV, which is not a robust resource in Humboldt County, and wave energy, an immature technology with no utility-scale cost experience. Furthermore, the preferred-scenario energy portfolios created by the engineering team and evaluated in this report make minimal use of either solar PV or wave energy. Summary figures of NREL's literature review on this subject can be found in Appendix B.4.2.

2.2 Energy Efficiency Cost Analysis

Improvements in energy efficiency can substantially reduce energy demand that must be served by the portfolio of renewable generation assets recommended by the RESCO team. There have been no detailed Humboldt County specific quantifications of 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 consisting of representatives from Pacific Gas and Electric (PG&E), Southern California Edison Company, Southern California Gas Company, San Diego Gas & Electric Company, the California Public Utilities Commission (CPUC), and the California Energy Commission.

The Itron study quantifies yearly (2007-2026) energy savings potential (electricity and natural gas) and associated costs by investor owned utility (IOU) service territory, Energy Commission climate zone, sector, building type, end-use category, energy type (electricity or natural gas), and measure. Incremental costs and energy savings for each efficiency measure are quantified relative to the most common base case technology. Estimates were appropriately scaled for Humboldt County and then aggregated by end-use efficiency category and sector.[11] These results were used to perform a full economic analysis of utility sponsored energy efficiency programs in Humboldt County.[12]

The levelized cost of energy borne by the IOU was calculated for each end-use efficiency category at three incentive levels (Base, Mid, and Full) over the 20-year study period using a real discount rate of 6 percent.[13] 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. Residential and commercial sector supply curves based on these LCOE values are presented in Figure 4 through Figure 7 below. As with all studies of energy efficiency potential, it is important to clearly 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 implicit utility sponsored energy efficiency programs already in place. The "Base" incentive supply curves in the figures below represent the market potential for efficiency measures incentivized in the 2004-2005 program cycle with incentive levels available in 2006. Thus, the "Base" incentive analysis serves as a close approximation for expected potential through 2026 under business as usual (BAU). Note that the "Base" supply curve should be horizontally subtracted from the "Mid" and "Full" incentive curves to estimate savings additional to BAU under these incentive scenarios.

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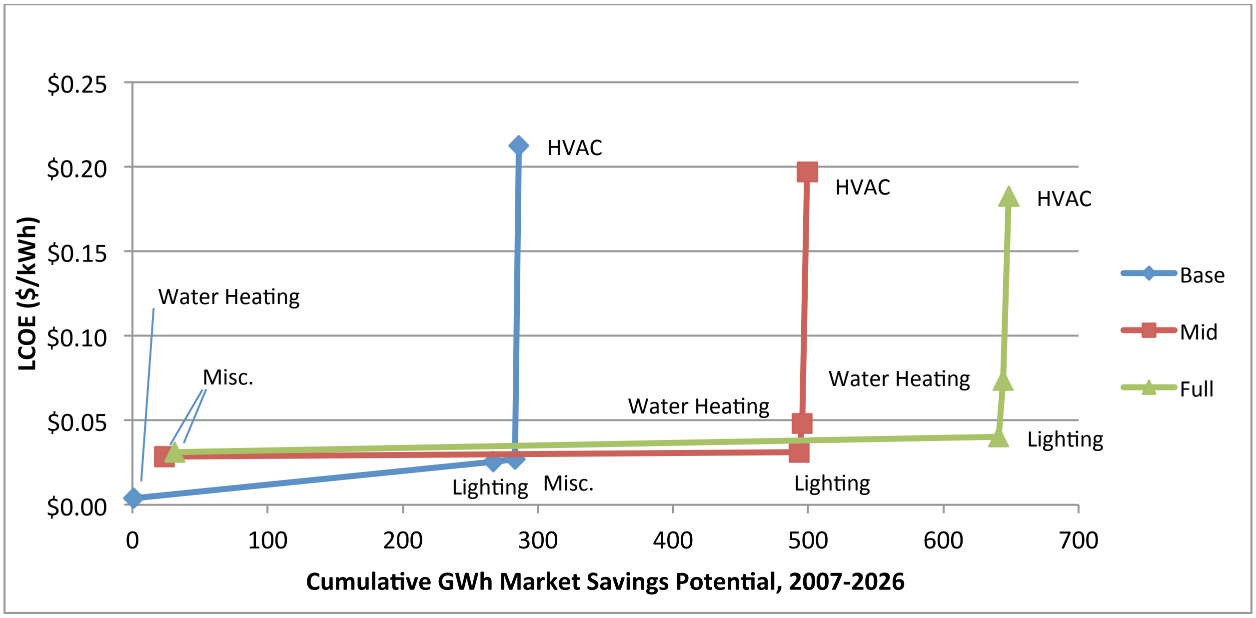
11 Note that this analysis only includes efficiency gains readily achievable through cost effective utility energy efficiency programs. A much larger resource exists that could potentially be capitalized on through innovative financing approaches such as Property Assessed Clean Energy (PACE) programs. A full description of the methodology used in this analysis can be found in Section 2.3.4 of the *Humboldt RESCO Resource and Technology Assessment Report*.

12 This economic analysis does not include demand response programs such as peak-load pricing.

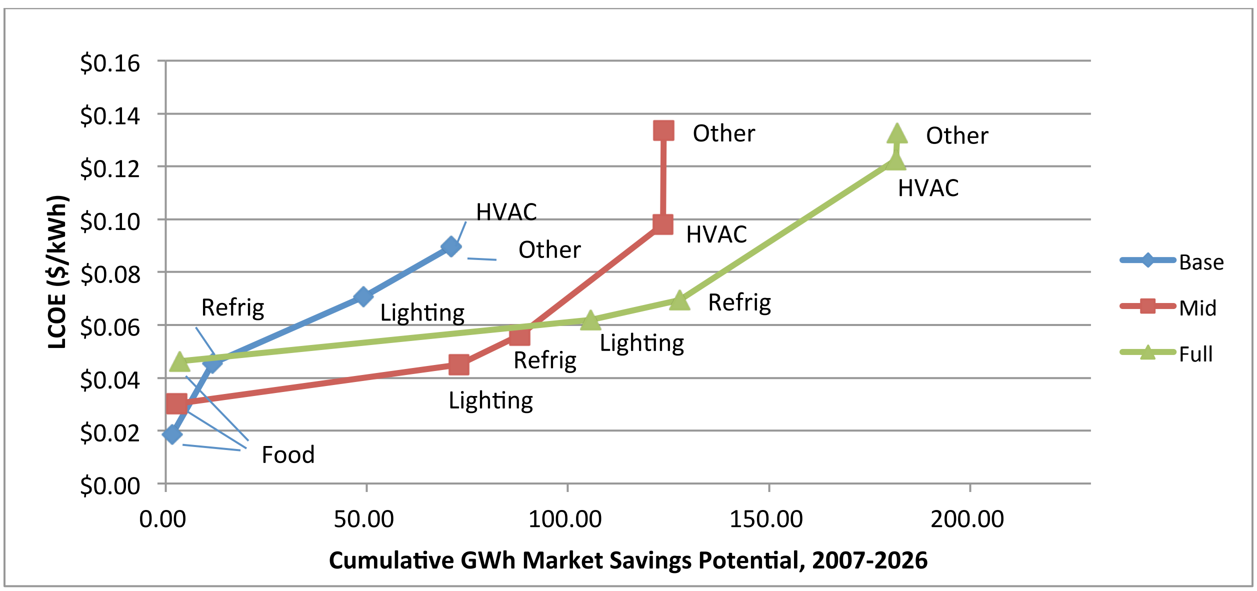
13 LCOE calculations were done from the utility's perspective (i.e. they only include incentive and programmatic costs borne by the utility).

Figure 4: Humboldt County Residential Electrical Energy Efficiency Supply Curve, 2007-2026



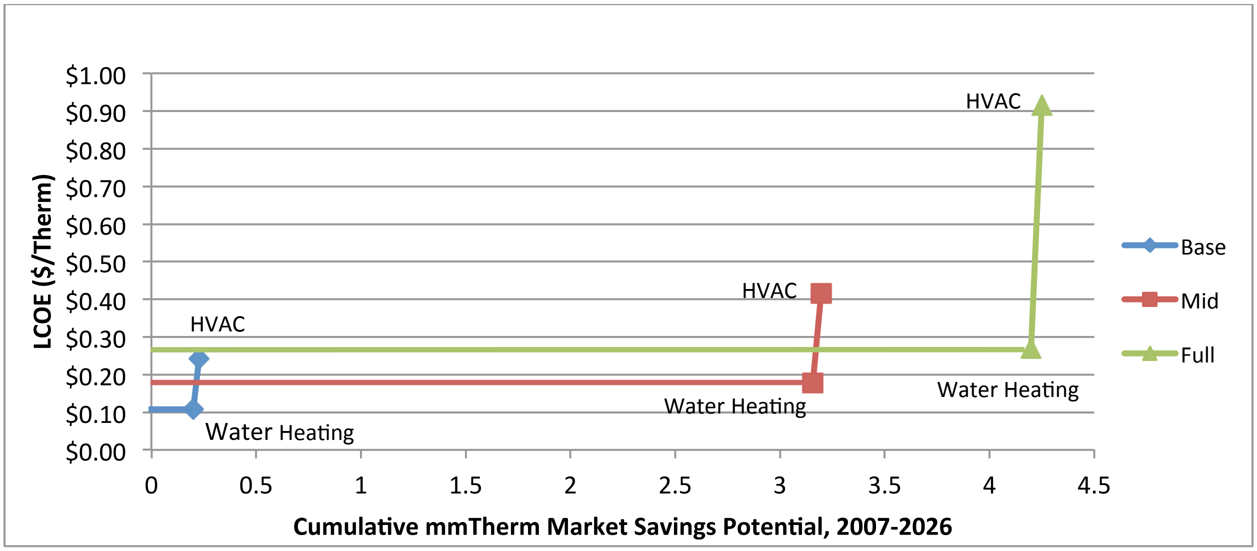
Source: SERC staff analysis

Figure 5: Humboldt County Commercial Electrical Energy Efficiency Supply Curve, 2007-2026



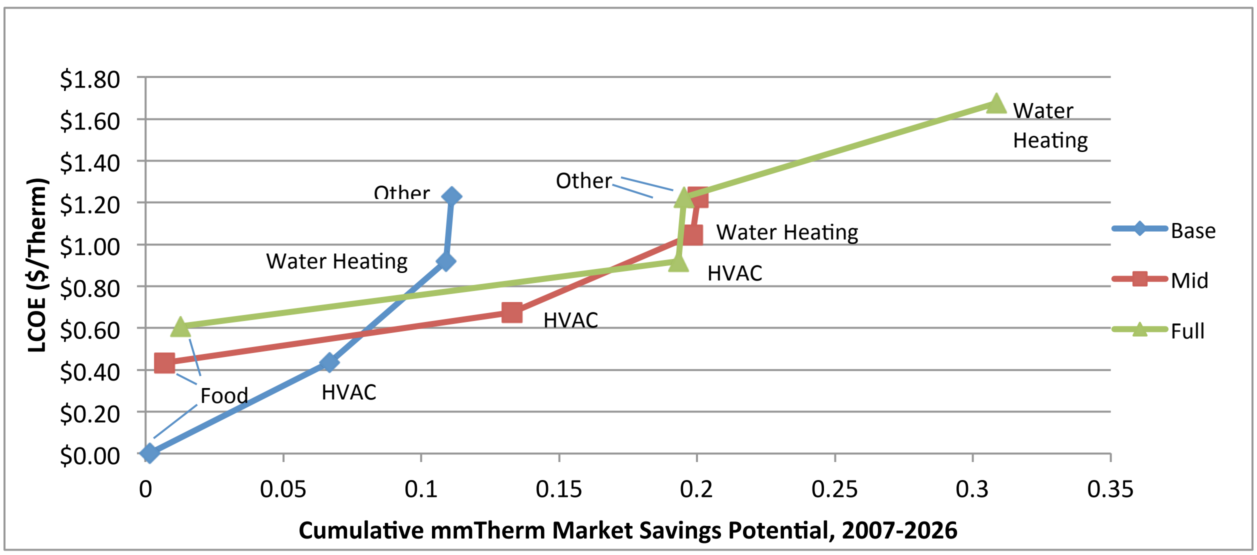
Source: SERC staff analysis

Figure 6: Humboldt County Residential Natural Gas Energy Efficiency Supply Curve, 2007-2026



Source: SERC staff analysis

Figure 7: Humboldt County Commercial Natural Gas Energy Efficiency Supply Curve, 2007-2026



Source: SERC staff analysis

These figures indicate that the residential sector dominates Humboldt County energy efficiency 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 percent and ~56 percent, respectively) with significant contributions also coming from refrigeration and heating, ventilation and air conditioning (HVAC) measures in commercial buildings.[14]

14 The Redwood Coast Energy Authority (RCEA), the local joint powers authority, estimates that their efforts to promote lighting efficiency as well as natural market uptake had achieved an approximately 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.

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 efficiency efforts in Humboldt County available at a low cost. In fact, if LCOE is calculated across all sectors and end-use categories rather than by individual end-uses, the full market potential could theoretically be captured for $0.05/kWh and $0.34/therm. Table 1 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. It is also important to note that LCOE values presented here are conservative given that only energy savings through 2026 are included in the calculation. In reality, many measures installed toward the end of the forecasting period have useful lives and corresponding energy savings that extend well beyond 2026. Energy savings data from this time period were not available from Itron, but their inclusion would further reduce the LCOE of energy efficiency across all sectors and end-use categories.

Table 1: LCOE and Savings Potential at the Sector Level

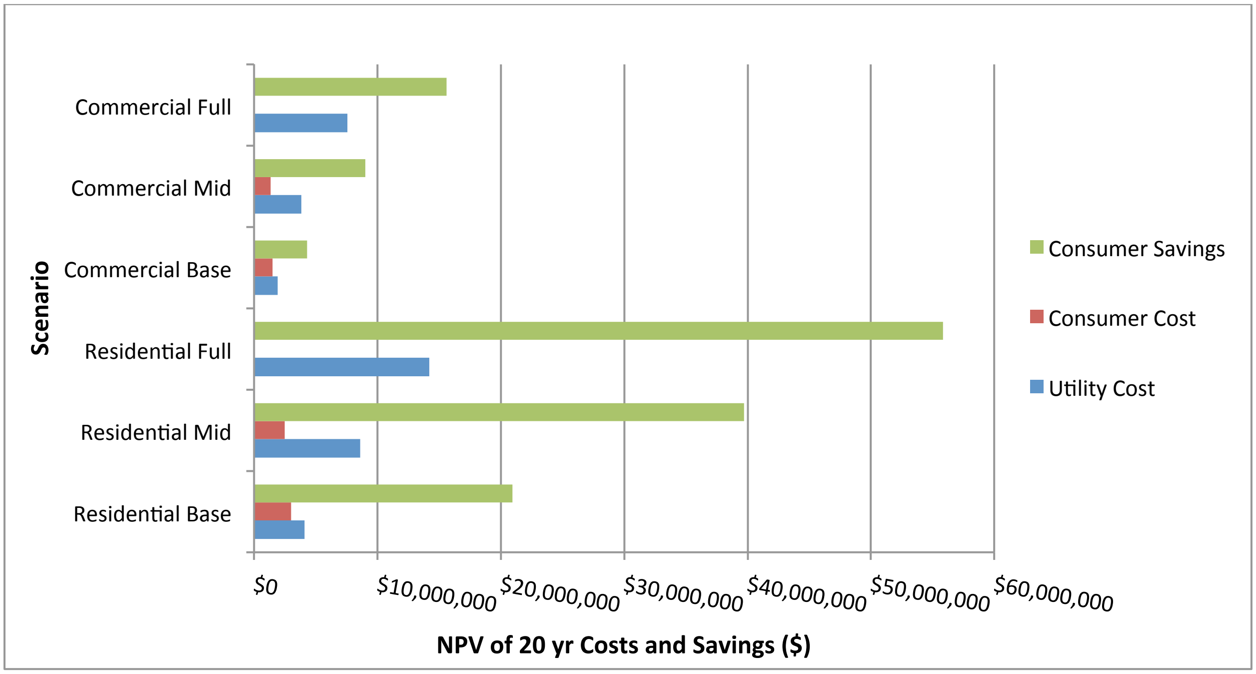
Incentive Level	Electricity LCOE ($/kWh)	2026 Savings Potential (GWh)	Natural Gas LCOE ($/Therm)	2026 Savings Potential (mmTherm)
Residential				
Base	$0.03	286	$0.12	0.23
Mid	$0.03	499	$0.18	3.20
Full	$0.04	648	$0.28	4.25
Commercial				
Base	$0.05	71	$0.64	0.11
Mid	$0.06	123	$0.80	0.20
Full	$0.08	181	$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: SERC staff analysis

Despite relatively low levelized costs, the total costs of these programs over the 20-year forecasting period are high for both the utility and the consumer. 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, efficiency costs are relatively low. Figure 8 and Figure 9 present the net present value of these costs and savings for each sector and incentive level.[15]

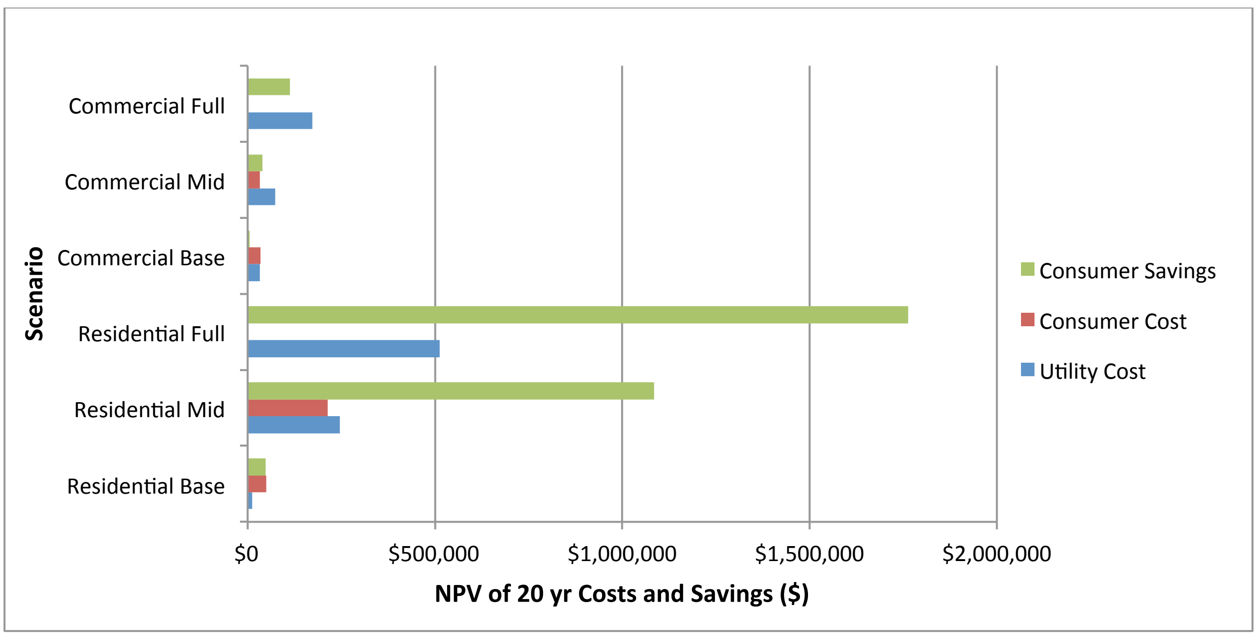
15 Using a 6% real discount rate. Consumer savings are net of up-front cost.

Figure 8: Costs and Savings from Utility Electrical Efficiency Programs, 2007-2026



Source: SERC staff analysis

Figure 9: Costs and Savings from Utility Natural Gas Efficiency Programs, 2007-2026



Source: SERC staff analysis

2.3 Heating Demand Cost Analysis

The economic model for heating costs focuses on installing and operating electric heat pumps instead of operating conventional heating equipment. This research takes a highly conservative approach to account for the cost of switching technologies from natural gas furnaces to heat pumps. The total cost for heating service in Humboldt County is assumed to include the cost of fuel plus the installed cost of geothermal heat pump systems. These assumptions neglect the fact that air source heat pumps (which cost considerably less than ground source) are generally more appropriate in Humboldt County due to the mild climate (CEC 2010). In addition, the cost of replacing existing natural gas heating equipment is ignored. Finally, a coefficient of performance of 3 was used in the analysis, which is also a conservative estimate as ground source heat pumps generally have a coefficient of performance of 4 (USDOE 2010). A lower coefficient results in more electricity consumed to meet the heating demand, which leads to a higher estimate of fuel cost than expected in practice.

2.4 Transportation Cost Analysis

Gasoline and petroleum diesel fuels accounted for nearly half of Humboldt County's total end use energy demand in 2003 and had a retail cost of about $137.3 million dollars (Zoellick et al., 2005). The uncertain supply and rising cost of oil coupled with the adverse impacts that fossil fuels have on the environment suggest that Humboldt County should develop a transportation strategy for decreasing its dependence on imported petroleum fuels. Alternative fuel sources such as biofuels, electricity, and hydrogen can be derived from local renewable resources, and can reduce GHG emissions, reduce dependence on imported oil, and make Humboldt County's transportation sector more self-sufficient.

2.4.1 Electric Vehicles

Electric vehicles have the potential to substantially displace gasoline demand with cleaner, locally generated electricity. The term electric vehicle (EV) is used throughout this report to refer to both plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs). In the *Humboldt County as a Renewable Energy Secure Community: Resource and Technology Assessment Report* (section 2.3.2 Fuel Switching - Transportation), electric vehicle technology was assessed and shown to be an energy demand growth option that can reduce GHGs and influence the portfolio of options recommended by the RESCO team.

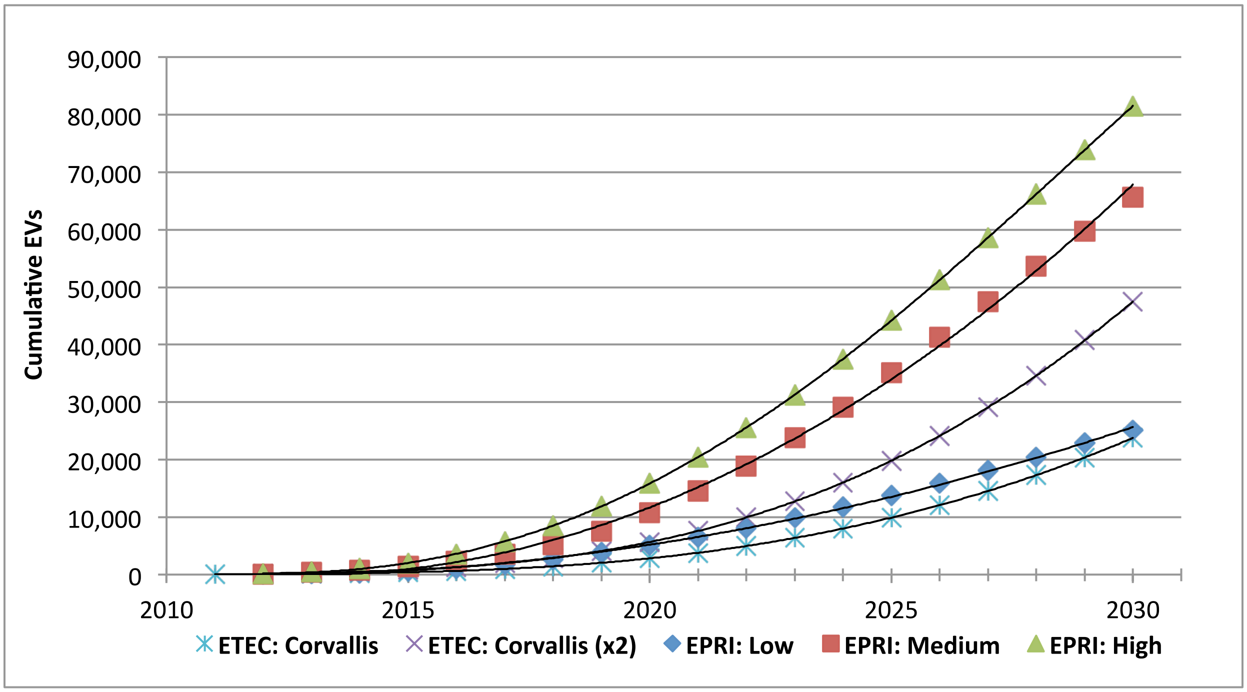
There have been no detailed assessments or quantifications of the costs and benefits that electric drive vehicles could have in Humboldt County. In order to estimate potential GHG reductions and associated costs, the literature was consulted.

2.4.2 Benefit / Cost Methodology

The electric vehicle benefit/cost analysis carried out in this report is based on the methodology laid out in the *Humboldt County as a Renewable Energy Secure Community: Resource and Technology Assessment Report* (section 2.3.2 Fuel Switching - Transportation), and is outlined below.

Three electric vehicle penetration scenarios were assumed for Humboldt County based on market share projections by EPRI (2007) and ETEC (2010): (1) A likely (medium) scenario corresponding to expected electric vehicle diffusion in Corvallis-Albany; (2) an optimistic (high) scenario corresponding to a doubling of the expected penetration in Corvallis-Albany; and (3) a maximum scenario corresponding to the EPRI Medium scenario, meant to serve as a cap for electric vehicle penetration in any given RESCO portfolio (Figure 10).

Figure 10: Projected Cumulative EVs in Humboldt County Based on Low, Medium, and High PHEV Scenarios and Corvallis-Albany EV scenario



Source: SERC compilation from EPRI (2007) and ETEC (2010)

Assumptions about electric vehicle architecture, performance, energy consumption, and capital and maintenance costs were collected from the literature source *Where Are the Market Niches for Electric Drive Vehicles* by Santini et al. (2010) and several personal communications with Bryan D. Jungers, Research Manager at E Source in Boulder, Colorado. Vehicles considered for this analysis are defined in Table 2 and more detailed vehicle architectures are summarized in Appendix B.6., Table 28:. Vehicle component costs and energy use are directly proportional to vehicle performance and are presented in Table 3. Capital costs (or vehicle retail price estimates) are projected costs at a manufacturing capacity of 100,000 vehicles per facility, expected to occur around 2020 and include basic charging equipment (Jungers, 2011).

Table 2: Description of Conventional and Electric Vehicles Considered for Adoption

Vehicle	Description
Conventional	Conventional vehicle; standard mid-size sedan powered by an internal combustion engine (e.g., Toyota Camry)
PHEV10	Plug-in hybrid electric vehicle with a power-split drivetrain and an all-electric range of 10 miles (e.g., Toyota Plug-in Prius)
PHEV40	Plug-in hybrid electric vehicle with a series drivetrain and an all-electric range of 40 miles
EREV30	Extended range electric vehicle; a plug-in hybrid electric vehicle with a series powertrain and an all-electric range of 30 miles; EREVs and series PHEVs are virtually identical, except that an EREV has an over-sized electric motor and battery that enable aggressive acceleration without triggering an engine-on event
EREV40	Extended range electric vehicle; a plug-in hybrid electric vehicle with a series powertrain and an all-electric range of 40 miles (e.g., the Chevrolet Volt was originally advertised as an EREV40, but is reportedly a PHEV40 with a power-split drivetrain)
BEV100	Battery electric vehicle with an all-electric range of 100 miles (e.g., Nissan Leaf)

Source: Santini et al. (2010)

Table 3: Estimated Conventional Vehicle and Electric Vehicle Component Costs and Retail Price Estimates in 2020

Vehicle	Glider	Powertrain: Engine	Powertrain: Transmission	Powertrain: Electric Motor 1 & Motor Controller	Powertrain: Electric Motor 2
Conventional	$9,955	$2,044	$705		
PHEV10	$9,955	$1,384	$590	$1,419	$610
PHEV40	$9,955	$1,264	$188	$1,867	$1,146
EREV30	$9,955	$1,324	$189	$1,881	$1,215
EREV40	$9,955	$1,324	$189	$1,881	$1,215
BEV100	$9,955		$183	$1,797	

Vehicle	Powertrain: Battery	Powertrain: Balance of Plant	Powertrain: On Board Charger	Powertrain Total	Original Equip. Mfg. Vehicle	Retail Price Estimate
Conventional		$425		$3,174	$14,180	$19,665
PHEV10	$2,663	$516	$150	$7,332	$19,715	$25,864
PHEV40	$5,299	$538	$400	$10,701	$24,201	$30,888
EREV30	$5,548	$544	$400	$11,101	$24,733	$31,484
EREV40	$6,519	$544	$400	$12,071	$26,025	$32,931
BEV100	$10,247	$463	$400	$13,090	$27,382	$34,450

Source: Santini et al. (2010)

A total cost of ownership model by Jungers (2011), which carries out a side-by-side lifecycle cost evaluation of multiple vehicle options, was modified and adapted to this analysis. Primary differences in the adapted total cost of ownership model are the inclusion of only electric vehicles currently on the market or near market introduction (Table 3) and a weighting scheme (75 percent PHEV, 25 percent BEV) to determine average electric vehicle energy use, costs, and benefits. Vehicle lifetime was assumed to be 17 years, with a battery replacement occurring at year 10 for all electric vehicles, based on a current battery warranty of 8 years offered by Chevrolet and Nissan. Annual mileage is assumed to be 11,000 miles and national PHEV utility factors developed by EPRI (Appendix B.6: Figure 39) are applied to estimate the fraction of annual miles driven that are derived from electricity. Carbon dioxide equivalent (CO_2e) emissions associated with gasoline combustion and electricity generation were estimated and integrated into the total cost of ownership model for each vehicle type. The retail price of electricity and the GHG emissions associated with electricity generation were based on Regional Energy Planning Optimization Model (REPOP) estimates according to three generation mixes (Business as usual, Medium renewables penetration, High renewables penetration)[16], each in the years 2020 and 2030. A discount rate of 6.4 percent was used and no salvage value, financing, or insurance were assumed. A complete list of model parameter assumptions is included in Appendix B.6: Table 29 and Table 30.

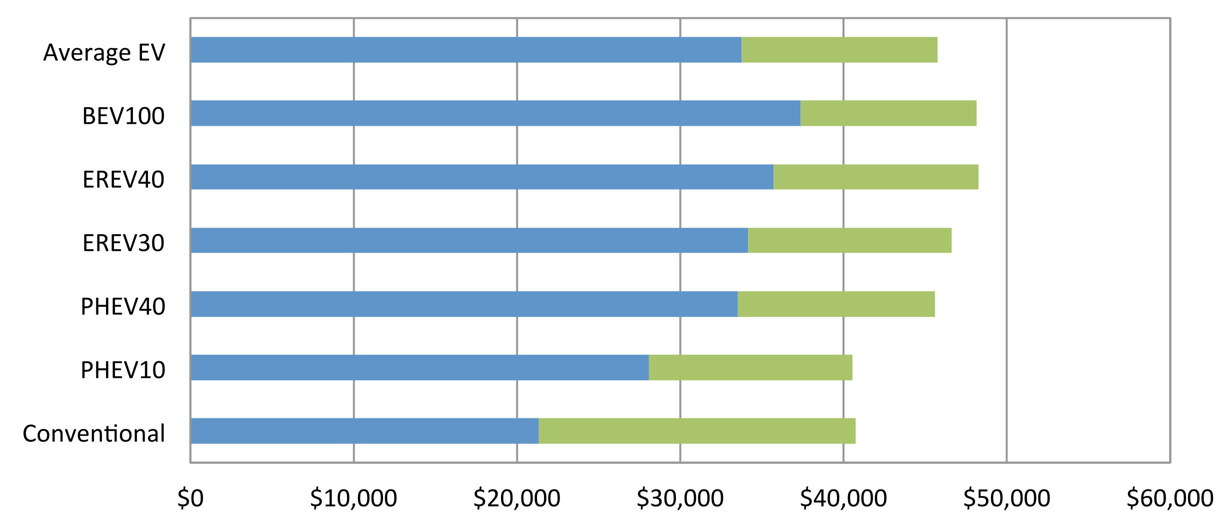
Only passenger vehicles (i.e., classified as autos or light trucks by the department of motor vehicles) were considered for replacement by an electric vehicle. It is also assumed that each electric vehicle adopted in Humboldt County is purchased as a new vehicle and displaces the purchase of a new mid-size conventional vehicle (e.g., Toyota Camry), with its respective fuel economy. It is assumed an electric vehicle will be retired from the county vehicle fleet after its lifetime of 17 years.

2.4.3 Results and Discussion

A benefit/cost analysis carried out in 2020 for a BAU generation scenario indicates that four of the five electric vehicles considered for adoption in Humboldt County have a higher lifecycle cost than a conventional vehicle. On average, the electric vehicles cost about $5000 more than the conventional vehicle (Figure 11). This is about 2.7 cents more per mile over the lifetime of the vehicles (Figure 12). Only the PHEV10 is competitive costing $200 less than the conventional vehicle. This is due to the lower cost of the smaller battery pack in the PHEV10. Lifecycle operation and maintenance costs are on average about $7,400 less for electric vehicles. This is due to reduced gasoline consumption and less frequent maintenance required by electric vehicles. However, capital costs for electric vehicles are substantially higher, resulting in higher overall lifecycle costs. Over the lifetime of the vehicle, an average of 47.3 tCO_2e (or 252 g CO_2e/mi) is avoided through the replacement of gasoline consumption with electricity. Figure 13 and Figure 14 show similar results in 2030 for a BAU generation scenario, only electric vehicles become more cost competitive as capital costs decrease due to economies of scale and projected manufacturing experience. On average in 2030, electric vehicles are $1500 more (or an additional $0.008/mi) than a conventional vehicle, while the PHEV10 is almost $3000 less (or $0.015/mi less) than the conventional vehicle.

[16] These three generation mixes are described in Appendix A, Table 19 of this report.

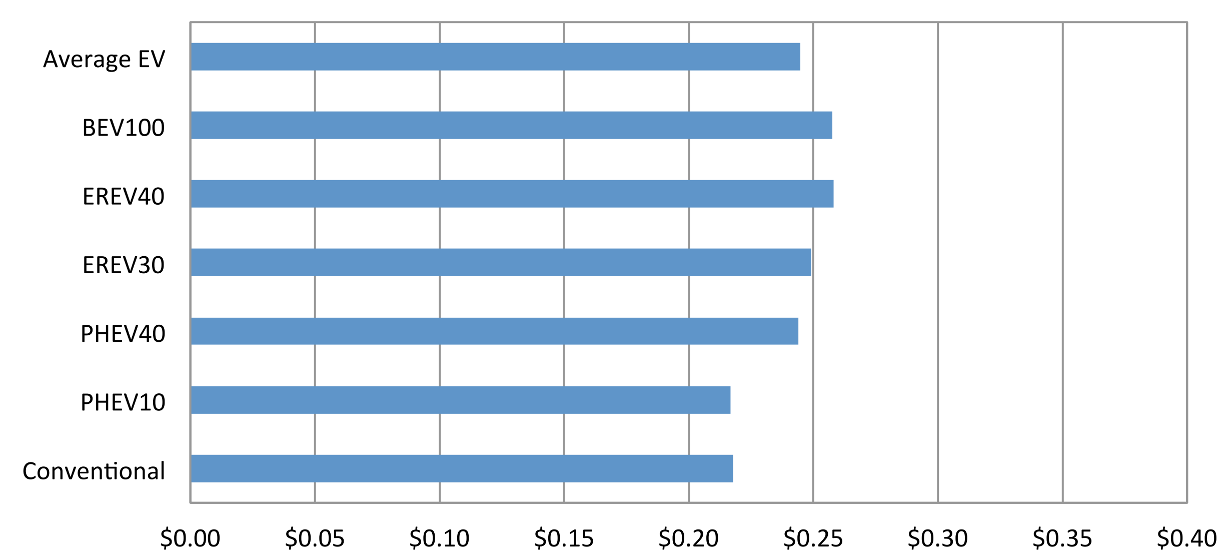
Figure 11: NPV of the Lifecycle Cost of Electric Vehicles Versus a Conventional Vehicle in 2020



	Conventional	PHEV10	PHEV40	EREV30	EREV40	BEV100	Average EV
Capital Cost	$21,336	$28,062	$33,514	$34,160	$35,730	$37,379	$33,752
O&M	$19,388	$12,468	$12,095	$12,447	$12,518	$10,770	$12,007

Source: SERC staff analysis

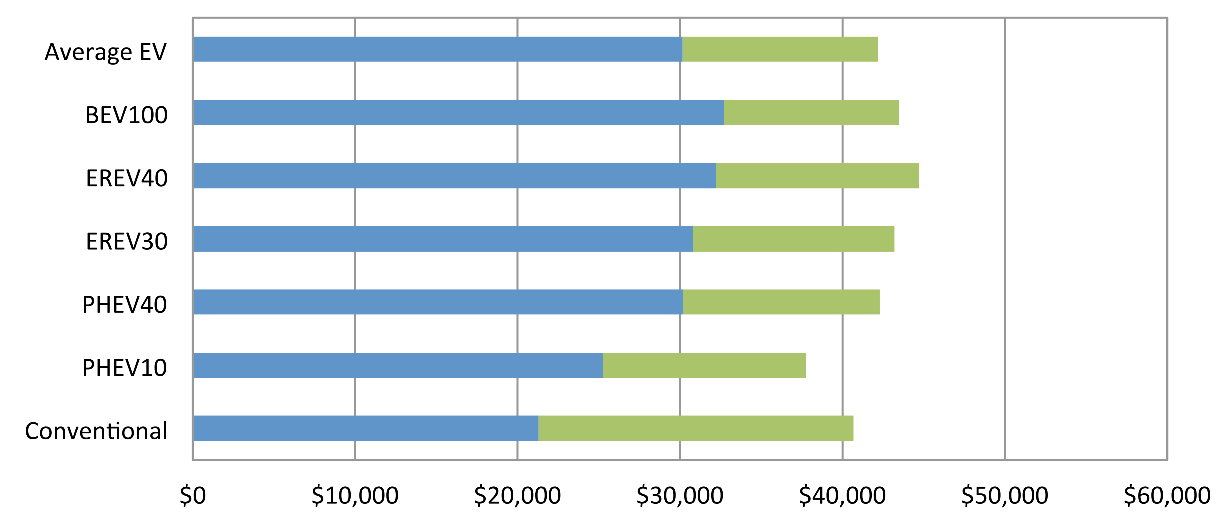
Figure 12: Levelized Cost ($/mi) of Electric Vehicles Versus a Conventional Vehicle in 2020



	Conventional	PHEV10	PHEV40	EREV30	EREV40	BEV100	Average EV
LCOE	$0.218	$0.217	$0.244	$0.249	$0.258	$0.257	$0.245

Source: SERC staff analysis

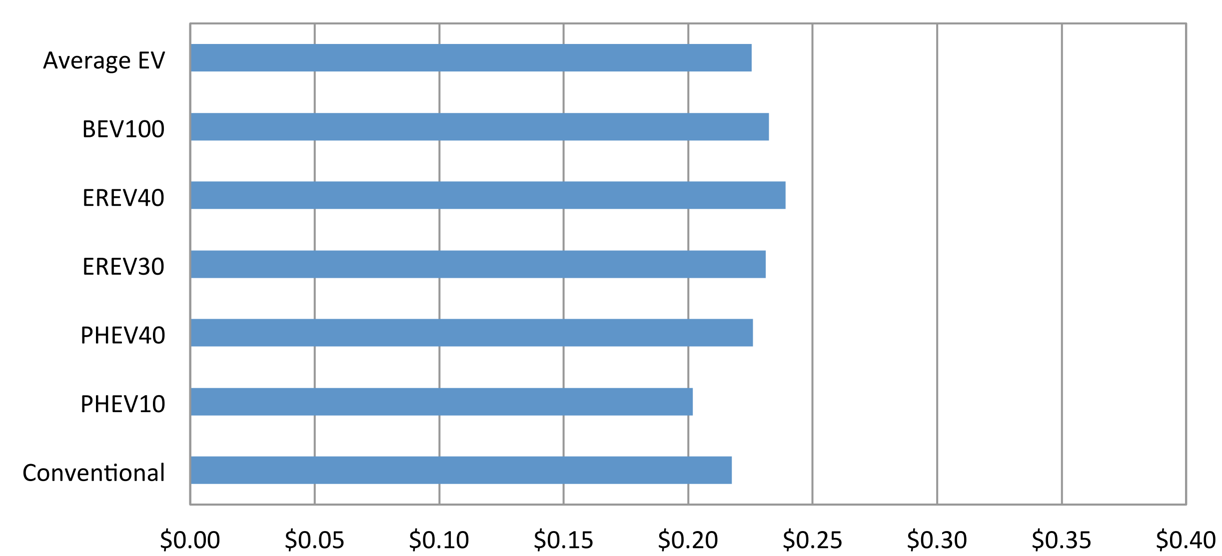
Figure 13: NPV of the Lifecycle Cost of Electric Vehicles Versus a Conventional Vehicle in 2030



	Conventional	PHEV10	PHEV40	EREV30	EREV40	BEV100	Average EV
Capital Cost	$21,282	$25,284	$30,196	$30,778	$32,192	$32,709	$30,168
O&M	$19,388	$12,465	$12,078	$12,433	$12,502	$10,749	$11,993

Source: SERC staff analysis

Figure 14: Levelized Cost ($/mi) of Electric Vehicles Versus a Conventional Vehicle in 2030



	Conventional	PHEV10	PHEV40	EREV30	EREV40	BEV100	Average EV
LCOE	$0.217	$0.202	$0.226	$0.231	$0.239	$0.232	$0.225

Source: SERC staff analysis

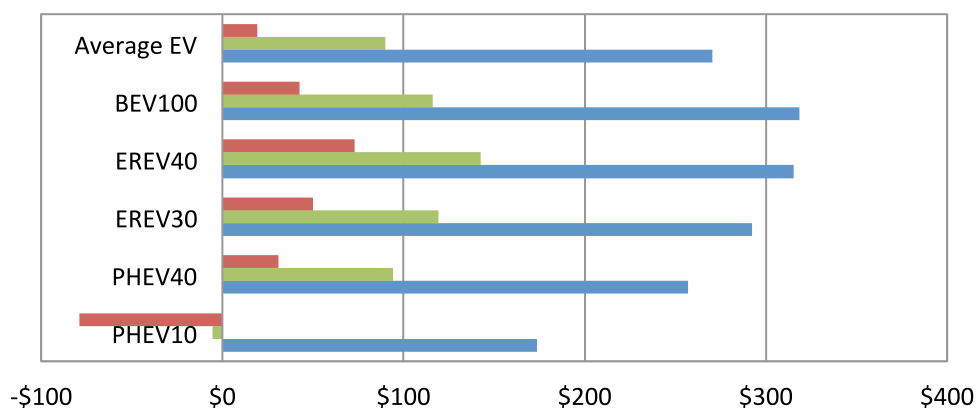
Vehicle GHG emissions and the damage they impose on the environment go uncaptured in the cost figures above. A major benefit of electric vehicles are the GHG emissions they avoid through reduced gasoline consumption. Table 4 shows the lifetime avoided GHG emissions (tCO_2e) by the average electric vehicle considered. Avoided emissions increase as a higher percentage of electricity, which powers electric vehicles, is generated from cleaner renewable energy. Similarly, the average cost for each metric ton of avoided emissions decreases as renewables penetration increases and the capital cost difference between conventional and electric vehicles shrinks. Figure 15 shows the cost of avoided emissions for each electric vehicle under different renewables penetration scenarios. Until a price is placed on CO_2e emissions these benefits go uncaptured in a standard lifecycle benefit/cost assessment.

Table 4: Average EV lifetime Avoided Emissions (tCO_2e) and Cost of Avoided Emissions ($\$/tCO_2e$), Assuming BAU, Medium Renewables Penetration, and High Renewables Penetration Scenarios

Year	2020			2030		
Scenario	BAU	Medium Renewables Penetration	High Renewables Penetration	BAU	Medium Renewables Penetration	High Renewables Penetration
Avoided Emissions (tCO_2e)	47.3	50.9	54.8	47.1	50.4	54.5
Cost of Avoided Emissions ($/tCO2e)	$98	$90	$85	$23	$21	$19

Source: SERC staff analysis

Figure 15: Cost of Avoided Emissions ($/tCO2e) for EVs Assuming a 2010 BAU Scenario, a 2020 Medium Renewables Penetration Scenario, and a 2030 High Renewables Penetration Scenario



	PHEV10	PHEV40	EREV30	EREV40	BEV100	Average EV
CAE (2030 HRP)	-$79	$31	$50	$73	$43	$19
CAE (2020 MRP)	-$5	$94	$119	$142	$116	$90
CAE (2010 BAU)	$174	$257	$292	$315	$319	$271

Notes
CAE: Cost of avoided emissions
HRP: High renewables penetration
MRP: Medium renewables penetration
BAU: Business as usual

Source: SERC staff analysis

Beginning in 2010, PHEVs and BEVs became eligible for a federal tax credit of up to $7,500 (U.S. Department of Energy, 2010). Such a credit closes the lifecycle cost gap between electric vehicles and the conventional vehicles in the previous two scenarios, and make electric vehicles more economically attractive to consumers. Continued government incentives to stimulate early electric vehicle adoption are vital to the broader market adoption that will be required to reduce electric vehicle battery and manufacturing costs through economies of scale.

2.4.4 Hydrogen Powered Mass Transit

While alternative-fuel mass transit is not a primary focus of this report, a preliminary analysis was carried out to explore the feasibility of a hydrogen powered transit system. Mass transit accounts for only about 1.5 percent of the total diesel fuel annually consumed in Humboldt County. Therefore, transitioning to a hydrogen (H_2) powered transit system would not have a major impact in reducing overall county GHG emissions. An analysis of the costs for a hydrogen transit system using electrolytic hydrogen indicates that it is an expensive option for reducing GHG emissions even when only considering operating costs.[17] Additionally, it would require a large capital investment to purchase fuel cell buses and build the necessary refueling infrastructure (Table 5). If the price of diesel increases to $9-$10 per gallon, then the operating cost of an electrolytic hydrogen transit system would be similar to a diesel-based system. However, the hurdle of a large initial capital investment would still remain. As the current transit system is revenue negative, Humboldt Transit Authority would need to find outside funding to cover the cost of the buses and refueling infrastructure. This could be difficult for a county with a small population and a relatively small transit ridership.

Table 5: Cost and GHG Emissions from an Electrolytic Hydrogen Fueled Transit System

Percentage of transit miles fueled by H_2	BAU (0 H_2 Buses)	10% (3 H_2 buses)	50% (17 H_2 buses)	100% (34 H_2 buses)
Total Capital Costs (Fueling Station and Buses)	N/A	$3.3 Million	$14.7 Million	$29 Million
Annual Operating Cost (% BAU)	100%	102%	111%	121%
CO_2 Emissions[17] (% BAU)	100%	97%	84%	68%
Cost of Avoided CO_2 ($/t$CO_2$ avoided)	N/A	$2,019	$1,760	$1,728

Source: SERC staff analysis

[17] The carbon intensity of the grid mix for this analysis is based on scenario C5 in the technical assessment report.

2.5 Bundled Energy Cost Analysis

Transmission and distribution (T&D) of energy are significant parts of the bundled cost of providing electricity, as well as liquid and gaseous fuels to end-users. Because the analysis considered electricity generation costs on a technology and geography-specific basis it was necessary to also estimate transmission and distribution and other costs (like nuclear decommissioning) that lead to a fully built up retail cost. The estimate for Humboldt County is $71.65/MWh and is added to the cost of generation for the various resources.

The retail cost of transportation and heating fuels is well known and includes transportation (i.e., transmission and distribution) bundled with exploration, extraction, marketing, and other costs. This analysis used the retail cost for those fuels directly and did not explore the individual components. Because both electricity and fuel costs are calculated on a retail basis, fuel switching decisions (e.g., from gasoline to electricity for electric vehicles) are on an equal basis.

The research team estimated the cost of electricity transmission and distribution and other expected electricity charges in Humboldt County using a combination of public documents available from the CPUC, PG&E, and other sources.

Table 6 below summarizes the estimates made in this report. An annual CPUC report on utility revenue requirements in 2009 provides overall revenue requirements for the major utilities in California, including PG&E (CPUC 2010). This analysis assumes the PG&E revenue requirements to be representative for Northern California. To normalize the overall revenue requirements on a "per MWh" basis revenue requirements were divided by the total *delivered* (i.e., billed for) electricity that PG&E reported in their 2009 Annual Report, 85,800 GWh (PG&E 2009).

Given the rural character and rugged geography of Humboldt County the analysis used a correction factor of 1.25 to increase the T&D components of the bundled electricity cost. A 2004 report on cost evaluations for energy efficiency and demand side management programs indicated that rural locations in both PG&E and Southern California Edison territory have increased distribution costs (E3 and RMI 2004). The correction factor we used is based on Figure 35 from that report, duplicated below in Figure 16, which shows that the distribution cost for the North Coast region (of which Humboldt Co. is a part) are 25 percent higher than the PG&E systemwide average. The assumption is that the particularly long (~120 mile) transmission line from Humboldt County to the Cottonwood interconnection with the Western Grid combined with rugged terrain within and surrounding the county leads to similarly inflated transmission costs. The research team therefore applied the 125 percent adjustment factor across T&D uniformly.

In addition to T&D costs, the team expects that the cost of Nuclear Decommisioning, Public Purpose Programs, and Ongoing Competition Transition Charges will continue to be borne by retail consumers in Humboldt County. Among other activities, Public Purpose Program charges fund the current-day energy efficiency programs in California, and it follows that any expansion in those programs would result in higher charges. This analysis uses separate estimates for the cost of expanded energy efficiency programs (see Section 2.2 above) and does not adjust the bundled cost estimate in cases with program expansion to avoid double counting the program costs. In other words, the Public Purpose Program Costs are fixed in the ecoomic model.

Some of the costs that are currently borne by retail consumers of electricity are remnants from the California Energy Crisis of 2001 and will shortly expire. Those are indicated with shading in Table 6 and were not included in the estimate of the total adder for bundled electricity service.

Table 6: Bundled Retail Electricity Component Cost Estimates (in addition to generation costs)

	PG&E Revenue Requirements[18]	PG&E System-wide Cost[19]	Humboldt County Estimate[20]
Item	**$(000)**	**$/MWh (load side)**	**$/MWh (load side)**
Transmission Total	$771,022	$8.99	$11.24
Distribution Total	$3,659,068	$42.66	$53.33
Nuclear Decommissioning	$23,846	$0.28	$0.28
Public Purpose Programs Total	$157,190	$1.83	$1.83
DWR Power Charge Revenues*	$1,593,664	$18.58	$18.58
DWR Bond Charge Revenues*	$406,569	$4.74	$4.74
AB1890 Rate Reduction Bonds*	$-14,194	$-0.17	$-0.17
Ongoing Competition Transition Charge	$426,566	$4.97	$4.97
Energy Recovery Bonds (PG&E only)*	$202,777	$2.36	$2.36
Total (without temporary charges)	**$5,037,692**	**$58.74**	**$71.65**

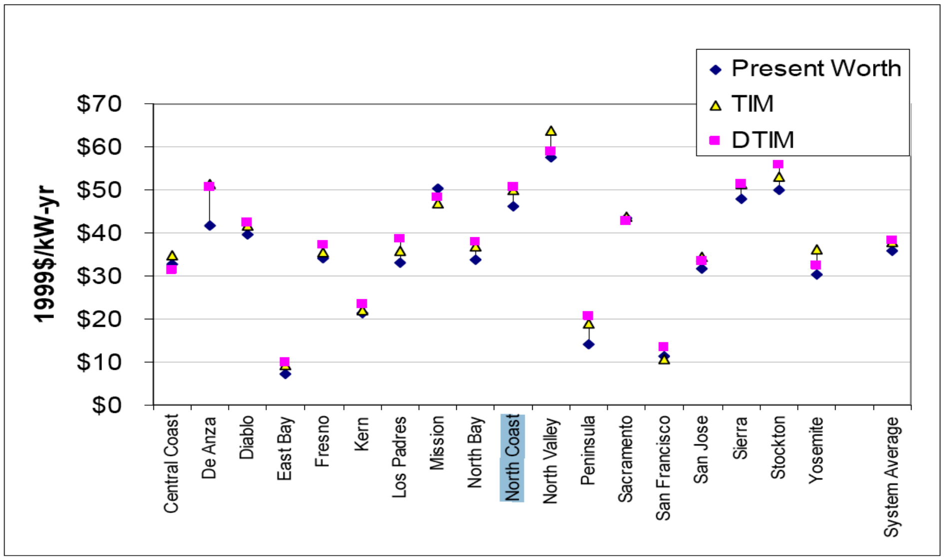
*Temporary charges (also shaded) that are not included in the total.
Source: SERC staff analysis

18 From CPUC 2010

19 Equal to the revenue requirements divided by the total system deliveries, 85,800 MWh in 2009 (PG&E 2009).

20 For T&D, equal to the system-wide cost times 1.25, a correction factor for the North Coast region. Unchanged for other cost components.

Figure 16: PG&E Electric Distribution Marginal Costs (from E3 and RMI 2004)



Source: 1999 PG&E General Rate Case Filing

2.6 Environmental Impacts

The levelized cost of electricity generation from fossil fuels is typically less than renewable energy technologies. That is due in part to the fact that there are *external damage* costs that are not taken into account, and that the levelized cost estimates are merely the *private* costs of production. California will soon be enacting a cap-and-trade program to reduce GHG emissions in accordance with Assembly Bill (AB) 32, however, which will result in the pricing of greenhouse gases that will be internalized into the overall (*social*) cost of fossil fuel-based energy generation. Consequently, one must address possible prices on carbon when determining the most cost effective generation mix for Humboldt County. Calculating the cost per unit of avoided CO_2e emissions due to renewable energy and energy efficiency investments will allow planners to evaluate which generation technologies are the least expensive in terms of carbon abatement. Table 7 displays the cost of avoided generation and cost per ton of avoided CO_2e for displacing natural gas fired generation with various renewable technologies.[21] Because the levelized cost of the various technologies depends on the installed capacity and assumed capacity factor, avoided generation costs and the cost of avoided carbon are specific to a given development scenario. These results are based on a "middle-of-the-road" or likely renewable energy portfolio in Humboldt County as identified in the resource and technology assessment.[22]

21 There has been recent debate regarding the carbon neutrality of electricity production from biomass power plants (Manomet 2010; EWG 2010). Issues include the prospect of deforestation from poorly regulated fuel wood harvest and reduced future carbon sequestration. A full discussion of this topic is beyond the scope of this report. This analysis assumes that biomass power plants in Humboldt County are carbon neutral.

22 The development scenario implicit in Table 7 includes: 18 MW small hydro & a 59% capacity factor; 76 MW biomass & a 67% capacity factor; 15 MW wind & a 27% capacity factor; 2 MW solar PV & a 14% capacity factor; and 15 MW wave energy & a 23% capacity factor.

Table 7: Levelized Cost per Unit of Avoided CO_2e from Displacing Natural Gas

Generation Technology	LCOE (2010$/MWh)	LCOE Less the Cost of Avoided Generation (2010$/MWh)	Cost of Avoided CO_2e (2010$/ton)
Wind	$82	-$8	-$17
Efficiency*	$51	-$7	-$15
Small hydro	$90	-$1	-$1
Biomass	$116	$26	$54
Wave	$135	$45	$94
Solar	$685	$595	$1,253

Note: LCOE less the cost of avoided generation is equal to the difference between the levelized cost of energy of each renewable technology and LCOE of the HBGS ($90/MWh). LCOE less the cost of avoided generation is based on the LCOE for the Humboldt Bay Generating Station (HBGS) rather than the cost of generation at the margin because this is a prospective analysis which puts all technologies on equal footing. A custom emissions factor of 0.949 lbs CO_2e/kWh was used based on the specifications of the new Wärtsilä internal combustion engines and typical fuel composition at the HBGS.

* Based on the electrical LCOE for the residential and commercial sectors combined at the full incentive level. Because energy efficiency is not a physical source of energy, here it is assumed that energy efficiency displaces marginal generation at the HBGS ($58/MWh).

Source: SERC staff analysis

These results indicate that small hydro, wind, and investing in full incentive-level efficiency programs would be cost effective on an avoided cost of generation basis alone, while the remaining renewable energy technologies would require an additional investment as compared to generation at the HBGS (under this particular development scenario). The "Cost of Avoided CO_2e" column shows the price on carbon that would be required to make each renewable technology cost competitive. These investments can be deemed economically feasible as carbon mitigation strategies if the cost of avoided CO_2e falls below a prevailing price of CO_2e. Small hydro, wind, and energy efficiency would be highly beneficial as carbon mitigation strategies at any carbon price, while biomass, solar, and wave would require a price on carbon of more than $50/ton, which is likely unrealistic in the near term.

2.6.1 Avoided Climate Change Mitigation Costs

There are long-term and potentially severe damage costs associated with climate change.[23] The scientific literature presents a broad consensus that a portion of the global warming trend observed in the recent past can be attributed to the anthropogenic release of GHGs. The International Panel on Climate Change (IPCC, 2007) estimates that a doubling (relative to pre-industrial times) of the atmospheric CO_2 concentration is likely to have a global warming impact in the range of 2 degrees to 4.5 degrees Celsius, with a best estimate of about 3 degrees Celsius. However, according to the Pew Center on Global Climate Change (2009), the growth rate of CO_2 emissions since 2000 has followed the least optimistic of International Panel on Climate Change development scenarios. This indicates that continuing BAU may lead to

23 This material draws from that of Hackett (2011).

greenhouse gas concentrations more than doubling by 2100, resulting in even more warming. Sokolov et al. (2009) supports a more severe warming scenario using the Massachusetts Institute of Technology Integrated Global System Model, which predicts median surface warming of 5.1 degrees Celsius by 2100. In fact all configurations of the model simulations result in a much lower probability of low to moderate (< 2.4 degree) warming, and a correspondingly higher probability of high warming, than suggested by the International Panel on Climate Change (2007).

Quantifying damages associated with various warming scenarios is challenging due to, among other variables, the long time frame, geographically variable impacts, and overall uncertainty relating to the interactive effects of warming on Earth's atmospheric, hydrologic, oceanic, and other systems. Current integrated assessment models combine relatively simplified global climate models with economic models, and provide estimates of physical and economic effects of warming on market and non-market sectors including water, agriculture, coastal infrastructure, human health, and ecosystem functions. Damage cost estimates for a particular climate change scenario over a given time period can then be combined with current emissions data to determine the marginal damage per ton of GHG (i.e. the net present value of damage costs resulting from one additional ton of CO_2e over the next 100+ years) (NRC, 2009). Different impact assessment models have somewhat unique methodologies for assessing these damages, but nearly all of the variation in model outputs can be attributed to assumptions about the discount rate and the extent of future gross domestic product (GDP) losses resulting from global warming. Table 8 below demonstrates that marginal damage estimates vary by approximately an order of magnitude based on discounting and by another order of magnitude from future damages.

Table 8: Marginal Global Damage Costs

	Damages from Benchmark Warming (\$/ton CO_2e)	
Discount rate	Relatively low (~1%-2% GDP)	Higher (~7%-11% GDP)
1.50%	10	100
3.00%	3	30
4.50%	1	10
Note: Due to the large uncertainty in the climate change economics literature, the NRC (2009) indicates that only rough, order of magnitude estimates are warranted.		

Source: NRC (2009)

Most commonly used impact assessment models operate under the assumption that damages are proportional to the size of the world economy and that the percentage loss in GDP is a power function of temperature rise. GDP losses vary depending on whether this function is linear, quadratic, or cubic. Accordingly, for any given warming estimate there is a wide range of potential GDP losses. Adding to this uncertainty, there is considerable debate over the appropriate discount rate to apply to long-term impacts. A real discount rate of approximately 3 percent is sometimes suggested for environmental impact analysis, but as Cline (2004) points out, a 3 percent real discount rate causes \$100 worth of avoided damages two hundred years from now to have a present value of only 27 cents. In other words, spending more than 27 cents today would not be justified in order to save \$100 in the distant future. Some analysts, such as Nordhaus (2008), use even higher discount rates (~4.5 percent) that are based on market interest rates. Due to the long timeframe, such high discount rates lead to marginal damage cost estimates that do not encourage substantive climate change mitigation policy. Cline (2004) suggests a discount rate of 1.5 percent and notes that the point of global warming policy is to take actions now, at potentially high costs, which will hedge uncertain but possibly severe damages far in the future. This is consistent with Stern (2006), who discounts at 1.4 percent. This rate assumes a per capita GDP growth rate of 1.3 percent and a low social utility discount rate of 0.1 percent.

Given the magnitude of potential consequences of BAU drawn from the analysis of the literature, the research team concluded that a discount rate of 1-3 percent and GDP losses of 7 percent or more are appropriate default model assumptions in this report. The parameter values result in marginal damage cost estimates in the range of \$50-\$100+ per ton of CO_2e. Table 9 shows the marginal damage costs per MWh of generating electricity at PG&E's HBGS over a range of potential carbon damage cost estimates.

Table 9: Estimated Marginal Damage Costs from Humboldt Bay Generating Station

Marginal damage cost per ton	@\$30/ton CO_2e	@\$50/ton CO_2e	@\$100/ton CO_2e	@\$120/ton CO_2e
Marginal damage cost per MWh*	\$14	\$24	\$47	\$57
* Assumes 59.5 kg CO_2e/mmBtu of natural gas and a heat rate of 7616 kJ/kWh (Wärtsilä, 2010). While the Wärtsilä internal combustion engines at the HBGS have dual-fuel capability (diesel and natural gas), this analysis is based only on natural gas combustion, which is anticipated to be the primary fuel.				

Source: SERC staff analysis

Comparing these costs to those in Table 7 above indicates that all of the renewable technologies except wave and solar become cost competitive with natural gas fired generation in the \$50-\$100 per ton CO_2e range.

2.6.2 Avoided External Damage Costs

Electricity generation, especially from fossil fuels, emits pollutants that have deleterious effects on human health, agriculture, and the environment. These damage costs are most commonly borne by individuals and are not factored in to the cost of electricity. Renewable energy technologies such as wind, wave, hydro, and solar have some pollution resulting from their manufacture and maintenance, but as compared to fossil based generation, their damage costs are essentially zero. Because this cost advantage is not typically included in electricity prices, the artificially low cost of fossil power often stands as a substantial entry barrier for renewable energy technologies.

Muller and Mendelsohn (2009) estimate the marginal damage costs associated with ammonia, nitrogen oxides, particulate matter, volatile organic compounds, and sulfur dioxide emissions from electricity generation nationwide. They use peer-reviewed concentration response functions to quantify premature mortalities, cases of illness, reduced timber and crop yields, enhanced depreciation of man-made materials, reduced visibility, and decreased recreation usage due to exposure for nearly 10,000 distinct sources of air pollution. Exposures are computed by multiplying county-level populations by county-level pollution concentrations and dollar values from the literature are assigned to the damages. Health damages, including premature mortality and morbidity, make up the vast majority (up to 95 percent) of monetized damage estimates (Muller and Mendelsohn, 2007). Humboldt County specific marginal damage cost estimates (2010\$/ton) from this model can be seen in Table 10 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 10: Humboldt County Marginal Damage Costs (2010$/ton)

Criteria Pollutant	Ground Level	Low Point Sources*	High Point Sources*
Ammonia (NH_3)	$608	$515	$309
Particulate Matter ($PM_{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 high point sources in Humboldt County.

General note: All damage cost estimates were adjusted from 2000$ to 2010$ using inflators derived from the GDP price index 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)

The effects of population density can be illustrated by examining national average damage costs associated with electricity generation from coal and natural gas (Table 11). While coal plays a minor to negligible role in PG&E's generation portfolio as of 2010, it is included for the sake of comparison (M. J. Bradley & Associates, 2010). The National Research Council (2009) evaluates average damage costs from 406 coal fired and 498 natural gas fired power plants in the United States. National average damage costs from both coal and natural gas are much higher than aggregated Humboldt County damages. This is expected because most power plants are in areas of high population density and thus have much higher exposure rates and associated damage costs for a given ton of emissions.

Table 11: National Average Damage Costs (2010$/ton)

	Damage Costs per Ton from Coal Combustion		Damage Costs per Ton from Natural Gas Combustion	
Criteria Pollutant	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Particulate Matter ($PM_{2.5}$)	$9,956	$8,698	$33,536	$61,832
Nitrogen Oxides (NO_x)	$1,677	$817	$2,306	$2,096
Sulfur Dioxide (SO_2)	$6,078	$2,725	$13,624	$30,392
Particulate Matter (10)	$482	$398	$1,782	$3,563

General notes: Damage costs for VOCs and NH_3 are also calculated but are not reported in National Research Council (2009) due to missing emissions data for a significant fraction of plants. National Research Council (2009) indicates that these pollutants make up a relatively small fraction of overall damage costs.

All damage cost estimates were adjusted from 2007$ to 2010$ using inflators derived from the GDP price index contained in the Budget of the United States Government: Historical Tables Fiscal Year 2011. http://www.gpoaccess.gov/usbudget/fy11/hist.html

Source: NRC (2009)

Although natural gas is typically a cleaner burning fuel than coal, average damage costs per ton for natural gas are considerably higher than for coal (Table 11). Though there is wide variability among plants of both types, higher costs are seen primarily because natural gas plants tend to be located in areas of high marginal damage costs per ton of pollutant. Because damage costs are heavily dependent on where they are emitted as well as the emissions intensity of the generating technology, it is useful to evaluate damage costs on a per MWh basis, which takes both factors into account. This is done in the table that follows. Table 12 shows national average damage cost estimates per MWh from the National Research Council (2009) for coal and natural gas. When weighted by net generation, average damages associated with electricity production from natural gas are approximately an order of magnitude less costly than from coal. These damage cost estimates should be viewed with caution, however, due to substantial variation and skew in the data. For coal, the lowest-damage 50 percent of plants (comprising 25 percent of net generation) produced 12 percent of damages, while the highest-damage 10 percent of plants (also 25 percent of generation) produced 43 percent of the damages. For natural gas, the 50 percent of plants with the lowest damages per plant, which accounted for 23 percent of net generation, produced 4 percent of the damages, while the 10 percent of plants with the highest damages per plant (24 percent of net generation) produced 65 percent of the damages.

Table 12: National Average Damage Costs (2010$/MWh) Weighted by Net Generation

	Damage Costs per MWh from Coal Combustion		Damage Costs per MWh from Natural Gas Combust.	
Criteria Pollutant	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Particulate Matter ($PM_{2.5}$)	$3.10	$4.60	$1.80	$5.90
Nitrogen Oxides (NO_x)	$3.60	$4.00	$2.40	$7.80
Sulfur Dioxide (SO_2)	$39.80	$4.30	$0.20	$0.70
Particulate Matter (PM_{10})	$0.20	$0.20	$0.10	$0.30
Total (equally weighted)	$46.10	$46.10	$4.50	$12.60
Total (weighted by net generation)	$33.50	$45.10	$1.70	$4.40
General note: All damage cost estimates were adjusted from 2007$ to 2010$ using inflation estimates derived from the GDP deflator contained in the Budget of the United States Government: Historical Tables Fiscal Year 2011. http://www.gpoaccess.gov/usbudget/fy11/hist.html				

Source: NRC (2009)

In Humboldt County, damage costs for local BAU electricity production on a per megawatt hour basis are considerably lower than national averages presented in Table 12 due to multiple reasons. First, as previously mentioned, Humboldt County has a relatively low population density, and so each ton of pollutant has lower damage costs associated with it than the national mean. Additionally, Humboldt County's largest electricity service provider, PG&E, no longer includes coal as a significant component its generation mix, and local natural gas generation utilizes internal combustion engines that have lower emissions factors than most conventional steam turbines. Table 13 presents Humboldt County damage cost estimates per MWh based on emissions data for the new HBGS provided by PG&E (CEC, 2006) and per ton damage cost estimates from Muller and Mendelsohn (2009). While these damage costs should theoretically be added to the cost of generation, they do not play a significant role in the economic analysis.

Table 13: Humboldt County Marginal Damage Costs ($/MWh)

Criteria Pollutant	Marginal Damage Cost ($/MWh)
Nitrogen Oxides (NO_x)	$0.005
Sulfur Dioxide (SO_2)	$0.005
Volatile Organic Compounds (VOC)	$0.01
Particulate Matter (PM_{10})	$0.01

Source: SERC staff analysis

CHAPTER 3: Economic Development Potential and Impact Assessment

3.1 Economic Development Potential from The Renewable Energy Industry Cluster

The discussion on investment in renewable energy is usually framed as being motivated by environmental concerns such as the mitigation of greenhouse gases and other pollution associated with conventional fossil fuel energy resources. Other arguments include a reduced reliance on fossil-fuel imports, particularly petroleum imports that oftentimes rely upon complementary investments in military resources to foster stable and secure global oil trade. Not to be overlooked, however, are the jobs, income, and tax revenues derived from construction and operation of renewable energy and energy efficiency projects that may create economic development benefits for local communities.

3.1.1 Economic Development Potential of Renewable Energy: Job Creation and Occupational Employment

Industries linked to renewable energy and energy efficiency have experienced above-average growth in recent years (Hanke and Sauer, 2009). According to the Pew Charitable Trust (2009), jobs in the US "clean energy economy" grew by an average of 1 percent annually during the past 10 years, while total US employment grew by an average of 0.4 percent annually. Roland-Horst (2008) estimates that energy efficiency measures have enabled California households to redirect their expenditures toward other goods and services, creating about 1.5 million full time equivalent jobs with a total payroll of $45 billion, driven by well-documented household energy savings of $56 billion from 1972-2006. According to Bezdek (2008), the renewable energy and energy efficiency industries created more than nine million jobs (both direct and indirect) across the US in 2007 alone. Bezdek notes that growth in industries linked to renewable energy and energy efficiency create good-paying jobs in manufacturing, construction, accounting, and management, among other occupational sectors.

One might argue that as renewable energy and energy efficiency merely displaces conventional energy, that no new jobs are actually being created. Kammen et al. (2006) and Wei et al. (2009) 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 15 in 2009 that analyze the economic and employment impacts of the clean energy industry (renewable energy and energy efficiency) in the United States and Europe. The central conclusion of this literature review and synthesis is that expanding the use of renewable energy has a significant positive impact on employment.

To make intermittent renewable generation facilities (with lower capacity factors) directly comparable to base-load fossil fuel-based generation facilities (with higher capacity factors), these studies calculate an "average installed megawatt of power" 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 14 below). The results are less clear for operations and maintenance—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 portfolios of renewable energy 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.

Table 14: Average Employment by Energy Generation Technology[24]

	Average Employment over Life of Facility (Jobs/MWa)		
	Manufacturing, 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*

* As energy efficiency measures have no capacity factor, average employment is reported in units of total job years/GWh of avoided energy consumption.

Source: Wei et al. (2009)

The construction and installation phase of renewable energy development creates jobs in manufacturing and construction sectors of the economy that have suffered disproportionately high unemployment rates (Kammen et al. 2006).

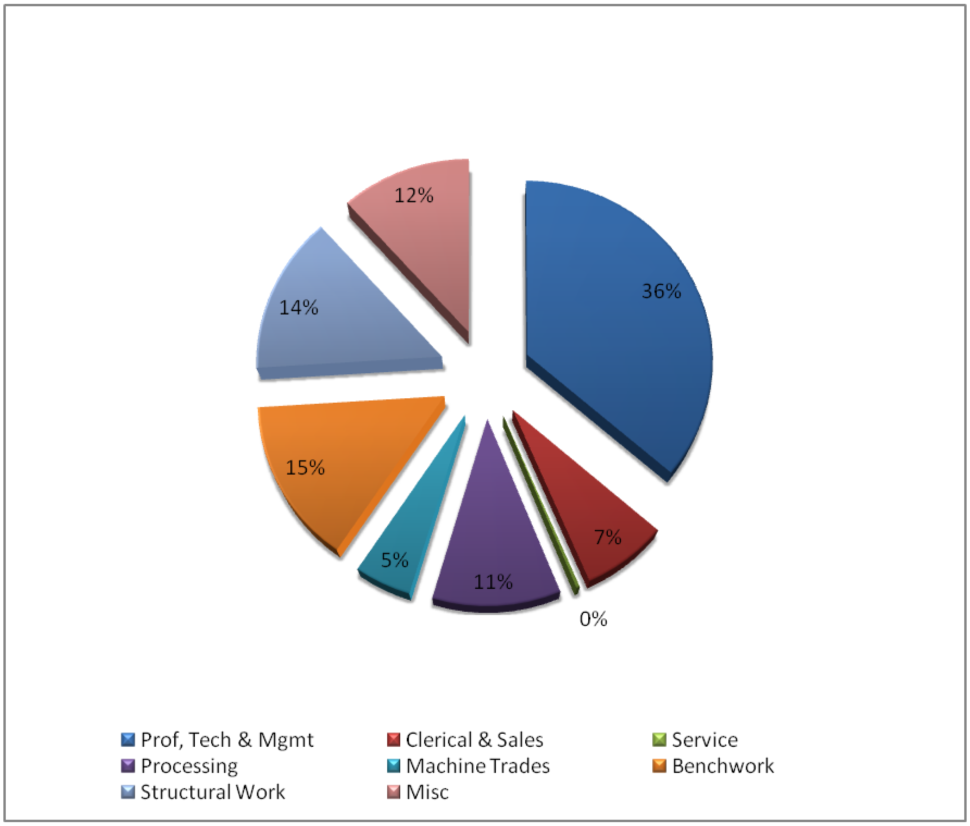
Singh and Fehrs (2001) gathered data on employment by occupation and by industry sector for solar PV, wind, and biomass-based electricity generation. Singh and Fehrs' solar PV and wind data derive from telephone and mail surveys of firms in the wind and PV industries with operations in the US. The biomass co-firing data derive from surveys of existing biomass energy projects (both dedicated and co-firing facilities) as well as a literature review. While biomass co-firing is not relevant to Humboldt County, the presentation below will focus on employment in silvicultural biomass fuel supply. Their survey estimates employment for solar PV and wind energy from the manufacturing of components through delivery, construction/installation, and operations over 10 years. The biomass portion of their study assumes an existing coal-fired power plant is used to co-fire biomass fuel, and thus the employment focus is on fuel production, transport, and processing on-site. Singh and Fehrs' employment study provides a useful complementary perspective for this report, as it is based on surveys of *direct employment by specific task or occupation*. In contrast, input-output (I-O) models such as JEDI (described below) generate *aggregated direct, indirect, and induced employment estimates*. Both the survey approach and the I-O approach provide insight into industry sectors that make up the renewable energy industry cluster, which will be addressed later in this section of the report.

The pie chart below (Figure 17) indicates that professional, technical, and management occupations are the largest single area of employment in residential-scale solar PV systems, followed by clerical and sales and structural work. Assuming that manufacturing occurs

[24] 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 percent 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.

outside of Humboldt County, then the largest source of local employment is in the construction trades for structural work associated with solar PV installation.

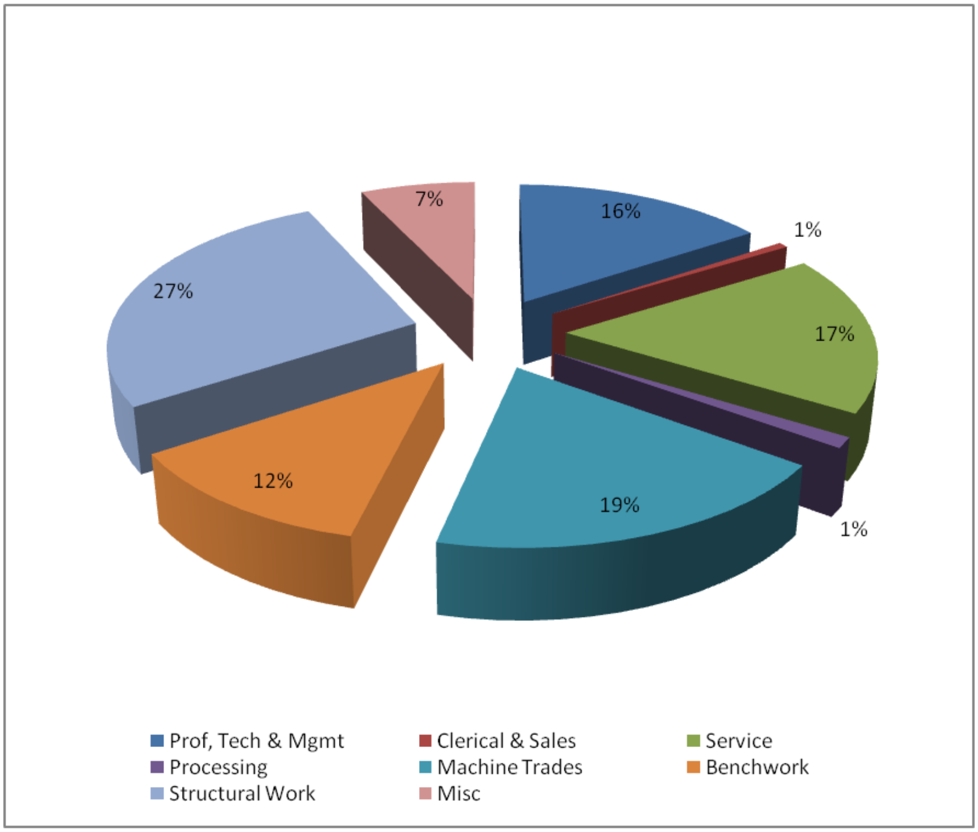
Figure 17: Shares of Total Job Creation by Solar PV Occupational Categories



Source: Singh and Fehrs (2001)

In contrast to solar PV, Figure 18 shows that structural work associated with construction trades is the largest single area of employment in utility-scale wind farms, followed by machine trades associated with manufacturing of wind turbines. More significant from a Humboldt County point of view, however, is that the third largest area of occupational employment with wind farms is associated with ongoing O&M during the operations phase.

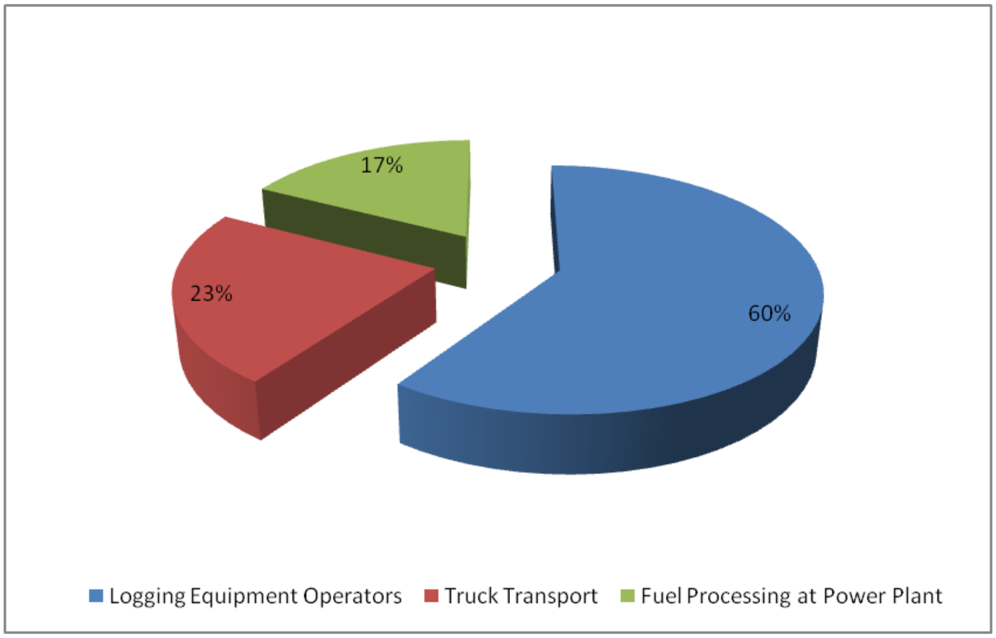
Figure 18: Shares of Total Direct Job Creation by Wind Occupational Categories



Source: Singh and Fehrs (2001)

The pie chart below (Figure 19) indicates that logging and other forestry-related equipment operators are the largest single area of occupational employment in the silvicultural biomass fuel supply, followed by truck transport and on-side fuel processing at the power plant. Unlike solar PV and wind, biomass facilities generate ongoing jobs in fuel supply during the operations phase.

Figure 19: Shares of Total Direct Job Creation by Silvicultural Biomass Fuel Supply



Source: Singh and Fehrs (2001)

3.1.2 Characterizing the Renewable Energy Industry Cluster

This section will identify the renewable energy industry cluster. A sectoral cluster is a group of businesses operating together within the same broad industry. According to Porter (1990), an industry cluster is a group of industries connected by specialized buyer-supplier relationships, or related by technologies or skills. Industry clusters can form around technology industries that benefit from extensive knowledge spillovers, or around traditional activities that may have formed around know-how but are now sustained by agglomeration economies (discussed below), or around unique or highly productive natural resources.

Table 15 displays renewable energy cluster relationships as designated by the North American Industry Classification System (NAICS). For example, the electric power generation, transmission, and distribution industry has a NAICS code of 2211. More specific types of electric power generation share the same code prefix followed by a unique numerical designation of its own (such as hydroelectric power generation: 221111).

Table 15: Industrial Sectors that are Elements of the Renewable Energy Industry Cluster, Operations Phase

Industry	NAICS Code	Notes
Electric Power Generation, Transmission, and Distribution	2211	
Electric Power Generation	22111	All technologies & resources
Hydroelectric Power Generation	221111	Includes wave, riverine, and tidal
Other Electric Power Generation	221119	Includes solar, wind, biomass, and geothermal, as well as low carbon fuels
Electric Power Transmission, Control, and Distribution	22112	Also includes industrial facilities that supply surplus energy onto the grid
Electric Bulk Power Transmission and Control	221121	
Electric Power Distribution	221122	
Steam and Air Conditioning Supply	221330	
Power and Communication Line and Related Structures Construction	237130	
Industrial Gas Manufacturing	324110	Includes low carbon fuels, hydrogen
Ethyl Alcohol Manufacturing	325193	
Heating Equipment, ex. Warm Air Furnaces	333414	
Professional, Scientific, and Technical Services	54	Includes research, engineering, manufacturing, and RE
Professional, Scientific, and Technical Services	541	Use of biofuels
Legal Services	5411	Permitting, energy policy.
Architectural, Engineering, and Related Services	5413	Research, development, design
Engineering Services	541330	
Geophysical Surveying & Mapping Services	541360	Site analysis
Surveying and Mapping (except Geophysical) Services	541370	
Solid Waste Combustors and Incinerators	562213	

Source: Dennis Mullins, Labor Market Consultant, Labor Market Information Division, State of California (2010)

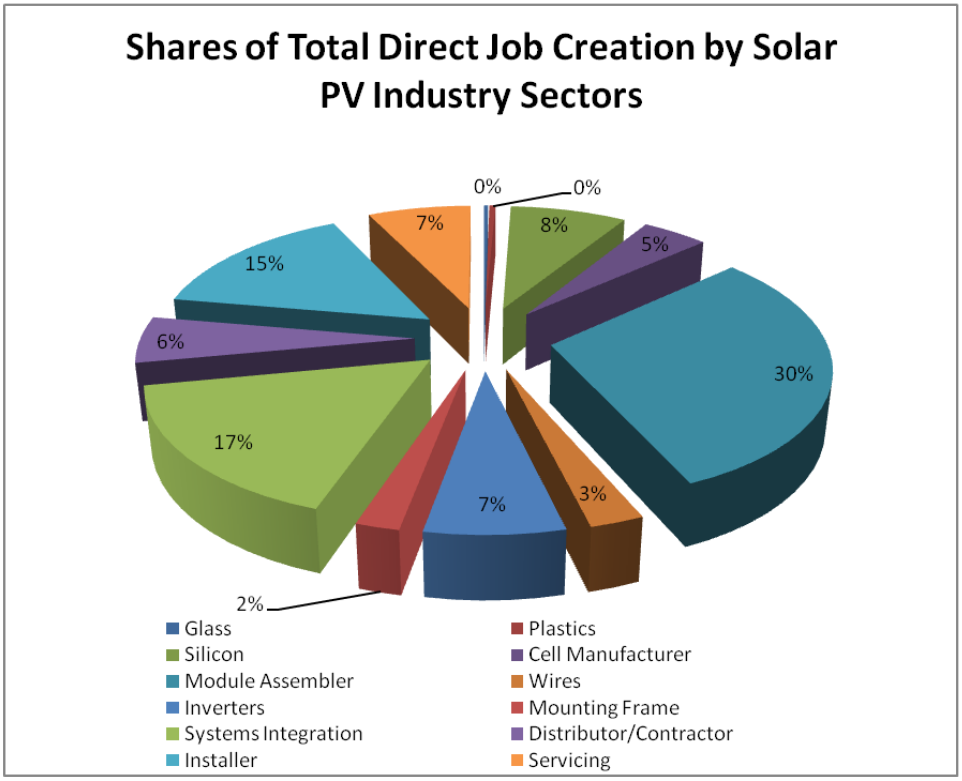
The analysis that follows begins by focusing on "vertical" industry cluster relationships. After that, "horizontal" industry cluster relationships with other "clean energy" industries are examined.

3.1.2.1 The Renewable Energy Industry Cluster: Vertical Industry Cluster Relationships

Vertical industry clusters reflect supply chain or market channel relationships. The analysis first focuses on upstream input supplier relationships with renewable energy generators, as downstream electricity transmission and distribution from renewable energy involves the same industry sectors as conventional electricity generation. This section begins with a summary of input supplier survey data generated by Singh and Fehrs (2001), and then turn to comparable input supplier data from the JEDI I-O model.

As seen in Figure 20, approximately 53 percent of employment in solar PV industry sectors is in specialized manufacturing and assembly of solar PV equipment. Another 40 percent of jobs are in mounting frames, system integration, distributor/contractors, and system installation sectors. Only about seven percent of jobs are in the servicing sector associated with ongoing operation of the solar PV systems.

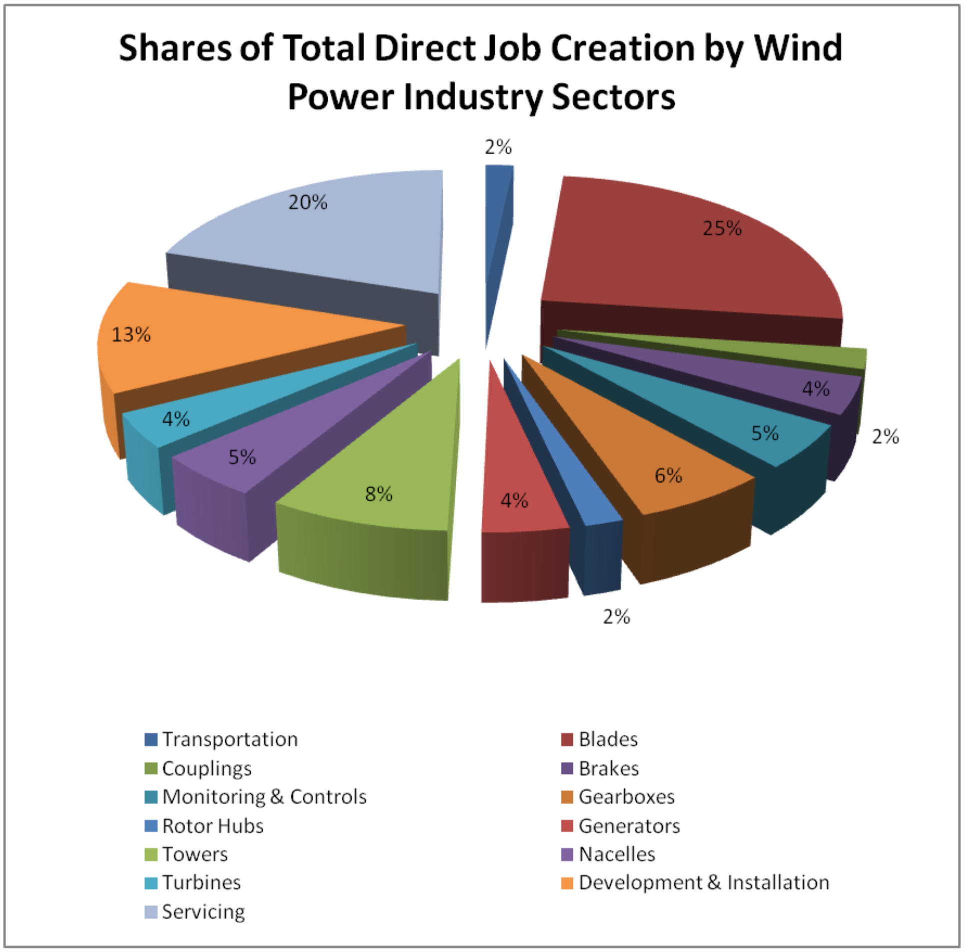
Figure 20: Shares of Total Direct Job Creation by Solar PV Industry Sectors



Source: Singh and Fehrs (2001)

In contrast with residential-scale solar PV, Figure 21 shows that an even larger share of total employment associated with utility-scale wind farms is in manufacturing industry sectors – approximately 66 percent. Of the remaining 34 percent (transportation, development and installation, and servicing), the largest area of employment is in servicing of the wind turbines during the operations phase.

Figure 21: Shares of Total Direct Job Creation by Wind Power Industry Sectors



Source: Singh and Fehrs (2001)

3.1.2.2 The Renewable Energy Industry Cluster: Horizontal Industry Cluster Relationships

This discussion now turns to a consideration of "horizontal" relationships that help define the renewable energy industry cluster. As Porter (1990) noted, industry clusters are not just a group of industries connected by specialized buyer-supplier relationships—industry clusters are also made up of related industries that utilize similar technologies or skills. Along these lines, the Pew Charitable Trusts (2009) characterize the following components of a "clean energy economy:"

- Clean Energy (27,672 jobs in California in 2007): These are the jobs, businesses, and investments that make up the renewable energy generation industry.
- Energy Efficiency (10,510 jobs in California in 2007): These are the jobs, businesses, and investments that help firms, households, organizations, and government to reduce energy consumption.
- Environmentally Friendly Production (13,666 jobs in California in 2007): Include jobs, businesses, and investments that seek to mitigate the harmful environmental impacts of existing products, and to develop and supply cleaner alternatives. Includes

transportation, manufacturing, construction, agriculture, cleaner conventional energy production, and materials.

- Conservation and Pollution Mitigation (64,799 jobs in California in 2007): Jobs, businesses, and investments in water and natural resource conservation, mitigation of pollution emissions, polluted site remediation, and recycling.

- Training and Support (8,743 jobs in California in 2007): Additional jobs, businesses, and investments that support the other four categories, including accountants, lawyers, researchers, trainers, and specialized vocational and other instructors that train workers for the clean energy economy.

According to the Pew Charitable Trust (2009), the "clean energy economy" concept was developed based on research and expert input, including an advisory panel for their report. They define the "clean energy economy" as generating new jobs, businesses, and investments while expanding clean energy production, increasing energy efficiency, reducing greenhouse gas emissions, waste and pollution, and conserving water and other natural resources.

To some extent these categories feature horizontal cluster relationships. In particular, the four primary categories likely share a skilled labor force that includes engineers, technicians, installers and repairers, equipment operators, distributors, and people in the construction trades, as well as specialized support personnel. In Humboldt County these horizontal cluster relationships likely includes engineering, natural resource, and planning consulting firms, construction equipment leasing firms, research organizations such as the Schatz Energy Research Center, College of the Redwoods and Humboldt State University, and various accounting and law firms.

3.1.2.3 The Renewable Energy Industry Cluster: Regional Economics

Marshall (1890) pioneered the concept of economies of agglomeration. These economies occur when firms in related industries spatially locate near each other (agglomerate). The economies of agglomeration derive from pecuniary externalities associated with scale and knowledge spillover effects. For example, large-scale agglomeration of firms within a particular industry fosters the creation of a larger pool of skilled local labor and specialized input suppliers. As Pedden (2006) notes, the lack of a skilled labor pool in rural areas can be an impediment to fostering a renewable energy industry cluster. In addition, newly created knowledge in one firm tends to spatially disseminate to other industry members in the agglomeration (Feldman and Audretsch, 1999). Knowledge spillovers offer an additional agglomeration economy, and serve as an important foundation to regional innovation dynamics (Karlsson and Manduchi, 2001). Locating within a geographic agglomeration can therefore confer a competitive advantage on individual firms, which helps explain how famous agglomerations such as Silicon Valley (technology) or Napa Valley (natural resources) develop and are sustained over time.

Few agglomerations are as obvious as Silicon Valley or Napa Valley, and therefore methods such as location quotient analysis are used to indicate possible agglomeration economies and competitive advantage for regional economies. From the standpoint of location quotients, California is among the top 7 states in terms of agglomeration in the clean energy sectors. In particular, data from the Pew Charitable Trusts (2009) indicates that California has a location quotient for employment in the "clean energy economy" equal to (0.71 percent/0.49 percent) or 1.45. A location quotient greater than 1.0 indicates a greater concentration of jobs in the region than in the overall economy. Therefore, there is an argument that California may possess agglomeration economies in the "clean energy economy" that may confer a degree of regional competitive advantage in that sector.

3.1.2.4 The Basis for a Renewable Energy Cluster in Humboldt County

Following Porter (1990), one can argue that Humboldt County's large renewable energy resource endowment provides it with the basis for the creation of a renewable energy industry cluster. In his comprehensive assessment of renewable energy resources in Humboldt County, Zoellick (2005) estimates that total local electricity generation via sustainable means could provide as much as 1500 MW of capacity and over 6000 GWh per year of electrical energy. This supply potential is over six times the county's current consumption rate. There is a very large unexploited wave energy resource, a large unexploited wind energy resource, and moderate and somewhat exploited woody biomass, riverine hydroelectric, and solar energy resources. Humboldt is also a center for energy research and innovation, involving organizations such as the Schatz Energy Research Center and the Redwood Coast Energy Authority.

3.1.3 Other Economic Development Considerations: Development and Ownership Structures

Different ownership and development structures have different economic development implications. While this issue is addressed in considerable detail elsewhere in the RESCO project, this section will briefly illustrate how the same project can generate substantially different economic development benefits depending on how it is owned and developed.

Consider two identical renewable energy projects that differ only in that one of them is locally owned, while the other is not. This issue has been most extensively studied in the context of wind energy. "Community wind" refers to a class of wind energy ownership structures. Projects are considered "community" projects when they are at least partially owned by individuals or businesses in the state and local area surrounding the wind power project. The opposite of community wind is an "absentee" project. In an absentee project, ownership is completely removed from the state and local community surrounding the facility. Thus, there is little or no ongoing direct financial benefit to state and local populations aside from salaries for local repair technicians, local property tax payments, and land lease payments (Lantz and Tegen, 2009).

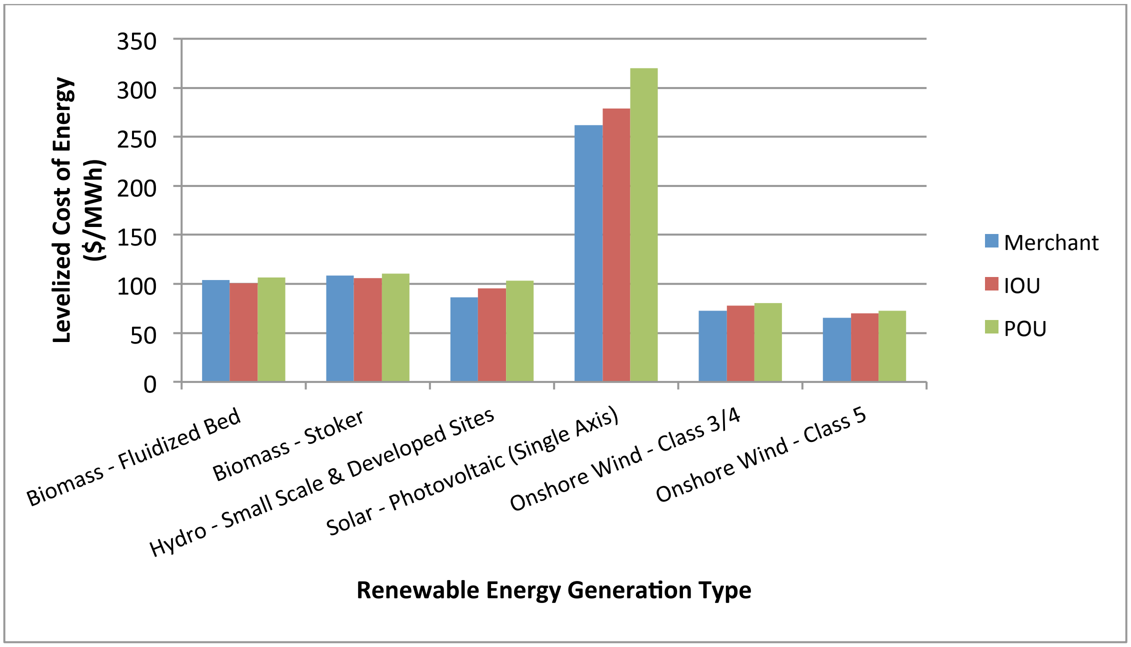
In their review of existing literature, Lantz and Tegen identify two primary conclusions. First, construction-period impacts are often thought to be comparable for both community-and absentee-owned facilities. Second, operations-period economic impacts are observed to be greater for community-owned projects. The majority of studies reviewed by Lantz and Tegen indicate that the range of increased operations-period impact is on the order of 1.5 to 3.4 times. Moreover, in new retrospective analysis of operating community wind projects, Lantz and Tegen find that total employment impacts from completed community wind projects are estimated to be on the order of four to six 1-year jobs per-MW during construction, and 0.3 to 0.6 long-term jobs per-MW during operations.

In addition, when comparing retrospective results of community wind to hypothetical average absentee projects, Lantz and Tegen find that construction-period employment impacts are 1.1 to 1.3 times higher and operations-period impacts are 1.1 to 2.8 times higher for community wind. The primary driver for the increased impact associated with community wind-type projects is the proprietor's income that is associated with local ownership. As a result, economic development policies that incentivize higher levels of local ownership are likely to result in increased economic development benefits to the local economy.

3.1.4 Market and Policy Interactions

A comparison of Energy Commission LCOE estimates for biomass, hydro, solar PV, and wind by ownership type can be seen in Figure 22. Solar PV clearly has the highest LCOE and the most variation due to ownership type, and wind power has the lowest levelized cost. In all cases where LCOE varies by ownership type, publicly owned utilities (POU) have the highest levelized cost. This is primarily because of favorable tax benefits for merchant and investor owned utility facilities that publicly owned utilities are unable to realize.

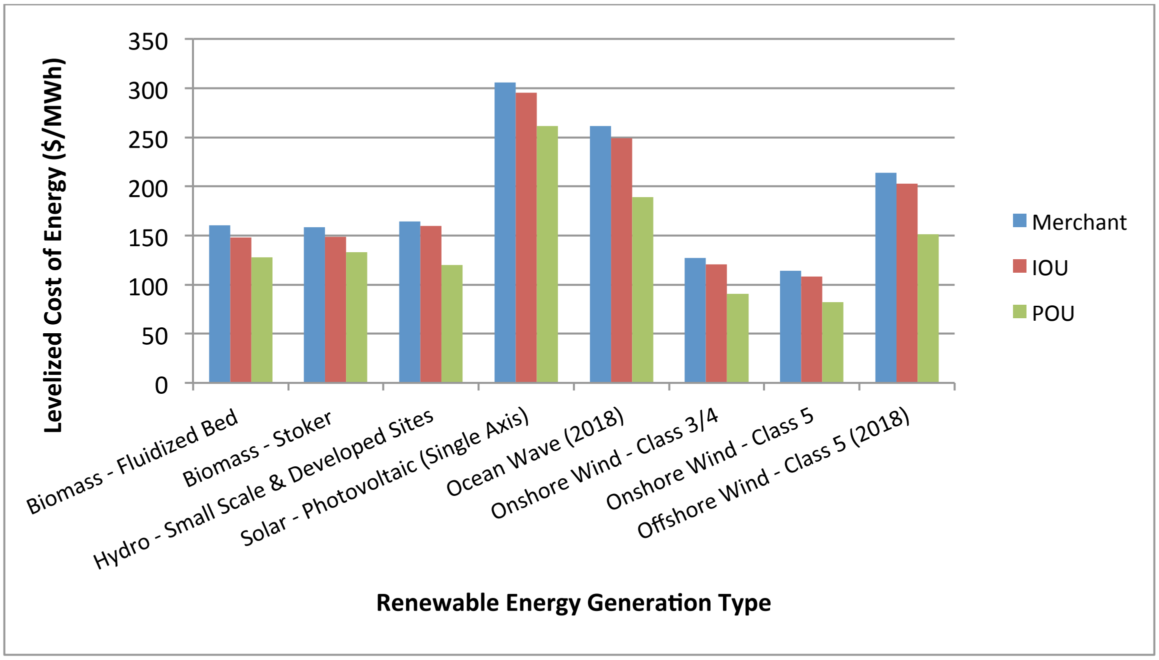
Figure 22: Levelized Cost of Energy Estimates by Generation and Ownership Type for Plants In-service in 2009



Source: Klein (2009)

Projecting to 2018, the Energy Commission estimates that the LCOE will be highest for merchant owned facilities for all technologies. This is a reversal from 2009 data in Figure 23 and is due to lower predicted tax benefits for all generation types in 2018. Solar PV still has the highest LCOE followed by wave and offshore wind.

Figure 23: Levelized Cost of Energy by Generation and Ownership Type for Plants In-service in 2018



Source: Klein (2009)

3.2 Economic Impact Assessment

The SERC research team developed highly specialized economic impact assessment models for each of the major renewable energy categories under analysis. The authors identified no other such studies done in northwestern California. One recent economic impact report for "upstate" California (the 20 northern California county region) by Gallo et al. (2009) used a much more crude modeling exercise in assessing the economic impacts of renewable energy development in northern California. In particular, Gallo et al. used existing IMPLAN (see Appendix C.1.1) sectors to approximate for different renewable energy categories. For example they treated residential-scale solar PV investments as if they were residential housing construction for the purpose of impact assessment. This approach fails to distinguish between solar PV and energy efficiency investments, for example, and fails completely in assessing utility-scale renewable energy projects using wave or wind or biomass resources. To their credit, Gallo et al. note that their results should be viewed with caution.

NREL has developed a suite of Jobs and Economic Development Impact assessment models for construction and operation of renewable energy power plants. The JEDI model is a type of input-output model. Both JEDI and I-O models are described in Appendix C of this economic report.

While some JEDI models were publicly released by NREL in time for us to customize them for the Humboldt County economy, the JEDI Biopower model (relevant to biomass combustion generators), the JEDI River Hydroelectric model, and the JEDI Marine Hydrokinetic model were not. Consequently the SERC economics team reverse engineered the available JEDI models and used that knowledge to develop SERC impact assessment models for biomass, riverine hydroelectric, wave energy, and energy efficiency. All of these SERC models incorporate JEDI industry aggregates and county multipliers that were prepared for the team by Marshall Goldberg of MSG & Associates (Goldberg is the JEDI model developer on contract with NREL). Moreover, development of the four SERC models included research of the authoritative renewable energy and energy efficiency literature, interviews of industry experts, and other documented sources of local economic conditions that relate to SERC impact assessment model components. To keep the analysis simple, the impact assessment models were built on the assumption of project finance deriving from outside of Humboldt County economy. The interested reader can turn to Appendix C.1.2 of this report for details on the SERC impact assessment models.

3.2.1 Economic Impacts Factors

The Regional Energy Planning Optimization Model model developed by the SERC research team is a powerful tool with the capacity to determine an optimal energy portfolio based on criteria such as minimizing GHG emissions or cost, or maximizing economic impacts. Dr. Hackett and the SERC team thus ran the JEDI and SERC impact assessment models to develop economic impact factor estimates on a per-megawatt basis for each generation technology. Individual impact factors were generated for earnings (2010$/MW), economic output (2010$/MW), and job creation (jobs/MW) during the construction and operating periods (Table 16). These factors were calculated using multiple illustrative runs of the JEDI and SERC economic impact assessment models for a range of realistic generation capacities for each technology. These impact factors are applicable to a range of capacity scales determined to be appropriate for the Humboldt County application.

Table 16: Economic Impact Factors

Impact Factor	SERC Biomass Model*	JEDI Solar PV Model	SERC River Hydro Model**	JEDI Wind Model***	SERC Wave Model*ŧ	JEDI Natural Gas Model*ŧŧ
Construction Phase						
Earnings ($/MW)	$97,705	$650,625	$171,659	$27,526	$38,910	$58,417
Economic Output ($/MW)	$493,783	$1,458,665	$1,178,586	$90,817	$263,520	$184,203
Jobs Created (Jobs/MW)	3.0	16.2	4.9	1.1	1.28	1.38
Operating Phase						
Annual Earnings ($/MW)	y = 54,843k + 46,782	$4,379	$56,236	$9,594	y = 15,063k + 6090	y = 18,362k + 3616.9
Annual Economic Output ($/MW)	y = 427,420k + 76,688	$6,335	$110,716	$24,950	y = 27031k + 20329	y = 80,951k + 10,973
Long Term Jobs Created (Jobs/MW)	y = 1.5377k + 0.931	0.1	1.2	0.2	y = 0.3006k + 0.1369	y = 0.3422k + 0.0882

* Note: "k" above is capacity factor. JEDI Models for Solar PV and Wind and the SERC river hydro model do not specify capacity factors.
** Note: The SERC river hydroelectric model is based on a number of small (1-2 MW) run-of-the-river systems on undeveloped sites that together sum to a given generation capacity. This scale was deemed appropriate given the resource availability in Humboldt and neighboring counties in the region.
*** Note: Impact factors for wind vary with total installed capacity. There is no simple mathematical expression that fully describes this relationship for the JEDI wind model. Consequently, per MW impact factors for the JEDI wind model are based on 50 MW of installed capacity (a total of 25 2-MW turbines).
ŧ Note: Of all the models, the wave model impact estimates are the least certain due to the immaturity of the technology.
ŧŧ Note: It is very unlikely that new natural gas generation capacity will be installed in the near future. Construction phase impacts are reported here merely as a comparison to the renewable technologies.

Source: SERC staff analysis

The biomass impact factors per MW above were obtained from ten runs of the SERC biomass model. Biomass power plants are typically 10-50 MW and costs are assumed to be approximately constant per MW over that small range. Ten runs were performed because while economic impacts are constant with respect to capacity, operations-phase impacts are dependent on capacity factor. Capacity factor was varied from 10 percent to 100 percent in 10 percent intervals, and a functional form was derived by fitting a curve to the resulting operations phase impacts.

Solar PV economic impact factors per MW were derived from three development scenarios (1 MW, 5 MW, and 10 MW of DC nameplate capacity) in the JEDI solar PV model. The research team estimate that each of these scenarios will consist of approximately 60 percent residential retrofits, 5 percent new residential, 15 percent small commercial, 20 percent large commercial, and 0 percent utility scale installations. Residential systems are assumed to be 3 kW; small commercial systems are assumed to be 25 kW; and large commercial systems are assumed to be 100 kW. Economic impacts were divided by the respective generation capacity to determine economic output and job creation on a per-MW basis. The SERC research team found no economies of scale effects in the JEDI solar PV model. This was expected because total installed solar PV capacity is made up of a number of small, facility-scale installations. Capacity factor is not included in the JEDI solar PV model because it has negligible effect on O&M costs and thus does not influence economic impacts.

The hydroelectric data above were obtained from one run of the SERC river hydro model customized for Humboldt County. This model is based on the assumption that a number of small (1-2 MW) model hydroelectric projects would be developed for a total of 20-40 MW of nameplate generating capacity. As the total generating capacity is comprised of a number of small projects appropriate to the Humboldt County application, economic impact factors are constant per MW, as the model scales up or down by varying the number of small facilities. Annual O&M cost in the model is assumed to be $123.69 per kW of nameplate capacity. This figure was derived from 2009 O&M costs for the 2 MW Ruth Lake Hydroelectric Generating Station provided by the Humboldt Bay Municipal Water District. As a result, capacity factor has no effect on economic impacts in this model. Interviews with regional hydroelectric operators indicate that approximately one full time equivalent worker would be needed for O&M at a 2 MW facility regardless of capacity factor.

Impact factors per MW for wind were obtained from fifteen runs (40 MW-300 MW, 20 MW intervals) of the JEDI Wind model customized for Humboldt County. The relatively large number of test runs occurred because of unaccountable discontinuities in model outputs per MW as nameplate capacity was varied. Further analysis by the SERC research team identified an error in the JEDI wind model, which was subsequently fixed by NREL. One additional run was performed at 50 MW as this is the size of the proposed Shell North American wind project on Bear River Ridge in Humboldt County. Total generation capacity is comprised of a number of 2 MW turbines. Economic impact values were divided by the respective generation capacity to determine economic output and job creation on a per MW basis. Some economies of scale are seen in both the construction and operating phases, but these effects cannot be adequately characterized by a simple mathematical function. Impact factors are thus reported based on the size of the proposed 50 MW project. The JEDI model for wind does not specify a capacity factor. All results are based on installed nameplate capacity.

Impact factors per MW for wave energy were obtained from 10 illustrative runs (ranging from 10 percent to 100 percent capacity factor in 10 percent intervals) of the SERC wave model for new wave power development. The SERC wave model has constant impacts per MW of installed nameplate capacity during the construction period, while impacts vary with capacity factor during the operating period.

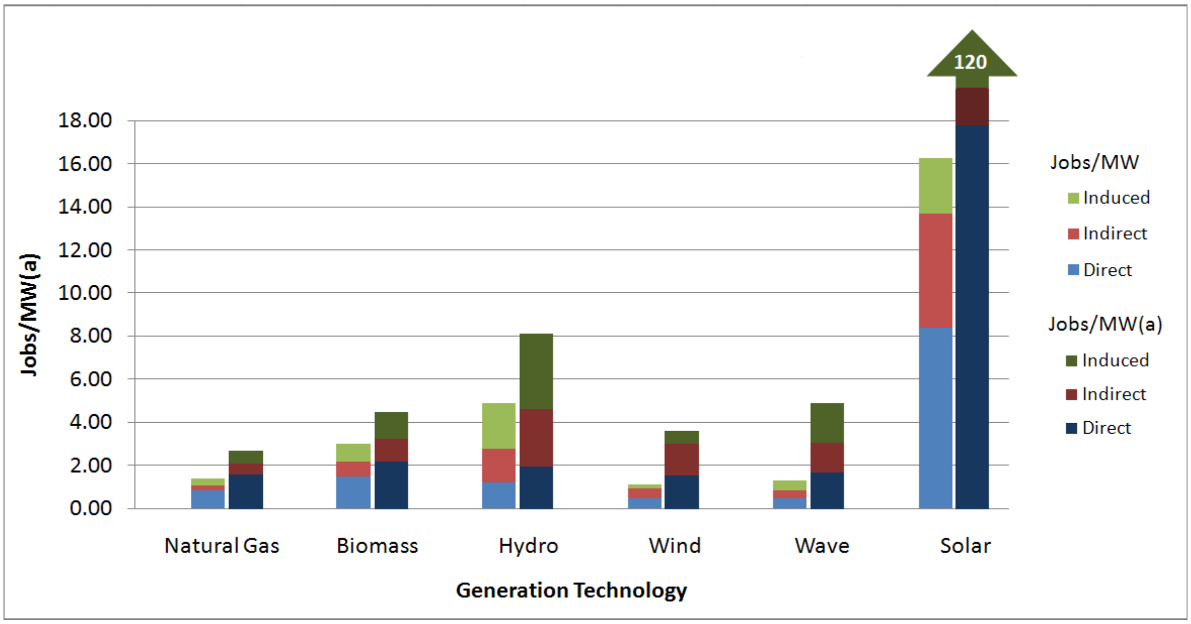
To compare the economic impacts of renewable energy, ten runs (ranging from 10 percent to 100 percent capacity factor in 10 percent intervals) of the JEDI model for natural gas were performed that approximate the impacts of the new 163 MW Humboldt Bay Generating Station. Economic impacts were assessed on a per MW basis as with the renewable technologies. It should be noted that the JEDI natural gas model was designed for a conventional combined cycle steam turbine generator, while the Humboldt Bay Generating Station utilizes a modular generating system with 10 Wärtsilä internal combustion engines, each with 16.3 MW of generating capacity. In order to modify the JEDI Natural Gas model to be applicable to the

Humboldt Bay Generating Station system, the SERC team solicited engineering and cost data from PG&E, the owner and operator of the Humboldt Bay Generating Station. These data include Humboldt Bay Generating Station construction costs, fixed and variable O&M costs, and heat rate for the new plant, which serve as custom inputs to the model. A personal correspondence with JEDI natural gas model developer Marshall Goldberg of MRG & Associates on 6/28/10 stated that these results should approximate economic impacts with reasonable accuracy.

Figure 24 and Figure 25 below show graphical representations of job creation impact factors from Table 16. To normalize for the intermittancy of renewables, job impacts/MW were also derated by capacity factor (jobs/MWa).[25] The derated impacts provide a more fair comparison across generation technologies with widely varied capacity factors based on the amount of power they are likely to contribute to the grid. For instance, because solar PV operates at a lower capacity factor than natural gas, more installed capacity would have to be constructed, operated, and maintained in order to satify 1 MW of additional demand with solar. Additionally, total job creation impacts/MW for each technology are divided into direct, indirect, and induced impacts (see Appendix C.1 for a descripion of impact types).
Figure 24 indicates that natural gas generation creates the fewest jobs per MWa during the construction phase while solar PV creates the most. The large number of jobs resulting from PV installation is due to the fact that 1 MW of installed capacity is comprised of many small scale residential and commercial installations, which is labor and capital intensive. Additionally, the Humboldt County solar resource is relatively poor, so when derated by capacity factor (13.5 percent), job creation per megawatt of anticipated solar PV power production is quite high. More generally, all of the renewable technolgies have higher construction phase job creation impacts than natural gas on a per MWa basis.

25 Figure 8 and Figure 9 assume capacity factors of 51 percent for natural gas generation, 67 percent for biomass, 26 percent for wave power, 60 percent for hydroelectric, 30 percent for wind, and 13.5 percent for solar PV.

Figure 24: Construction Phase Job Creation per MW(a)



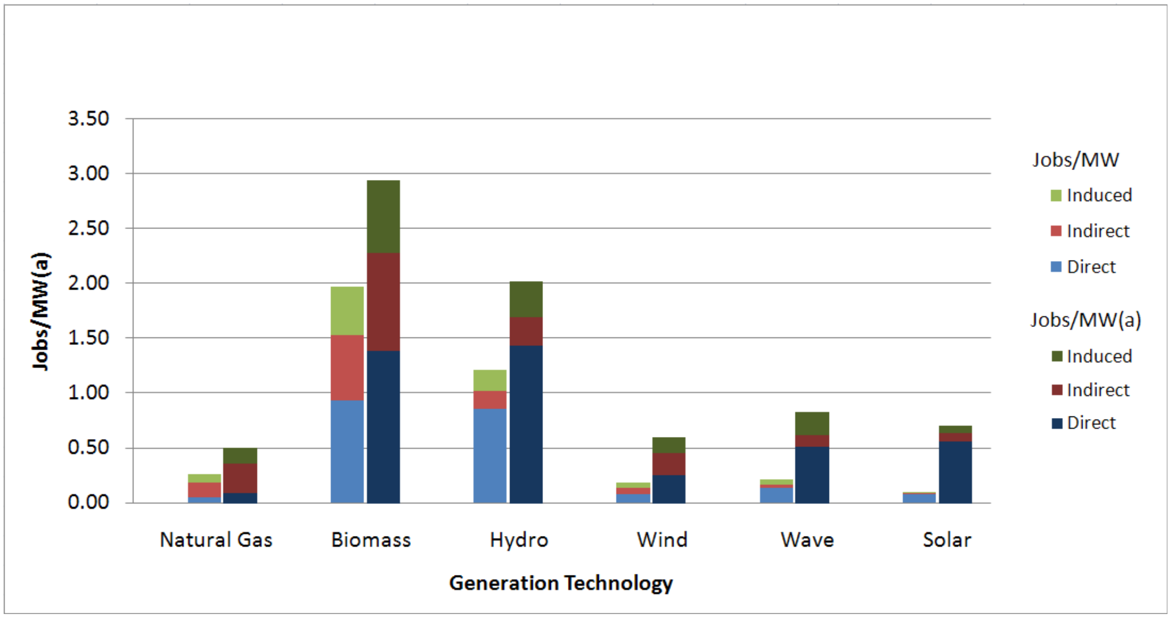
Source: SERC staff analysis

Solar PV, wind, and wave energy create the fewest long term jobs per MW during the operating phase, primarily because they are not subject to fuel costs and require relatively low maintenance. When derated by capacity factor however, all of the renewable technologies have a higher job creation impact (per MWa), than natural gas fired generation. Biomass power production creates the most jobs during the operations phase. Approximately half of these job creation impacts are plant workers (direct jobs) and about a third are in the local fuel supply chain (indirect jobs).[26] Because of the prolific timber industry in and around Humboldt County, biomass benefits from a higher proportion of indirect impacts than any of the other technologies. Natural gas generation also benefits from some local fuel supply chain impacts, though not nearly as substantial as biomass.[27]

26 Personal communications with local biomass plant operators suggested that they employ approximately 1 worker per MW of installed capacity.

27 13 percent of the natural gas used at the Humboldt Bay Generating Station is assumed to come from local sources. This figure was calculated based on 2008 Humboldt County gas field production as a fraction of 2008 countywide natural gas use from the Energy Commission. Interviews with local biomass plant managers indicated that approximately 75 percent of their fuel is sourced locally.

Figure 25: Operations Phase Job Creation per MW(a)



Source: SERC staff analysis

None of the economic impact models employed in this study calculate net impacts. However, by using a suite of models for the entire portfolio of energy options, net job creation can easily be inferred. Because all renewable technologies have higher job creation impacts/MWa than natural gas generation during the construction and operations phases, any combination of renewable technologies used to offset natrual gas will have positive net impacts.

Diagrams showing economic output and earnings impact factors are not included here, but these impacts can be compared by examining Table 16 above. In general, construction and operations phase economic output and earnings impacts among generation technologies exhibit a similar relationship as seen for job creation (per MWa). Solar PV and wind, however, have lower economic output impacts during the operations phase.

3.2.2 Economic Impacts From Energy Efficiency

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. Due to 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 17). While the efficiency model 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.

Table 17: 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	5.3
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

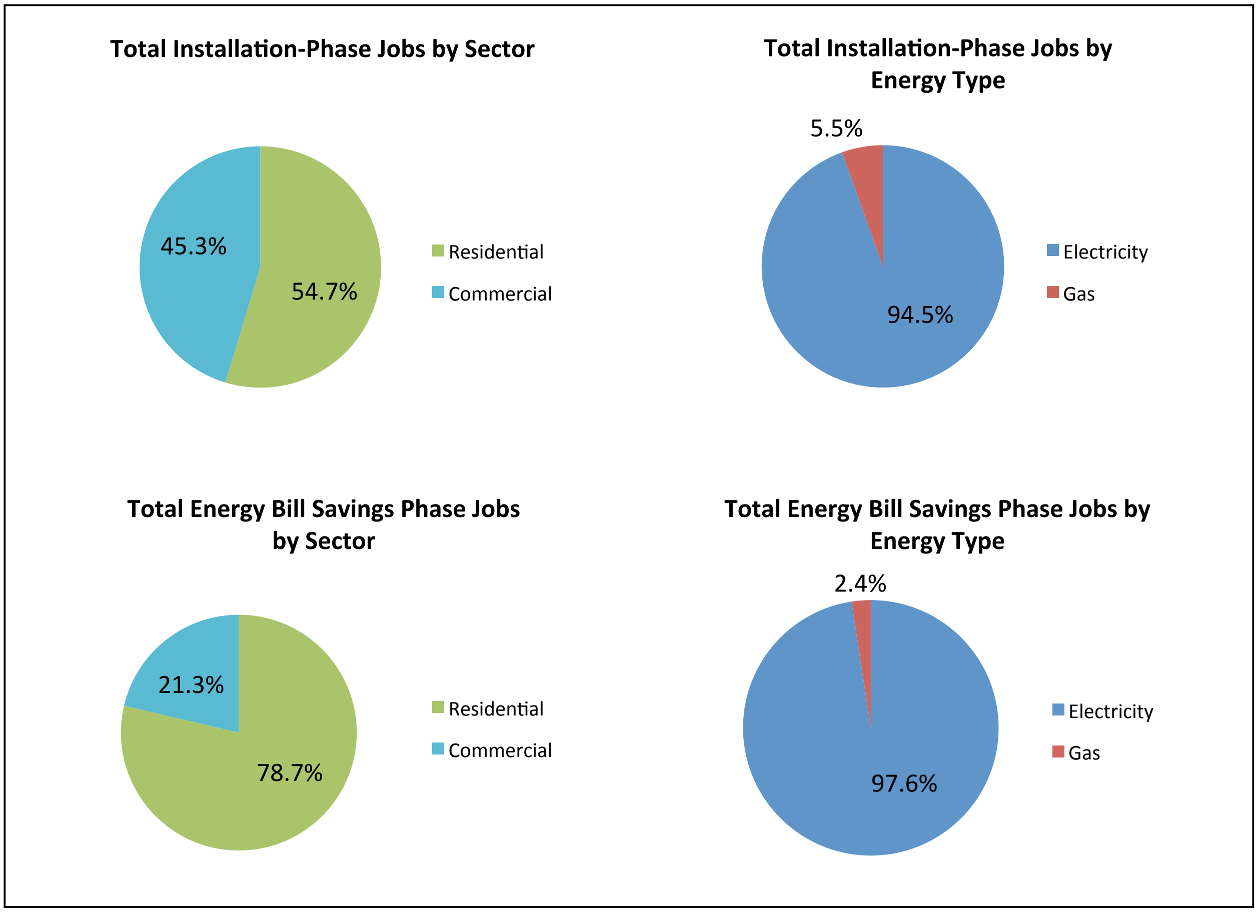
Source: SERC staff analysis

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 mean job creation is anticipated to 15.6 full time equivalent (FTE) jobs/yr. This amounts to approximately 0.37 full time equivalent jobs/GWh, which is consistent with the meta-reviews by Kammen et al.(2006) and Wei et al. (2009) (Table 14).[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 (SWEEP, 2002; 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. The model results indicate that energy bill savings creates nearly twice the number of jobs as installation, driven by mean net present value savings of $3.7 million annually.

As demonstrated in section 2.2, 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 17 are distributed between the residential and commercial sectors and between electricity and natural gas.

28 Total present value job creation from electrical energy efficiency programs is estimated at 303 jobs over the 20-year forecasting period, with an associated energy savings of 830 GWh.

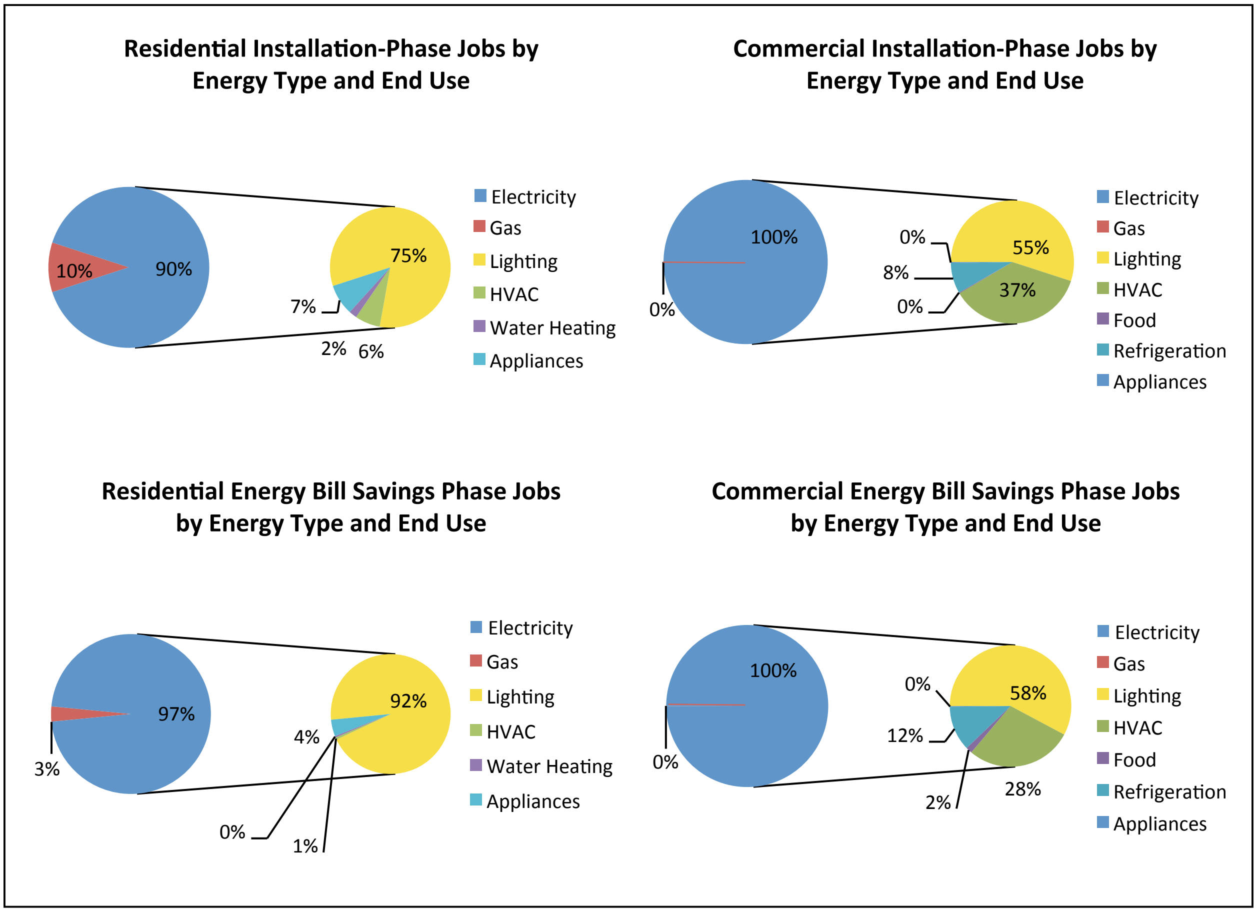
Figure 26: Full Incentive Level Energy Efficiency Job Impact Distribution by Sector



Source: SERC staff analysis

Looking at the residential and commercial sectors more closely, the majority of job creation impacts are, as expected, from lighting upgrades (Figure 27). This is especially true in the residential sector, where 75 percent of installation job creation and 92percent 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.

Figure 27: Full Incentive Level Energy Efficiency Job Impact Distribution by End Use



Source: SERC staff analysis

3.2.3 Economic Impacts of Preferred Scenario Generation Portfolios

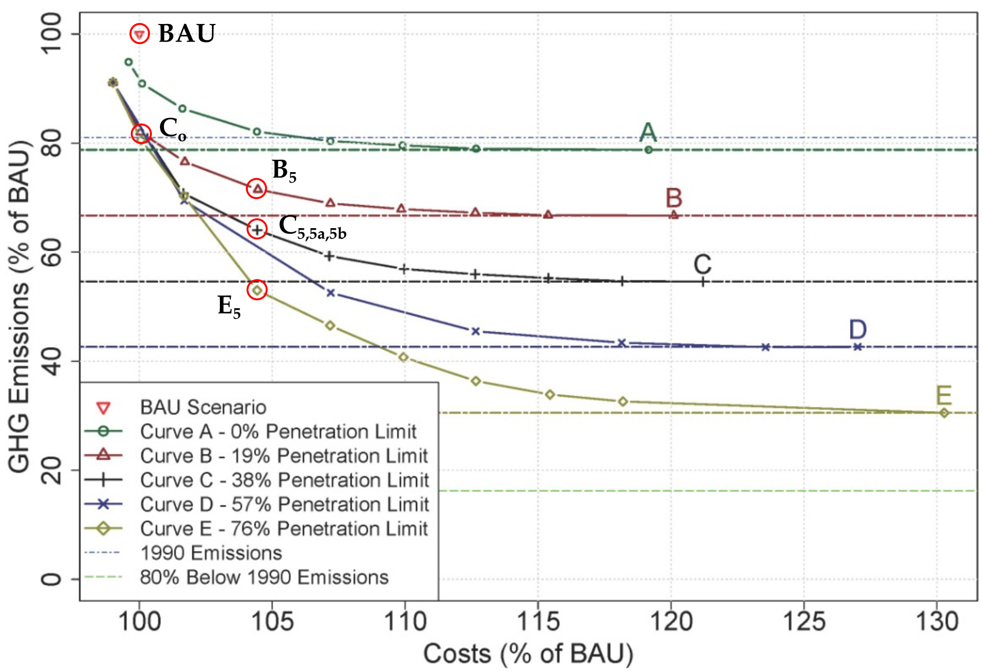
Using cost assumptions detailed in this report, the SERC Regional Energy Planning Optimization Model was employed to identify optimal portfolios of energy options that satisfy a range of design criteria and constraints.[29] Figure 28 displays five optimality curves that demonstrate the tradeoff between GHG reductions (y-axis) and cost (x-axis) under various levels of electricity demand. Curves A-E represent increasing penetrations of heat pumps and electric vehicles (i.e. a larger fraction of Humboldt County heating and transportation needs are satisfied with electricity rather than petroleum fuels). Circled points on the optimality curves are the preferred scenarios identified by the SERC engineering team.[30] These points were chosen because they represent a wide range of GHG reduction potential at a "reasonable" increase in cost (5 percent or less). The JEDI and SERC models were used to perform a full economic impact analysis for each of the preferred scenario portfolios. It is important to realize that the criteria

29 The optimization model is based on electricity, heating, and transportation demand projections for 2030. The economic impact assessment models used in this analysis are built around input-output multipliers from 2008. This means that the economic impact estimates presented here assume that the local economy has a similar structure in 2030 as in 2008.

30 For a full description of the Regional Energy Sector Optimization Model and the preferred scenarios, please refer to the Humboldt RESCO technical engineering report.

associated with any given point on the optimality curves may be satisfied by a number of different energy portfolios. The optimization model employs a differential evolution algorithm in which a swarm of particles converge on an optimal solution. Each particle surrounding the solution represents an option that satisfies the design criteria with a variation in the installed capacity for each generation technology. While total costs and GHG reductions are approximately the same for each particle, tradeoffs between technologies can result in a range of local economic impacts. This point is illustrated by exploring the impacts of three variations of the same point on optimality curve C (C_5, C_{5a}, and C_{5b}). Ultimately, the costs, GHG reduction benefits, and economic impacts of each preferred scenario will be used to inform the RESCO strategic plan.

Figure 28: Optimality Curves and Preferred Scenarios



Source: SERC staff analysis

In deriving the economic impacts of full energy portfolios that include efficiency measures to reduce demand, it is important to note that in each case this analysis takes into account reduced conventional energy generation at the HBGS to arrive at a net impact result. In section 3.2.1 this report demonstrated that all of the renewable technologies have larger construction and operations phase impacts per MWa than the natural gas fired generation they replace. Additionally, each of the preferred-scenario portfolios includes some amount of electrical load building caused by shifting some fossil fuel-based heating and transportation demand onto the electric grid.

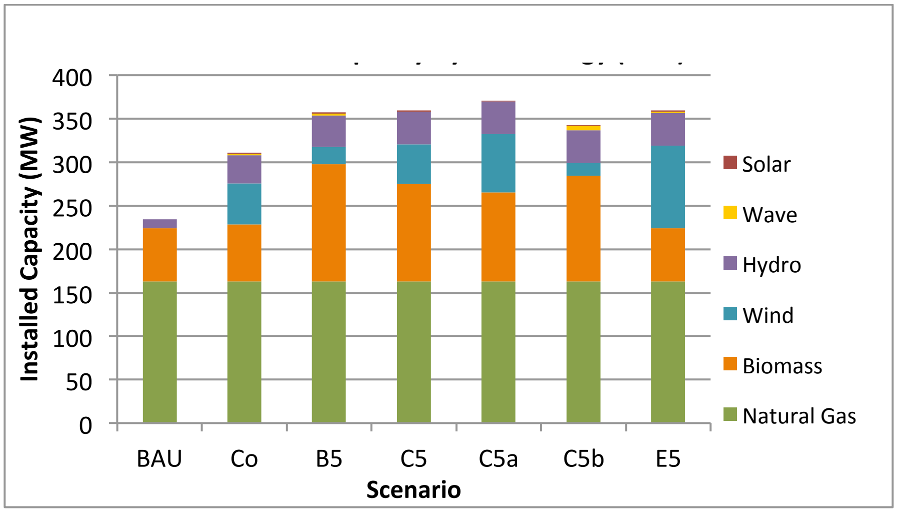
Thus any of the preferred scenarios are expected to have net positive economic impacts over BAU.[31] The magnitude of the net impacts, however, will be dependent upon the composition of

31 While we do not address the economic impacts of higher penetrations of electric vehicles or heat pumps, we expect that a transition to electrified heating and transportation would result in net positive economic impacts. A substantial penetration of heat pumps and electric vehicles would require infrastructure development (e.g., installing charging stations and distribution system upgrades) and would result in fuel cost savings (electric vehicles cost less to operate than conventional vehicles), and this would create local jobs and economic stimulus.

each energy portfolio and the overall percentage of electricity supplied by renewables. Therefore, before comparing the economic impacts of each scenario, it is important to understand the constituent elements of each portfolio.

Figure 29 shows the total installed nameplate capacity of each generation technology for each scenario. The BAU scenario is comprised of 163 MW of natural gas-fired power, 60.8 MW of biomass-fired power, and 10.4 MW of small hydro capacity. Each of the preferred scenarios includes BAU capacity plus additional renewable energy build-out consisting primarily of biomass, wind, and small hydro. As mentioned previously, scenario C_5 has two variations; C_{5a} is a low biomass/high wind variant, and C_{5b} is a high biomass/low wind variant.

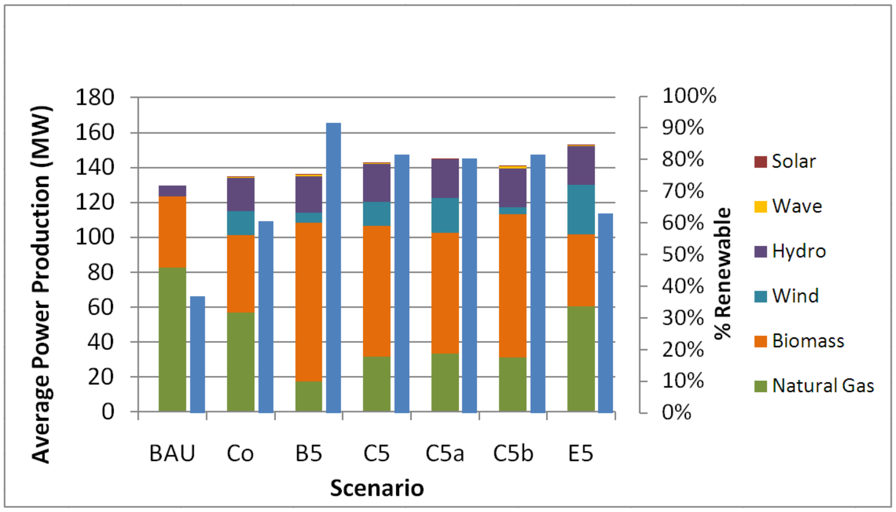
Figure 29: Preferred Scenario Installed Capacity by Technology



Source: SERC staff analysis

The installed capacities in Figure 29 were multiplied by expected capacity factors to depict the average power contribution of each technology to the overall grid mix (Figure 30, stacked columns). The percentage of renewables in each scenario is also shown in Figure 30 (blue column adjacent to stacked columns read on right vertical axis). The projection for BAU in 2030 is 37 percent renewable electricity with a grid mix comprised of natural gas, biomass, and hydroelectric energy. Two of the scenarios, C_o and E_5, do not meet the RESCO objective of 75 percent renewables. Scenario C_o is 61 percent renewable and is included in the analysis because it achieves a 20 percent reduction in carbon emissions at no cost increase over BAU. E_5 is 63 percent renewable and is included to show that there could potentially be a tradeoff between achieving 75 percent renewables and achieving larger carbon reductions at the same cost. Scenarios B5, C5, C5a, and C5b all achieve between 80 percent and 92 percent renewable electricity, most of which is generated with biomass.

Figure 30: Preferred Scenario Average Power Production by Technology



Source: SERC staff analysis

Table 18 reveals that all of the preferred scenarios have substantial positive net economic impacts over BAU. Scenario B_5 has the greatest economic impacts in both the construction and operations phases while C_o has the least. It might be expected that scenario E_5 would have the greatest economic impacts, as a significant portion of the county's heating and transportation energy demand is shifted to the electricity sector. This shift would increase electricity demand and would therefore increase economic activity in the electricity sector. Instead scenario E_5 has the second lowest overall impacts. Looking back to Figure 30 above, scenario E_5 also has the second lowest percentage of renewable energy serving Humboldt County load. This is no coincidence. Recall that on a per MWa basis, all of the renewable energy generation technologies have higher economic impacts per MW than natural gas generation. It therefore follows that a higher percentage of renewables should loosely translate into higher economic impacts.[32] Indeed, this is the pattern that is observed in all impact categories. Scenario B_5 has the highest penetration of renewables and the greatest economic impacts. During the construction phase, a total of 461 full time equivalent jobs are expected to be created with associated earnings of $15 million and an economic output of $78.5 million. If it is assumed that the construction of these projects is distributed evenly between 2010 and 2030, then approximately 23 full time equivalent jobs would be created annually. During the operations phase, 168 full time equivalent jobs are anticipated each year, along with annual earnings of $1.9 million and annual economic output of $26.2 million.

32 The term "loosely" used here as there could be many other factors at play. For instance, in scenario E5, there is a tradeoff between investing in renewable energy and investing in electric vehicles and heat pumps. Investing in electric vehicles and heat pumps would have their own economic impacts, which could be substantial.

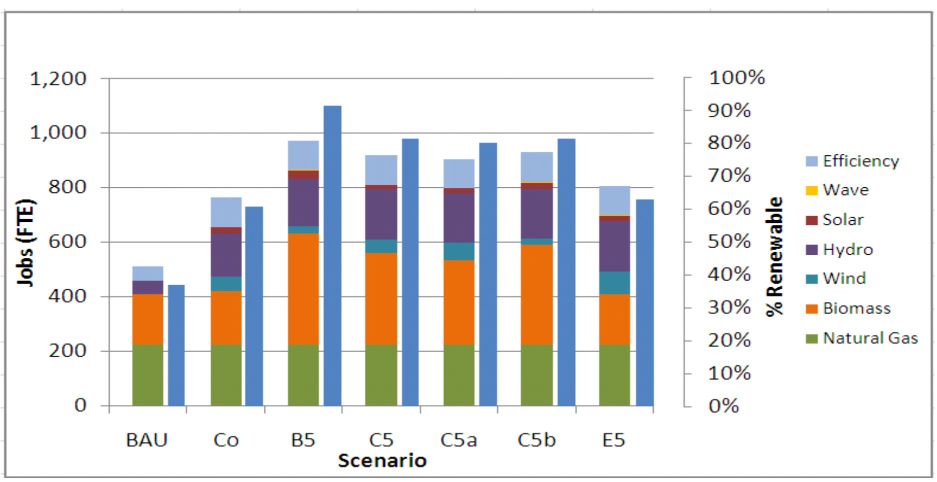
Table 18: Net Economic Impacts by Scenario[33]

	Scenario	Construction Phase Impacts Jobs (FTE)	Earnings (millions of 2010$)	Output (millions of 2010$)	Operations Phase Impacts Annual Jobs (FTE)	Earnings (millions of 2010$/yr)	Output (millions of 2010$/yr)
Total Impacts	**BAU**	510	$19.6	$80.9	180	$7.9	$32.5
Net Impacts	**Co**	253	$9.2	$45.0	46	$1.9	$4.2
	B5	461	$15.0	$78.5	168	$6.9	$26.2
	C5	408	$14.2	$72.2	133	$5.6	$19.6
	C5a	396	$13.8	$69.6	118	$4.9	$16.8
	C5b	419	$14.7	$76.3	149	$6.2	$22.6
	E5	295	$10.5	$52.4	51	$2.2	$4.5

Source: SERC staff analysis

As earnings and output follow the same general pattern as job creation in both the construction and operations phases, the remainder of this discussion will focus on job creation.[34] Figure 31 and Figure 32 demonstrate how job creation is distributed across technologies in the construction phase and operations phases, respectively. In the construction phase, total job creation varies nearly proportionately with the percentage of renewables in the energy generation portfolio. The magnitude of the impacts from each renewable energy category is largely a function of installed capacity and the labor intensity of the construction process. In the operations phase, the same general trend is observed, but a much larger proportion of the impacts result from the biomass industry. As discussed before, this is because the local biomass fuel supply chain creates a large number of local indirect jobs. The two variations on scenario C_5 illustrate this point. C_{5a} is the low biomass/high wind variation and C_{5b} is the high biomass/low wind variation. Scenario C_{5b} is anticipated to create 31 additional jobs each year relative to C_{5a}.

Figure 31: Preferred Scenario Construction Phase Job Creation by Technology

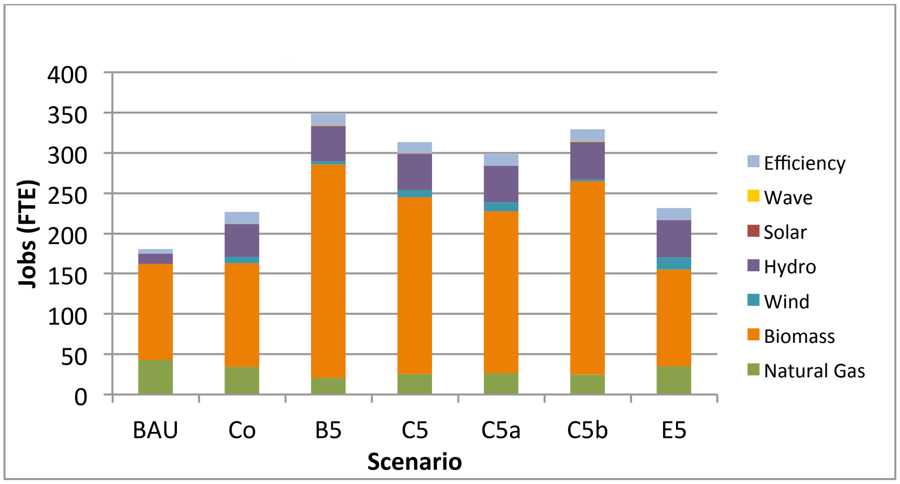


Source: SERC staff analysis

33 All impacts are in present value terms.

34 The full results of this analysis, including the breakdown of direct, indirect, and induced impacts, can be found in Appendix C.1.4.

Figure 32: Preferred Scenario Operations Phase Job Creation by Technology



Source: SERC staff analysis

CHAPTER 4: Conclusions

This report has described the costs and economic impacts associated with a plan to move Humboldt County toward a cleaner and more sustainable energy future. Elements of this analysis include categories of renewable energy for which appropriate resources exist within the county, different levels of energy efficiency investments, and shifting part of fossil fuel-based heating and transportation energy onto the electrical grid. The results of this economic analysis were used by SERC researchers as inputs in running the optimization model that identified optimal renewable energy generation and energy efficiency scenarios for Humboldt County. We have shown that those scenarios can serve Humboldt County load with a majority of locally generated renewable energy at moderate cost relative to BAU.

This analysis shows that these clean energy scenarios have positive net economic impacts in terms of county jobs and income. Furthermore, many of these scenarios feature substantial greenhouse-gas reductions with modest increases in cost. Biomass, hydro, and to a lesser extent wind play a central role in the preferred scenarios identified by the SERC research team. The analysis also reveals the cost-effective nature of most energy efficiency measures, particularly associated with residential lighting measures. While energy efficiency is cost-effective, the overall scale of potential energy savings is relatively small in comparison to the more prominent types of renewable energy generation. Our energy efficiency analysis is somewhat novel in that it also provides estimates of the regional economic impact from investment in energy efficiency measures.

Biomass-fired energy generation plays a prominent role in the preferred scenarios identified by the SERC research team. Humboldt County has a substantial renewable forest biomass resource. Existing supplies of biomass fuel usually derive from timber harvest and mill waste, and potential new supplies could result from coordination with fuel reduction efforts in rural areas subject to wildfire risk. Jobs associated with gathering, transporting, and processing biomass fuel results in biomass energy having proportionately larger economic impacts in the operations phase relative to other forms of electricity generation evaluated in this report. As a result, electricity derived from biomass combustion has the potential to produce beneficial economic impacts in the form of jobs and income to the local economy. The economic benefits of having a high proportion of biomass-fired energy generation must be weighed against the need for a diverse energy portfolio, concerns about environmental impacts associated with deforestation, and the specific economic development goals of Humboldt County.

As the focus shifts from study to implementation, the economic analysis tools developed here will be useful to planners, developers, and policy makers as they seek to understand the economic impacts associated with specific renewable energy project proposals or energy efficiency incentive programs. Estimates of jobs and income from project development must be weighed along with other social and environmental benefits and costs as communities move towards a clean energy future. For example, as Humboldt County moves forward with its energy development goals, it will be important to begin specific project-level analysis. Several small projects are already underway such as a micro-hydroelectric project on the Yurok Indian Reservation and the Humboldt Waste Management Authority's bio-digester and landfill gas projects. Economic impact assessments of these and other projects would highlight their specific economic development potential for the county.

Looking beyond Humboldt County, the approaches we used to develop our impact assessment models can serve as a starting point for studies in other counties. It should also be noted that our modeling approach could be scaled up to multi-county regions or even states. In fact, larger geographical scales tend to have more coherent regional economies that feature fewer leakages and therefore have larger economic impacts for a given expenditure in construction or operation of a generating facility. In contrast, impact assessment becomes increasingly more problematic for smaller sub-county regions that lack quantitative input-output economic data.

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APPENDIX A:
Acronyms and Definitions

Acronyms

BAU	Business as usual
BEV	Battery electric vehicle
CO_2e	Carbon dioxide equivalent
CPUC	California Public Utilities Commission
DEER	Database for Energy Efficiency Resources
EV	Electric vehicle
FTE	Full time equivalent
GDP	Gross domestic product
GHG	Greenhouse gas
GW(h)	Gigawatt (hour)
HBGS	Humboldt Bay Generating Station
HVAC	Heating, ventilation, and air conditioning
IMPLAN	Impact analysis for planning
I-O	Input-output
IOU	Investor owned utility
JEDI	Jobs and Economic Development Impact
kW(h)	Kilowatt (hour)
LCC	Life cycle cost
LCOE	Levelized cost of energy
MW(h)	Megawatt (hour)
NAICS	North American Industrial Classification System
NREL	National Renewable Energy Laboratory
NPV	Net present value
O&M	Operations and maintenance
PG&E	Pacific Gas and Electric Company
PHEV	Plug-in hybrid electric vehicle
POU	Publicly owned utility
PV	Photovoltaic
RCEA	Redwood Coast Energy Authority
REPOP	Regional Energy Planning Optimization Model
RESCO	Renewable Energy for Secure Communities
SERC	Schatz Energy Research Center
T&D	Transmission and Distribution
WACC	Weighted average cost of capital

Definitions

CAPACITY FACTOR – The ratio of the actual output of a power plant over a period of time and its output if it had operated at full nameplate capacity over the same time period.

FULL TIME EQUIVALENT – One worker employed full time for the equivalent of one year.

INSTANT CAPITAL COST - A standard economic method of estimating the up-front cost of a project. Instant capital cost is based on the assumption that the project was completed overnight, and therefore no interest-based financial carrying costs on construction loans are incurred in the construction period.

LEVELIZED COST OF ENERGY – The constant price per unit of energy that causes the investment to just break even: earn a present discounted value equal to zero.

LIFE-CYCLE COST - An estimate of the total cost (in present value terms) of a constructing, installing, operating, and maintaining a power plant or other facility over its useful life.

MARGINAL COST OF SUPPLY - The incremental cost borne by the electricity generator when an additional unit of electricity (e.g., one MWh) is supplied to serve load.

Scenario Definitions

Throughout the analysis presented in this report, several comparisons are made to "business as usual." The transportation analysis also refers to a "medium renewables penetration" scenario and a "high renewables penetration" scenario. These scenarios are described in Table 19 below.

Table 19: Estimated Retail Cost of Electricity and Power Plant Emissions Factor Based on Different Electricity Generation Scenarios

Year	Generation Scenario	Generation Scenario Description	Retail Cost ($/MWh)	Generation Emissions (tCO_2e/MWh)
2010	Business as usual	• Natural Gas: 63.5% • Biomass: 31.6% • Hydroelectric: 4.8% • Photovoltaic: 0.1%	122.4	0.269
2010	Medium renewables penetration	• Wind: 50 MW • Wave: 15 MW • Biomass: +20 MW • Hydroelectric: +10 MW • PV: +0.5 MW • EV penetration: 20% • Heat Pump penetration: 20% • Efficiency penetration: 20%	123.5	0.152
2010	High renewables penetration	• Wind: 125 MW • Wave: 30 MW • Biomass: +70 MW • Hydroelectric: +13 MW • PV: +1 MW • EV penetration: 38% • Heat Pump penetration: 38% • Efficiency penetration: 100% • Storage: 15 MW	128.5	0.035
2020	Business as usual	Similar to 2010, Business as usual	121.6	0.275
2020	Medium renewables penetration	Similar to 2010, Medium renewables penetration	122.7	0.162
2020	High renewables penetration	Similar to 2010, High renewables penetration	128.0	0.043
2030	Business as usual	Similar to 2010, Business as usual	120.9	0.281
2030	Medium renewables penetration	Similar to 2010, Medium renewables penetration	123.3	0.178
2030	High renewables penetration	Similar to 2010, High renewables penetration	127.4	0.050

Source: SERC staff analysis

APPENDIX B: Cost Analysis - Definitions, Methods, and Additional Results

B.1 Life-cycle Cost Analysis

Life-cycle cost is an estimate of the total cost (in present value terms) of a constructing, installing, operating, and maintaining a power plant or other facility over its useful life (DOE, 2005). Life-cycle cost is a useful metric for comparing the overall costs of multiple technologies. The life-cycle cost calculation is relatively simple, as shown in Figure 33 below, though estimating costs properly can be challenging.

Figure 33: Life-cycle Cost Calculation

> Lifecycle cost (LCC) * = Up-front cost + operations and maintenance cost + fuel and other variable input costs + anticipated repair or replacement cost – salvage value.
>
> *where all dollar amounts are converted to present values by discounting

Source: SERC

The necessary cost data for the RESCO life-cycle cost analyses were collected from multiple authoritative sources including the Energy Commission, the National Renewable Energy Lab (NREL), Energy and Environmental Economics (E3), and the Electric Power Research Institute (EPRI). Specific life-cycle cost calculations are dependent upon the particular portfolio renewable energy generation categories and capacity factors. Consequently, in this report only life-cycle cost components are described. All available and relevant data from these sources was collected and compiled in a spreadsheet to provide RESCO researchers with ready access to technology specific costs categorized by the life-cycle cost components listed above. These cost components were collected for biomass-fired electricity plants, wind power farms, wave power farms, solar PV installations, and hydroelectric installations.

B.2 Levelized Cost of Energy (LCOE)

The levelized cost of energy (LCOE) is a useful measure that estimates the cost per unit of energy generated by a given energy technology over its useful life. It is a natural extension of the life-cycle cost 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. The LCOE for a project may be modified depending on the type of ownership model being used to develop the energy project. In general LCOE can be thought of as the total life-cycle cost divided by the total life-cycle quantity of energy. Life-cycle energy production is discounted at the same rate as life-cycle cost. In cases where public utilities are able to employ (cost plus rate of return) pricing, life-cycle cost can be replaced by the life-cycle revenue requirement implied by cost-recovery pricing (Gilman et al. 2008).

Figure 34: The Levelized Cost of Energy (LCOE) Calculation

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

Source: Gilman et al. (2008)

The equation above (Figure 34) is for a commercial or residential project where no third party financing is used; therefore, the required rate of return for the investors is not included. 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. The summation in the denominator begins at $n = 1$, which is the first year that the project produces energy. The numerator summation starts at $n = 0$ to include first costs in the calculation, i.e., C_0 is equivalent to the project's capital costs.

Humboldt County estimates for LCOE vary based on the installed capacity and capacity factor of each technology in each scenario. The LCOE values used in this analysis are based on a "middle of the road" scenario for new renewable energy development in the county (Table 20) and the costs specified in section B.4 below.

Table 20: Assumptions for LCOE Analysis

Technology	Capacity (MW)	Assumed Capacity Factor	LCOE ($/MWh)
Natural gas	163	50.80%	$90.30
Solar PV	1	13.54%	$685.10
Wind	15	26.77%	$82.45
Wave	15	22.62%	$134.87
Hydro	7.5	58.85%	$90.00
Biomass	15	67.49%	$116.02

Source: SERC staff analysis

A real discount rate of 7 percent was used in this analysis. This was based on the authoritative *Comparative Costs Of California Central Station Electricity Generation* report by the CEC (2010), which uses a developer's weighted average cost of capital (WACC) as the discount rate (Table 21:).

Table 21: Weighted Average Cost of Capital Estimates (Discount Rate)

	Average Case			
	% Equity	**Equity Rate**	**Debt Rate**	**WACC**
Merchant Fossil	60.0%	14.47%	7.49%	10.46%
Merchant Alternatives	40.0%	14.47%	7.49%	8.45%
Default IOU	52.0%	11.85%	5.40%	7.70%
Default POU	0.0%	0.0%	4.67%	4.67%
	High Case			
	% Equity	**Equity Rate**	**Debt Rate**	**WACC**
Merchant Fossil	80.0%	18.00%	10.00%	15.59%
Merchant Alternatives	60.0%	18.00%	10.00%	13.17%
Default IOU	55.0%	15.00%	9.00%	10.65%
Default POU	0.0%	0.0%	7.00%	7.00%
	Low Case			
	% Equity	**Equity Rate**	**Debt Rate**	**WACC**
Merchant Fossil	40.0%	14.47%	7.49%	8.45%
Merchant Alternatives	35.0%	14.00%	6.00%	7.21%
Default IOU	50.0%	10.00%	6.00%	6.78%
Default POU	0.0%	0.0%	4.00%	4.00%

Source: CEC (2010)

The ownership structures for renewable energy development in Humboldt County are still uncertain, but they are likely to either be merchant or IOU facilities. The average of merchant fossil, merchant alternative, and default IOU WACC in the average case results in a nominal discount rate of 8.87 percent. This analysis assumes that inflation rate in the near to long term will be ~1 percent to 3 percent, ultimately giving an estimated 7 percent real discount rate.

Additionally, Energy and Environmental Economics (E3, 2008) recommends an 8 percent to 10.5 percent nominal discount rate for independent power producers investing in renewable energy projects. A 7 percent real discount is within this range after adjusting 1-3 percent for inflation. A 7 percent real discount rate is also recommended by NREL in the recent *Cost and Performance Assumptions for Modeling Electricity Generation Technologies* report (NREL, 2011).

B.3 Marginal Cost Of Supply

The marginal cost of supply is the incremental cost borne by the electricity generator when an additional unit of electricity (e.g., one MWh) is supplied to serve load. The Energy Information Administration's electricity market module, a component of its national energy modeling system, provides guidance on calculating the marginal cost of supply (EIA, 1999). The marginal cost of supply in the national energy modeling system is equal to the sum of marginal fuel costs and marginal O&M costs. The marginal cost of supply for a particular power plant with an operating history can be calculated from past performance data. The marginal cost of supply in this report is calculated from technology-specific fuel and operating costs that derive from authoritative sources (e.g., Energy Commission, NREL) and that are customized to Humboldt County operating conditions and installed technologies. In the case of the HBGS, marginal O&M costs 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 Energy Information Administration for natural gas sold to California electric power generators. 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. 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).

B.4 RESCO Analysis Electricity Generation Cost Assumptions

B.4.1 Cost Assumptions by Technology

Table 22 through Table 27 provide justification for the electricity generation cost assumptions used in this analysis.

Table 22: Natural Gas Cost Assumptions

Natural Gas		
Cost Category	**Cost**	**Source**
Plant Construction Cost ($/KW)	$1,450	PG&E Application for Certification of the Humboldt Bay Repowering Project (CEC, 2006)
Cost of Fuel ($/mmbtu)	$6.67	Linear regression of natural gas prices sold to electricity generation consumers (EIA, 2010). While there is considerable year to year variability in prices, a general upward trend is observed in the years 1997-2009. 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. 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 (~ -$0.03).
Fixed Operations and Maintenance Cost ($/kW)	$27.00	PG&E Application for Certification of the Humboldt Bay Repowering Project (CEC, 2006)
Variable Operations and Maintenance Cost ($/MWh)	$10.00	PG&E Application for Certification of the Humboldt Bay Repowering Project (CEC, 2006)
Heat rate for Wärtsilä engine (kJ/kWh)	7,616	Wärtsilä website http://www.wartsila.com
Lifetime	25+	Wärtsilä website http://www.wartsila.com

Table 23: Wave Energy Cost Assumptions

Wave		
Cost Category	**Cost**	**Source**
Plant Construction Cost ($/KW)	$2,587	KEMA (2009) CEC study: KEMA, inc. 2009. Renewable Energy Cost of Generation Update. CEC 500-2009-084. Sacramento, CA: California Energy Commission.
Fixed O&M Costs ($/kW)	$36	KEMA (2009) CEC study: KEMA, inc. 2009. Renewable Energy Cost of Generation Update. CEC 500-2009-084. Sacramento, CA: California Energy Commission.
Variable O&M Costs ($/MWh)	$12	KEMA (2009) CEC study: KEMA, inc. 2009. Renewable Energy Cost of Generation Update. CEC 500-2009-084. Sacramento, CA: California Energy Commission.
Lifetime	25	

Table 24: Solar PV Cost Assumptions

Solar PV		
Cost Category	**Cost**	**Source**
Base Installed System Cost ($/KWDC)	$9,090	NREL JEDI model for Solar PV default cost values for 1MW of total capacity. Assumes 20 percent large commercial (2 100kw systems), 15 percent small commercial (6 25kw systems), 5 percent residential new construction (17 3kw systems), and 60 percent residential retrofit (200 3 kw systems). The cost at left is a weighted average cost for the systems specified.
Annual Direct Operations and Maintenance Cost ($/kW)	$10.70	NREL JEDI model for Solar PV default cost values for 1MW of total capacity. Assumes 20 percent large commercial (2 100kw systems), 15 percent small commercial (6 25kw systems), 5 percent residential new construction (17 3kw systems), and 60 percent residential retrofit (200 3 kw systems). The cost at left is a weighted average cost for the systems specified.
Lifetime	20+	
*While JEDI default values above are at the high end of the range of costs identified by the literature review, these costs are reasonable for the small, discrete, primarily residential installations expected in Humboldt County. ** Resulting levelized costs are also well outside the range presented in the literature. This is due to a combination of the high capital costs for discrete installations and the low capacity factor (13 percent) resultant from Humboldt County's marginal solar resource.		

Table 25: Wind Energy Cost Assumptions

Wind		
Cost Category	**Cost**	**Source**
Installed Project Cost ($/KW)	$2,107	NREL JEDI model for wind default cost value.
Operations and Maintenance Cost ($/kW)	$24.38	NREL JEDI model for wind default cost values for a 50MW project - varies from $20.93/kw (for projects of 200MW or more) to $26.53 (for projects of 20MW or less)
Lifetime	20-25	

Table 26: Biomass Energy Cost Assumptions

Biomass		
Cost Category	**Cost**	**Source**
Plant Construction Cost ($/KW)	$3,447	Average of various recent authoritative studies circa 2008-10 (CEC, 2010; Lazard, 2008; E3, 2008).
Fixed O&M Costs ($/kW)	$160.10	Value drawn from Klein (2009) CEC Central Station study for 38 MW stoker boiler system.
Variable O&M Costs (not including fuel) ($/MWh)	$6.98	Value drawn from Klein (2009) CEC Central Station study for 38 MW stoker boiler system.
Fuel Cost ($/BDT)	$32.00	Personal communication with local biomass power plant operators resulted in estimates of ~$32/Bone Dry Ton (BDT). This is believed to be the most accurate estimate for Humboldt County and is used here as the default price.
Burn Rate (BDT/MWh)	1.1	Personal communication with mangers of Humboldt County biomass power plants indicated that they use more than 1 BDT/MWh. The reason for this is that they often utilize biomass from inventory that has become somewhat damp due to Humboldt County's humid and wet climate. This communication resulted in a burn rate estimate of 1.1 BDT/MWh.
Lifetime	20-30	
* While the capital and O&M costs presented here are consistent with the authoritative literature, the low fuel costs results in a LCOE that is lower than the range presented in the literature. Personal communications are considered to be the most accurate representations of local biomass energy costs.		

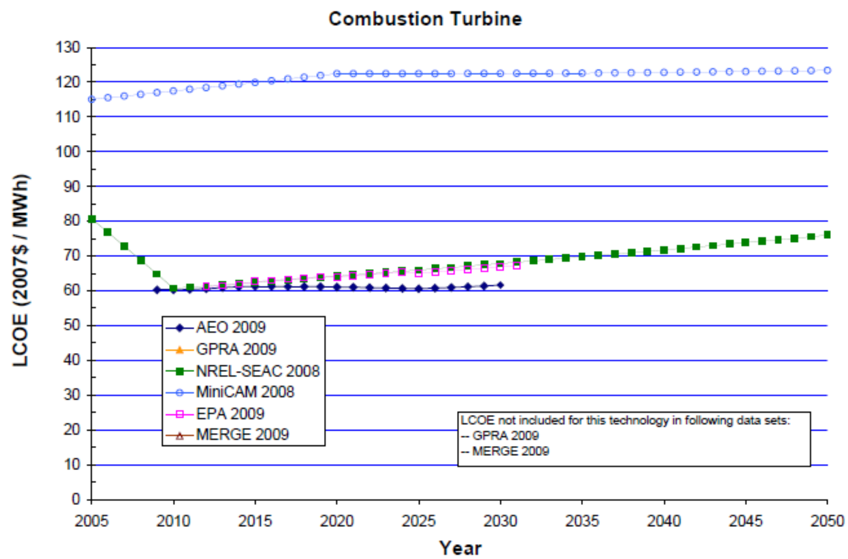
Table 27: Small Hydro Cost Assumptions

Small Hydro (1-2MW)		
Cost Category	**Cost**	**Source**
Plant Construction Cost ($/KW)	$4,500	Oregon Office of Energy (2002) and RETScreen Natural Resources Canada (2004) suggest ~ $4,000/kW of capacity. An Interview with Ross Burgess (operator of 1.625 MW micro hydro run of the river system with several diversions in Humboldt County) on 16 June 2010 confirmed that ~ $4,000 / kW was representative of his costs. KEMA (2009) gives an estimate for a 1 MW facility in $2010 of $3,938.44/kW. Given these estimates, the default value is set to $4,500/kw. This value is near the high end of the range of literature estimates, but those estimates are for developed sites without power. This cost estimate assumes that a realistic cost for developed sites is ~$4000/kW and the extra $500/kW will cover site development.
O&M Costs ($/kW)	$123.69	Value drawn from O&M cost data provided by the Humboldt Bay Municipal Water District for its 2 MW Ruth Lake "Matthew's Arm" facility.
Lifetime	30-50	
* These costs, along with a relatively high capacity factor (58 percent) result in levelized costs somewhat lower than the range presented in the literature. The authoritative literature notes that costs for small hydro facilities are highly location specific. Based on interviews with local operators, the research team considers these costs to be accurate.		

B.4.2 Learning Curve Effects by Technology

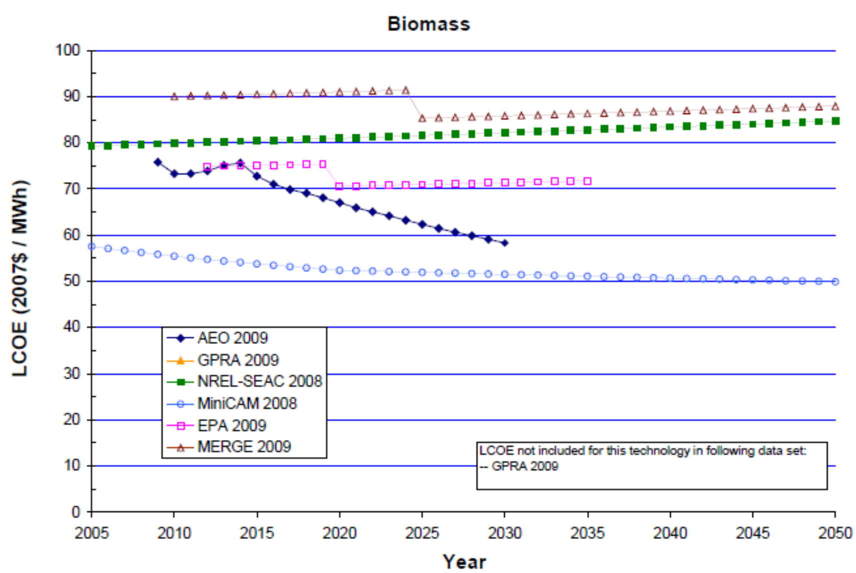
NREL performed an extensive review of cost and performance assumptions for modeling electricity generation technologies (NREL, 2011). The following plots show a summary of this review for each technology (Figure 35 through Figure 38). Due to the variation in learning curve effects in the literature, the possibility of future bottlenecks in non-substitutable inputs, and project investments throughout the study period, the RESCO analysis assumes static real technology and fuel costs.

Figure 35: Learning Curve Cost Projections – Combustion Turbine



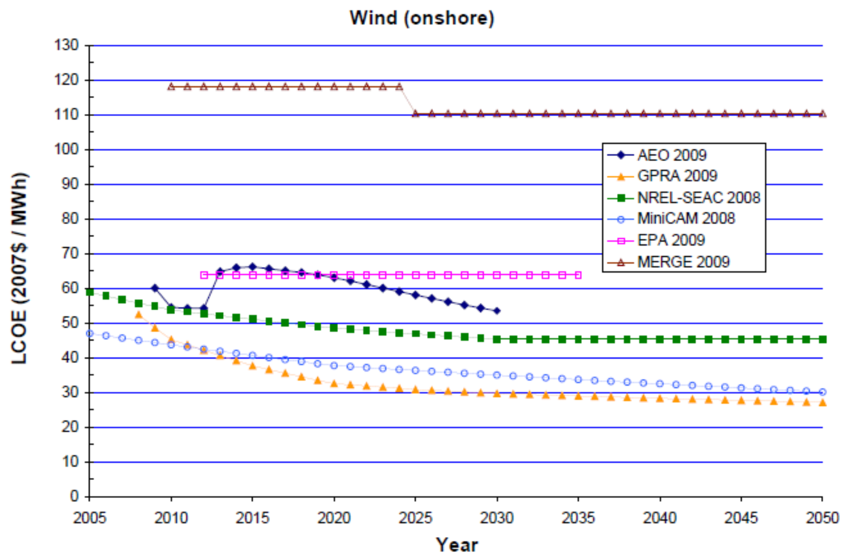
Source: NREL (2011)

Figure 36: Learning Curve Cost Projections - Biomass



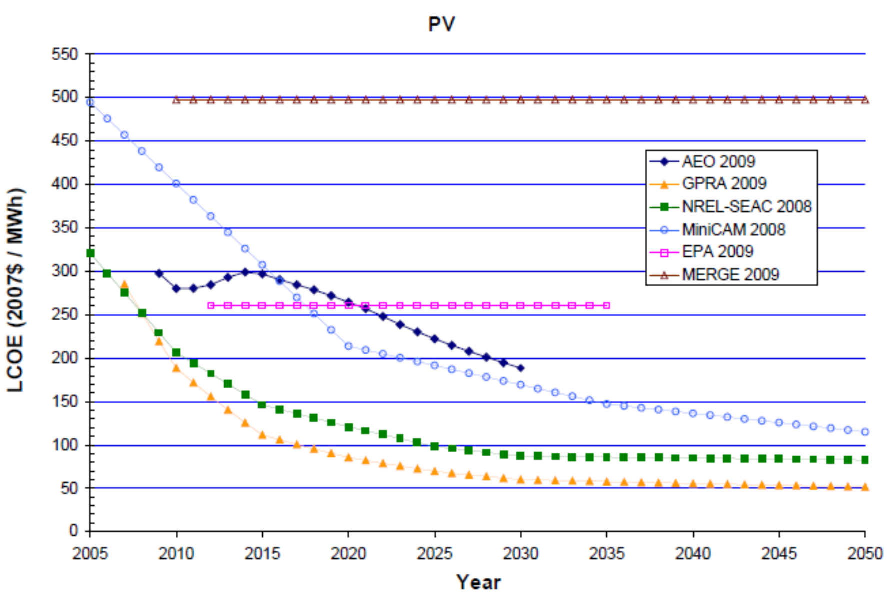
Source: NREL (2011)

Figure 37: Learning Curve Cost Projections – Onshore Wind



Source: NREL (2011)

Figure 38: Learning Curve Cost Projections – Solar PV



Source: NREL (2011)

B.5 Avoided Generation and Damage Costs

Investing in renewable energy and energy efficiency will allow Humboldt County to meet its energy needs without generating additional electricity at the new natural gas fired Humboldt Bay Generating Station. The cost of this avoided generation is equal to the difference between the levelized cost of renewable energy or energy efficiency and the LCOE of the HBGS. As this is a long-run, prospective analysis, displaced generation is assumed to have a cost equal to the full LCOE rather than the levelized variable cost (or marginal cost of supply). The LCOE for the HBGS used in this analysis is $90/MWh. This cost is based on the BAU scenario for 2030 used in the Regional Energy Planning Optimization Model developed by the SERC research team. It includes the marginal cost of dispatch described above, capital costs and fixed O&M costs from the Application for Certification for the Humboldt Bay Repowering Project (CEC, 2006), a capacity factor of 50 percent, and the heat rate of the Wärtsilä internal combustion engines (7616 KJ/kWh).

Avoided climate change mitigation costs and avoided external damage costs were calculated based on the avoided generation cost. The avoided generation cost ($/MWh) was divided by custom emissions factors (lb CO_2e or criteria pollutant/kWh) for the internal combustion engines at the HBGS to ultimately obtain the price per avoided ton of pollutant.[35]

35 GHG and criteria pollutant emissions factors were calculated based on emissions data provided by Wärtsilä (2010) and from PG&E's *Application for Certification for the Humboldt Bay Repowering Project* (CEC, 2006).

B.6 Transportation Cost Analysis

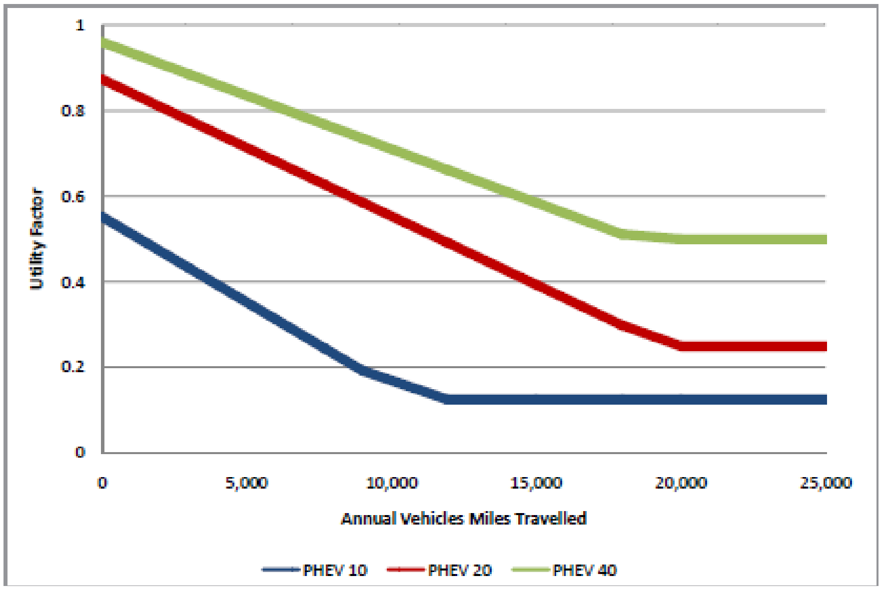
Table 28: Drivetrain Components of Vehicles Considered for Adoption

Component / Vehicle Name	Gross Vehicle Weight (kg)	ICE Power (kW)	MC Peak Power (kW)	MC Cont. Power (kW)	MC2/Gen Peak Power (kW)	MC2/Gen Cont. Power (kW)
Conventional	2111	135	0	0	2	2
PHEV10	2201	80	76	38	45	30
PHEV40	2321	70	108	54	68.25	68.25
EREV30	2325	75	109	54.5	73.2	73.2
EREV40	2355	75	109	54.5	73.2	73.2
BEV100	2185	0	103	51.5	0	0
Component / Vehicle Name	**BOL ESS Total Nominal Energy (kWh)**	**EOL ESS Total Nominal Energy (kWh)**	**BOL ESS Power-to-Energy Ratio (1/hr)**	**EOL ESS Power-to-Energy Ratio (1/hr)**	**Degree-of-Elec. (%)**	**CD Useable Energy *(kWh)***
Conventional	0.0	0.0	0.0	0.0	0%	0.00
PHEV10	5.0	4.0	15.5	15.5	41%	2.30
PHEV40	16.9	13.5	4.4	4.4	44%	8.96
EREV30	12.4	9.9	15.4	15.4	59%	6.42
EREV40	16.3	13.1	12.1	12.1	59%	8.64
BEV100	33.2	26.6	5.8	8.3	100%	18.6

Notes
ICE: internal combustion engine
MC: electric machine/motor
MC2: electric machine/motor #2
Gen: generator
BOL: beginning of life
EOL: end of life
ESS: energy storage system
CD: charge-depleting

Source: Santini et al. (2010)

Figure 39: PHEV Utility Factor as a Function of All-electric Range and Annual Vehicle Miles Travelled, assuming Nightly Charging.



Source: EPRI (2007)

Table 29: Lifecycle Benefit / Cost Analysis Parameter Assumptions

Category	Parameter	Units	Value	Source
Battery	Battery Average Lifetime	yr	10	Jungers, 2011
	Battery Efficiency (Round-trip)	%	90	Jungers, 2011
	Battery Warranty	mi	100000	Chevrolet; Nissan, 2011
	Battery Warranty	yr	8	Chevrolet; Nissan, 2011
Charging	Charger Efficiency (Level 1)	%	95	Jungers, 2011
	Charger Efficiency (Level 2)	%	85	Jungers, 2011
	Charge Rate (Level 1) (110-120V, 15-20A)	kW	1.44	INL (DOE), 2008
	Charge Rate (Level 2) (240V, 40A)	kW	3.3	INL (DOE), 2008
	Charge Rate (Level 3) (480V, 80A)	kW	38.4	INL (DOE), 2008
	Charger Capital Cost (Level 2)	$	2272	Santini et al., 2010
	Vehicle Charges per day	charge/day	1	Jungers, 2011
	Driving Days	day/yr	360	Jungers, 2011
Discount Rate	Discount Rate	%	6.4	Jungers, 2011
Emissions	Gasoline Well to Wheels CO2e	g/MJ	97.800	CAARB
	Electricity Generation (BAU, 2010)	tCO_2e/MWh	0.26893	REPOP estimate, 2011
	Elec. Gen. (BAU, 2020)	tCO_2e/MWh	0.27518	REPOP estimate, 2011
	Elec. Gen. (BAU, 2030)	tCO_2e/MWh	0.28122	REPOP estimate, 2011
	Elec. Gen. (MRP, 2010)	tCO_2e/MWh	0.15208	REPOP estimate, 2011
	Elec. Gen. (MRP, 2020)	tCO_2e/MWh	0.16170	REPOP estimate, 2011
	Elec. Gen. (MRP, 2030)	tCO_2e/MWh	0.17768	REPOP estimate, 2011
	Elec. Gen. (HRP, 2010)	tCO_2e/MWh	0.03546	REPOP estimate, 2011
	Elec. Gen. (HRP, 2020)	tCO_2e/MWh	0.04258	REPOP estimate, 2011
	Elec. Gen. (HRP, 2030)	tCO_2e/MWh	0.05018	REPOP estimate, 2011
EVs	PHEV10 Weight	%	25	Jungers, 2011
	PHEV40 Weight	%	13	Jungers, 2011
	EREV30 Weight	%	13	Jungers, 2011
	EREV40 Weight	%	25	Jungers, 2011
	BEV100 Weight	%	25	Jungers, 2011
	Utility Factor (PHEV10, 10k VMT)	%	16.67	EPRI, 2007
	Utility Factor (PHEV30, 10k VMT)	%	63.2	EPRI, 2007
	Utility Factor (PHEV40, 10k VMT)	%	71.11	EPRI, 2007

Notes
BAU: business as usual
MRP: medium renewables penetration
HRP: high renewables penetration
VMT: vehicle miles traveled

Table 30: Lifecycle Cost / Benefit Analysis Parameter Assumptions

Category	Parameter	Units	Value	Source
EVs	BEV Maintenance Cost	$/mi	0.0077	EPRI, 2004
	PHEV Maintenance Cost	$/mi	0.02671	EPRI, 2004
	CV Maintenance Cost	$/mi	0.03598	EPRI, 2004
	CV Maintenance Cost	$/mi	0.0454	BTS, 2009
	Tire Maintenance Cost	$/mi	0.0083	BTS, 2009
	Vehicle Lifetime	year	17	CAARB
Fuel	Gasoline Price (2010-2030)	$/gal	4.00	Humboldt County estimate, 2011
	Retail Electricity (BAU, 2010)	$/kWh	0.12240	REPOP estimate, 2011
	Retail Electricity (BAU, 2020)	$/kWh	0.12164	REPOP estimate, 2011
	Retail Electricity (BAU, 2030)	$/kWh	0.12092	REPOP estimate, 2011
	Retail Electricity (MRP, 2010)	$/kWh	0.12347	REPOP estimate, 2011
	Retail Electricity (MRP, 2020)	$/kWh	0.12274	REPOP estimate, 2011
	Retail Electricity (MRP, 2030)	$/kWh	0.12329	REPOP estimate, 2011
	Retail Electricity (HRP, 2010)	$/kWh	0.12853	REPOP estimate, 2011
	Retail Electricity (HRP, 2020)	$/kWh	0.12796	REPOP estimate, 2011
	Retail Electricity (HRP, 2030)	$/kWh	0.12737	REPOP estimate, 2011
Humboldt County	Driving Fraction (Freeway)	%	60	Estimated from CADOT, 2009
	Driving Fraction (City)	%	40	Estimated from CADOT, 2009
	Average Annual Miles Driven	mi/yr	11,000	Estimated from CADOT, 2009 and CADMV, 2008
	Average Daily Driving Distance	mi/day	30	Estimated from CADOT, 2009 and CADMV, 2008
	City Driving Schedule		UDDS	Jungers, 2011
	Highway Driving Schedule		HWFET	Jungers, 2011
	New Vehicle Sales (CA)	%	7.89	Estimated from CADMV, 2001-2007
	Fraction light duty trucks	%	56.7	Estimated from CADMV, 2001-2007
	Average Fuel Efficiency of CV	mi/gal	18	Estimated from CADOT, 2009 and CADMV, 2008
	Average Fuel Eff. of New CV (City)	mi/gal	25.9	BTS, 2009
	Average Fuel Eff. of New CV (Hwy)	mi/gal	37.6	BTS, 2009
Incentives	Federal Tax Credit (BEV)	$	7500	U.S. Department of Energy, 2010
	Federal Tax Credit (PHEV)	$	7500	U.S. Department of Energy, 2010

Notes
BAU: business as usual
MRP: medium renewables penetration
HRP: high renewables penetration
CV: conventional vehicle

APPENDIX C: Economic Impact Assessment - Definitions, Methods, and Additional Results

C.1 Economic Impact Assessment

Economic impact assessment, or the use of predictive multipliers to determine economic impacts from a change in final demand for an industry, derived from the work of Wassily Leontief and his development of input-output (I-O) economic theory during the mid to late 20th century. I-O analysis is now a widely used tool for estimating economic impacts from regional to multinational levels and has been used to determine economic impacts from renewable energy development in the United States and abroad (Allan et al., 2008; Caldes, et al., 2009; Ciorba et al., 2004; ECOTEC, 1999; Hillebrand, et al., 2006; Kulisic et al., 2007; Lehr et al., 2008; Madlener and Koller, 2007).

The starting point of any I-O analysis is a matrix of inter-industry interactions depicting the flow of goods and services between industries. The resulting I-O tables are now produced by many countries on a national economy scale with great sectoral detail; in the United States, the Bureau of Economic Analysis releases benchmark I-O data every five years for 528 industries (Listokin et al., 2002). Industry I-O tables are used to derive Type I multipliers that predict direct and indirect effects on the total output of an economy from a change in final demand for a single or multiple industries. I-O tables are typically expanded to include household interactions with industry from which Type II multipliers are derived that predict economic impacts from changes in household income and the resulting changes in consumption that affect industry.

Direct impacts correspond to the effects on the primary industries involved in meeting the change in final demand for a product or service. For example, in the development of a wind power plant, the primary industries involved would be the construction company contracted to erect the wind turbines or the company that manufactured the wind turbines. Indirect impacts correspond to the effects on the secondary industries that provide goods or services to the primary industries. A company that provides steel to a wind turbine manufacturer would be an example of a secondary industry. Induced impacts correspond to the effects on industries due to changes in household income resulting from the direct and indirect impacts to local industries. For example, if the direct and indirect impacts on a county result in increased jobs and wages for households in the county, then those households would be "induced" to spend more for goods and services (e.g. groceries, healthcare, etc.). The extent to which households are induced to spend in a particular industry is typically estimated with personal consumption expenditures for the region.

C.1.1 The NREL Jobs and Economic Development Impact (JEDI) Suite

Several software programs exist for conducting non-survey regional economic impact assessments including IMPLAN, REMI, and RIMS II. Specifically, a thorough understanding of IMPLAN's regionalization methods proves to be important when conducting a regional economic impact assessment of renewable energy development because of the integration of IMPLAN multipliers into the Jobs and Economic Development Impact (JEDI) software suite developed by the National Renewable Energy Laboratory (NREL). 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, 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 power (EERE, 2009a).

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 US Bureau of Economic Analysis 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. JEDI simply requires the input of corresponding IMPLAN regional multipliers, however, 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. In the RESCO project, the JEDI suite and the SERC models based on JEDI (see below) are used to determine the direct, indirect, and induced economic impacts created by renewable energy development in Humboldt County. The JEDI Natural Gas model provides impacts associated with the most prevalent fossil based generation in Humboldt County as a comparison to renewable development.

C.1.2 SERC Impact Assessment Model Suite

JEDI models for biomass, river hydroelectric, and wave energy are currently under development but were not available for customization to Humboldt County during the preparation of this report. Consequently, Professor Hackett and the SERC economics team developed custom models for these renewable technologies using the same basic structure of the JEDI models and populated them with cost information drawn from the authoritative literature and interviews with local operators.

One of the SERC models is the biomass impact assessment model for Humboldt County. The information on the allocation of construction-phase and operations-phase costs by category was drawn from Bain et al. (2003), and specific capital cost and O&M cost factors were drawn from Klein (2009) and from other recent cost studies.[36] Fuel consumption information was drawn from the same sources, as well as from interviews with several biomass power plant operators in Humboldt County. Fuel price was developed from industry sources, Harrill and Han (2010), and interviews with several local biomass power plant operators. The proportion of construction and operations-phase inputs sourced from Humboldt County was determined from numerous interviews by the SERC research team with engineering firms, craft unions, planning consultants, and biomass power plant operators, from other JEDI models customized for Humboldt County, as well as from 2008 IMPLAN regional use coefficients for Humboldt County. The resulting model parameters were then refined through test-run comparisons with documented biomass power plant benchmarks (Klein, 2009).

SERC developed a river hydroelectric impact assessment model, which models relatively small (1 to 2 MW) power plants that are likely to be run-of-the-river systems. This model was developed using installed project cost drawn from a small hydroelectric power plant facility in KEMA (2009), and adjusted using interview information from the operator of a 1 to 2 MW hydroelectric power plant in the region. Overall project construction costs were allocated by share to labor, engineering, and other construction costs using the same proportions as in the SERC biomass model. Outside research indicates that these are relatively standard and stable

36 Black & Veatch, 2010; E3, 2008; EIA, 2009; Klein et al., 2007; Klein, 2010; Lazard, 2008; O'Donnell et al., 2009; and PIER, 2007.

proportions. The proportion of construction and operations-phase inputs sourced from Humboldt County was developed following the methodology used in the SERC biomass model. Annual O&M costs were taken from 2009 operations data from the Humboldt Bay Municipal Water District's 2 MW Ruth Lake hydroelectric facility. The resulting model parameters were refined through test-run comparisons with levelized cost benchmarks (Klein, 2007).

A wave energy impact assessment model was also developed by SERC. Two key documents used in developing the wave model were KEMA (2009) and ECONorthwest (2009). From KEMA (2009) Professor Hackett and the SERC research team extracted an installed construction cost factor (per MW of capacity), as well as cost factors for fixed and variable O&M costs. From ECONorthwest (2009) the team extracted detailed cost breakdowns by category for both construction-phase and operations-phase. The team then developed its own local share default values based on numerous interviews with engineering firms, craft unions, planning consultants, and other energy experts. The resulting model parameters were then refined through test-run benchmark comparisons (where relevant) with the ECONorthwest study on the economic impacts of wave farm development in Oregon.

Finally, SERC developed an energy efficiency impact assessment model using the same basic design as the biomass and other SERC models. The main distinction between the efficiency model and other SERC models is that instead of construction phase and operating phase impacts, the efficiency model estimates economic impacts from energy efficiency measure installation and from consumer energy bill savings. The majority of the cost and savings information for this model was derived from Itron (2008) as detailed in the technical assessment report. Labor cost information at the measure level was derived from the Energy Commission and CPUC sponsored Database for Energy Efficiency Resources (DEER). Local share default values for materials and labor were developed based on mulitiple interviews with RCEA, local contractors, retailers, and wholesalers. Local share default values for the spending of energy bill savings were established based on the SERC research team's in-depth knowledge of the Humboldt County economy. The resulting model parameters were refined through test-run comparisons with the Southwest Energy Efficiency Project study on energy efficiency and job creation in Colorado (Geller et.al., 2009).

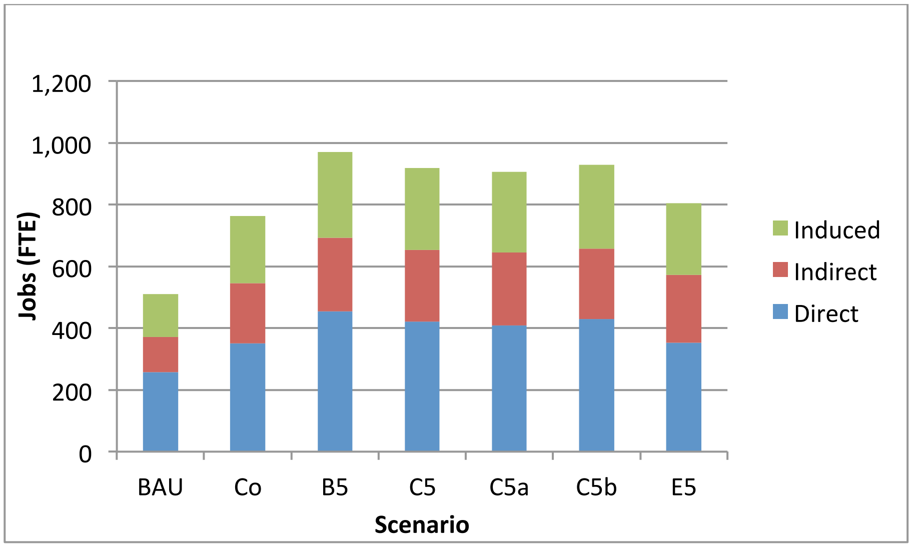
C.1.3 Customizing JEDI and SERC Models for Humboldt County-Specific Analysis

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 which 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 the SERC research team worked with the JEDI software developer, Marshall Goldberg of MRG & Associates, to derive the appropriate multipliers for use in the JEDI models 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 are obtained for the appropriate industry aggregates used in the JEDI suite, these can simply be pasted into the User Add-In Location tab found on any JEDI model. The SERC research team designed the SERC impact assessment models to utilize the same Humboldt County multipliers as the JEDI models.

C.1.4 Humboldt County Economic Impacts - Additional Results

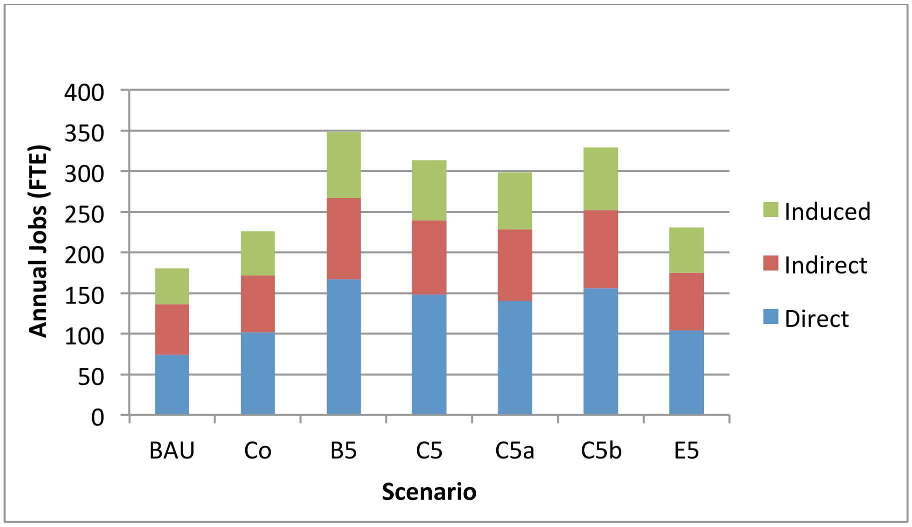
For each of the preferred scenarios, Figure 40 through Figure 45 show how economic impacts are distributed between direct, indirect, and induced impacts.

Figure 40: Preferred Scenario Direct, Indirect, and Induced Construction Phase Job Creation



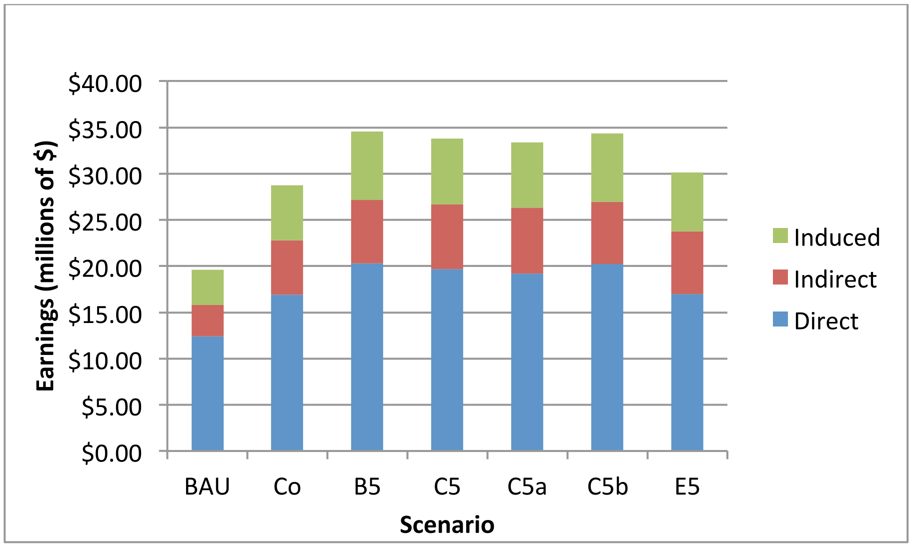
Source: SERC staff analysis

Figure 41: Preferred Scenario Direct, Indirect, and Induced Operations Phase Job Creation



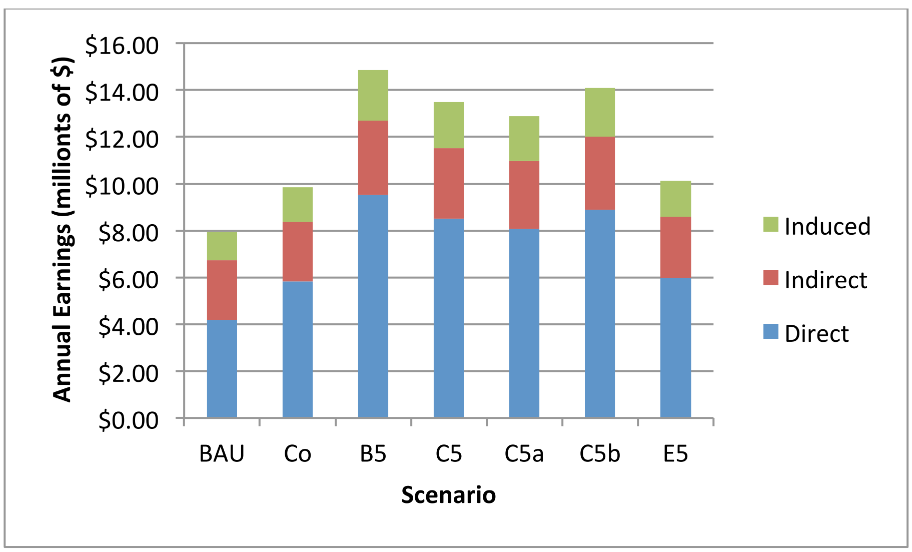
Source: SERC staff analysis

Figure 42: Preferred Scenario Direct, Indirect, and Induced Construction Phase Earnings



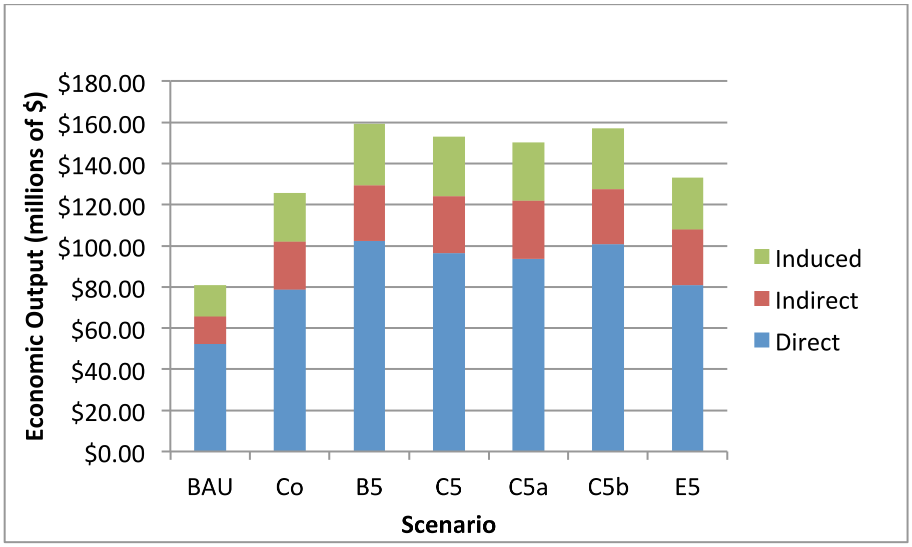
Source: SERC staff analysis

Figure 43: Preferred Scenario Direct, Indirect, and Induced Operations Phase Earnings



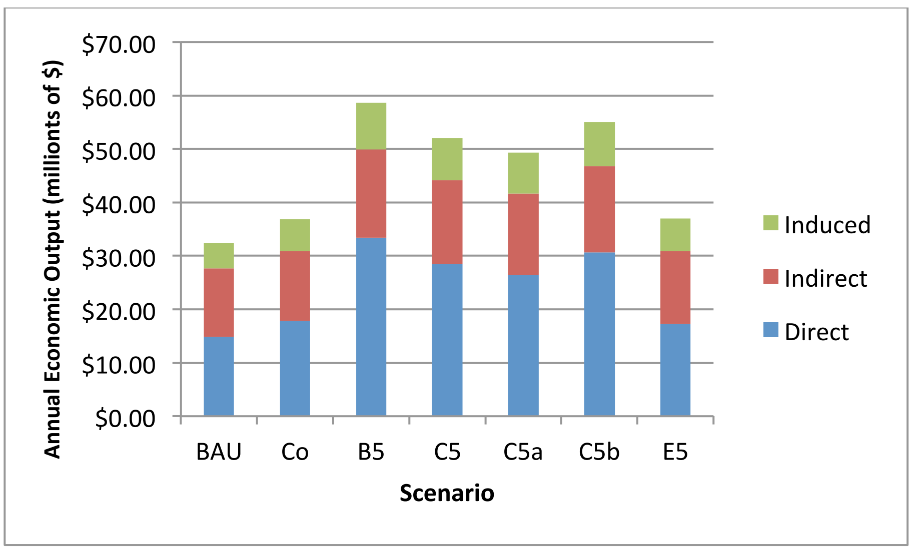
Source: SERC staff analysis

Figure 44: Preferred Scenario Direct, Indirect, and Induced Construction Phase Economic Output



Source: SERC staff analysis

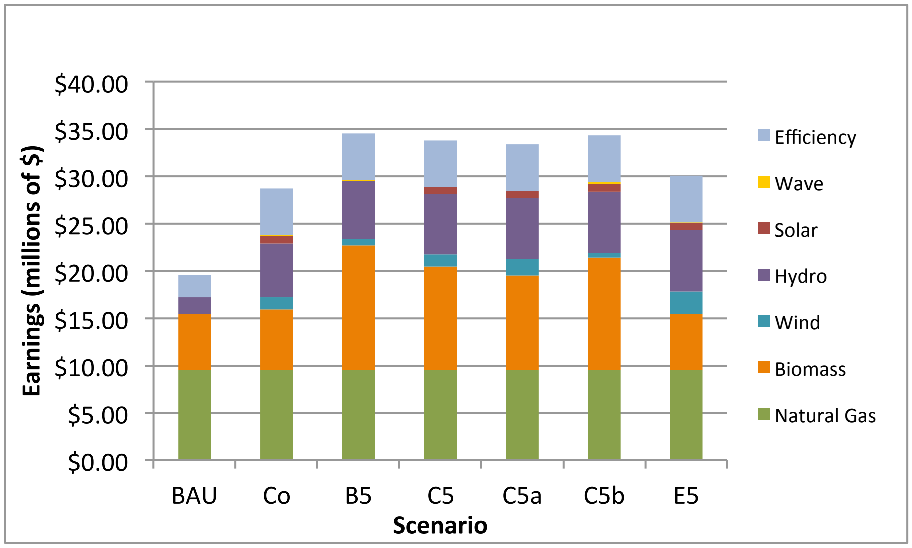
Figure 45: Preferred Scenario Direct, Indirect, and Induced Operations Phase Economic Output



Source: SERC staff analysis

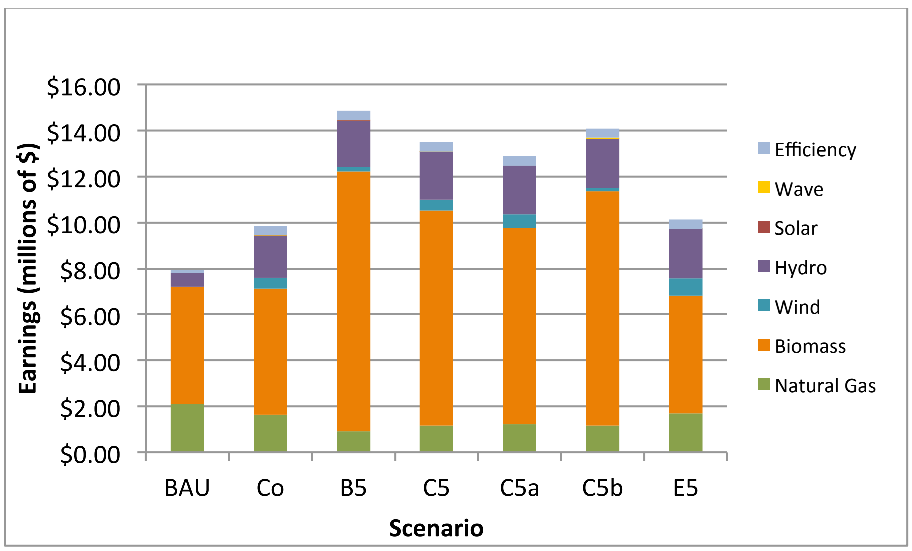
For each of the preferred scenarios, Figure 46 through Figure 49 demonstrate how earnings and economic output are distributed between technologies.

Figure 46: Preferred Scenario Construction Phase Earnings by Technology



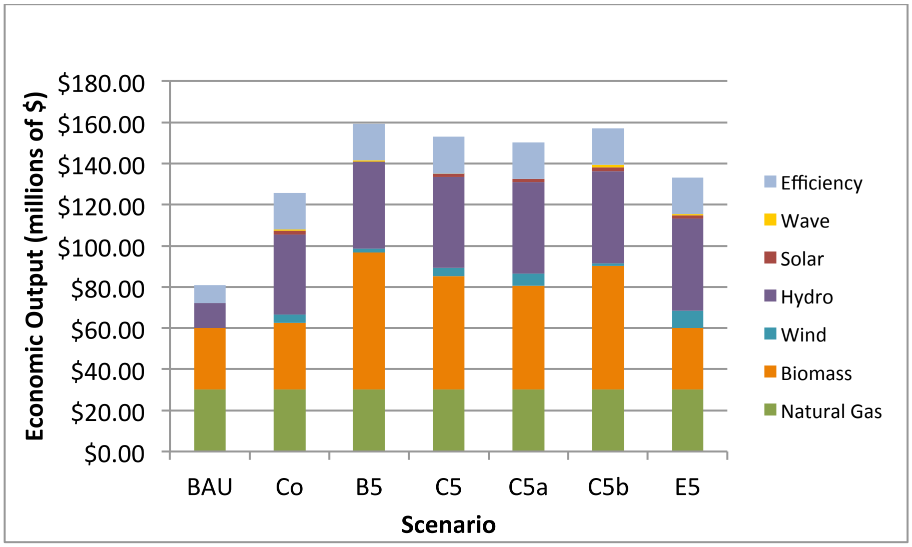
Source: SERC staff analysis

Figure 47: Preferred Scenario Operations Phase Earnings by Technology



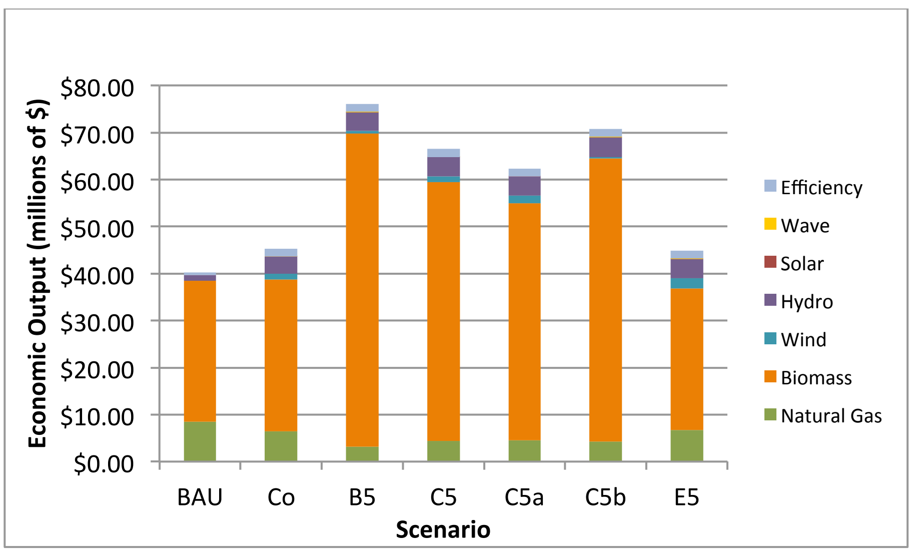
Source: SERC staff analysis

Figure 48: Preferred Scenario Construction Phase Economic Output by Technology



Source: SERC staff analysis

Figure 49: Preferred Scenario Operations Phase Economic Output by Technology



Source: SERC staff analysis

Table 31: Economic Impacts for BAU

Scenario BAU - Humboldt County business as usual projection for 2030.					**Construction Phase Impacts**			**Operations Phase Impacts**		
Technology	**Total Installed Capacity (MW)**	**Capacity Factor (%)**	**Average Power Production (MW)**	**Impact Type**	**Jobs (FTE)**	**Earnings (millions of 2010$)**	**Output (millions of 2010$)**	**Annual Jobs (FTE)**	**Earnings (millions of 2010$/yr)**	**Output (millions of 2010$/yr)**
Natural Gas	163	50.80%	82.8	Onsite Labor Impacts (Direct)	133	$6.82	$19.05	8	$0.41	$0.41
				Supply Chain Impacts (Indirect)	41	$1.26	$5.18	22	$1.35	$6.67
				Induced Impacts	51	$1.44	$5.79	13	$0.35	$1.41
				Total Impacts	**226**	**$9.52**	**$30.03**	**43**	**$2.11**	**$8.49**
Biomass	60.83	66.70%	40.6	Onsite Labor Impacts (Direct)	89.58	$3.35	$19.57	56.71	$3.29	$13.68
				Supply Chain Impacts (Indirect)	42.94	$1.25	$5.05	36.02	$1.09	$5.65
				Induced Impacts	50.17	$1.35	$5.40	27.17	$0.73	$2.93
				Total Impacts	**182.7**	**$5.94**	**$30.02**	**119.90**	**$5.10**	**$22.26**
Hydro	10.4	59.60%	6.2	Onsite Labor Impacts (Direct)	12.44	$0.71	$8.03	8.92	$0.48	$0.74
				Supply Chain Impacts (Indirect)	16.35	$0.49	$1.86	1.63	$0.05	$0.19
				Induced Impacts	21.91	$0.59	$2.36	2.05	$0.06	$0.22
				Total Impacts	**50.69**	**$1.79**	**$12.26**	**12.61**	**$0.58**	**$1.15**
Efficiency	Base			Onsite Labor Impacts (Direct)	23.25	$1.56	$5.48	0.00	$0.00	$0.00
				Supply Chain Impacts (Indirect)	12.79	$0.37	$1.44	2.68	$0.08	$0.32
				Induced Impacts	15.11	$0.41	$1.63	2.55	$0.07	$0.27
				Total Impacts	**51.15**	**$2.34**	**$8.55**	**5.23**	**$0.14**	**$0.60**
Total Impacts				Onsite Labor Impacts (Direct)	259	$12.44	$52.14	74	$4.18	$14.82
				Supply Chain Impacts (Indirect)	113	$3.37	$13.53	62	$2.56	$12.83
				Induced Impacts	139	$3.78	$15.17	44	$1.20	$4.84
				Total Impacts	**510**	**$19.58**	**$80.85**	**180**	**$7.94**	**$32.50**

Source: SERC staff analysis

Table 32: Economic Impacts for Scenario Co

Scenario C_o - This scenario features a 21% penetration of electric vehicles, a 16% penetration of heat pumps, 97% efficiency, and a 0% increase in BAU cost.

					Construction Phase Impacts			Operations Phase Impacts		
Technology	**Total Installed Capacity (MW)**	**Capacity Factor (%)**	**Average Power Production (MW)**	**Impact Type**	**Jobs (FTE)**	**Earnings (millions of 2010$)**	**Output (millions of 2010$)**	**Annual Jobs (FTE)**	**Earnings (millions of 2010$/yr)**	**Output (millions of 2010$/yr)**
Natural Gas	163	34.90%	56.9	Onsite Labor Impacts (Direct)	133	$6.82	$19.05	8	$0.41	$0.41
				Supply Chain Impacts (Indirect)	41	$1.26	$5.18	16	$0.95	$4.88
				Induced Impacts	51	$1.44	$5.79	10	$0.28	$1.11
				Total Impacts	**226**	**$9.52**	**$30.03**	**34**	**$1.63**	**$6.39**
Wind	46.8	29.80%	13.9	Onsite Labor Impacts (Direct)	21	$0.33	$0.33	4	$0.32	$0.32
				Supply Chain Impacts (Indirect)	21	$0.75	$3.02	3	$0.08	$0.63
				Induced Impacts	8	$0.23	$0.91	2	$0.06	$0.24
				Total Impacts	**51**	**$1.30**	**$4.26**	**9**	**$0.46**	**$1.19**
Wave	1.6	26.00%	0.4	Onsite Labor Impacts (Direct)	0.70	$0.02	$0.27	0.22	$0.01	$0.03
				Supply Chain Impacts (Indirect)	0.59	$0.02	$0.07	0.05	$0.00	$0.01
				Induced Impacts	0.76	$0.02	$0.08	0.09	$0.00	$0.01
				Total Impacts	**2.05**	**$0.06**	**$0.42**	**0.35**	**$0.02**	**$0.04**
Biomass	65.6	67.40%	44.2	Onsite Labor Impacts (Direct)	96.65	$3.61	$21.12	61.12	$3.54	$14.70
				Supply Chain Impacts (Indirect)	46.33	$1.34	$5.45	38.72	$1.17	$6.08
				Induced Impacts	54.13	$1.45	$5.83	29.22	$0.78	$3.15
				Total Impacts	**197.11**	**$6.41**	**$32.39**	**129.06**	**$5.49**	**$23.93**
Hydro	32.9	58.40%	19.2	Onsite Labor Impacts (Direct)	39.35	$2.24	$25.41	28.22	$1.53	$2.34
				Supply Chain Impacts (Indirect)	51.71	$1.55	$5.90	5.17	$0.14	$0.60
				Induced Impacts	69.31	$1.86	$7.46	6.49	$0.17	$0.70
				Total Impacts	**160.37**	**$5.65**	**$38.78**	**39.89**	**$1.85**	**$3.64**
Solar	1.3	13.50%	0.2	Onsite Labor Impacts (Direct)	10.9	$563.84	$883.39	0.1	$4.43	$4.43
*** Earnings and economic output are in thousands of dollars**				Supply Chain Impacts (Indirect)	6.9	$202.56	$699.52	0.0	$0.48	$1.91
				Induced Impacts	3.4	$95.10	$381.90	0.0	$0.31	$1.23
				Total Impacts	**21.2**	**$861.49**	**$1,964.81**	**0.1**	**$5.22**	**$7.57**
Efficiency	Full			Onsite Labor Impacts (Direct)	48.33	$3.32	$11.50	0.00	$0.00	$0.00
				Supply Chain Impacts (Indirect)	26.66	$0.77	$3.00	7.50	$0.21	$0.90
				Induced Impacts	31.64	$0.85	$3.41	7.12	$0.19	$0.77
				Total Impacts	**106.63**	**$4.94**	**$17.90**	**14.62**	**$0.40**	**$1.67**
Total Impacts (Gross)				Onsite Labor Impacts (Direct)	350	$16.91	$78.57	102	$5.82	$17.81
				Supply Chain Impacts (Indirect)	194	$5.89	$23.32	70	$2.56	$13.10
				Induced Impacts	219	$5.94	$23.86	55	$1.49	$5.97
				Total Impacts	**764**	**$28.74**	**$125.75**	**226**	**$9.86**	**$36.87**
Total Impacts (Net from BAU)				Onsite Labor Impacts (Direct)	92	$4.47	$26.43	28	$1.64	$2.98
				Supply Chain Impacts (Indirect)	81	$2.52	$9.78	8	$0.00	$0.26
				Induced Impacts	80	$2.16	$8.68	11	$0.28	$1.13
				Total Impacts	**253**	**$9.16**	**$44.89**	**46**	**$1.92**	**$4.38**

Source: SERC staff analysis

Table 33: Economic Impacts for Scenario B5

Scenario B_5 - This scenario features a 19% penetration of electric vehicles, an 18% penetration of heat pumps, 95% efficiency, and a 5% increase in BAU cost.					Construction Phase Impacts			Operations Phase Impacts		
Technology	**Total Installed Capacity (MW)**	**Capacity Factor (%)**	**Average Power Production (MW)**	**Impact Type**	**Jobs (FTE)**	**Earnings (millions of 2010$)**	**Output (millions of 2010$)**	**Annual Jobs (FTE)**	**Earnings (millions of 2010$/yr)**	**Output (millions of 2010$/yr)**
Natural Gas	163	10.60%	17.3	Onsite Labor Impacts (Direct)	133	$6.82	$19.05	8	$0.41	$0.41
				Supply Chain Impacts (Indirect)	41	$1.26	$5.18	6	$0.34	$2.14
				Induced Impacts	51	$1.44	$5.79	6	$0.16	$0.64
				Total Impacts	**226**	**$9.52**	**$30.03**	**20**	**$0.91**	**$3.19**
Wind	19.9	29.80%	5.9	Onsite Labor Impacts (Direct)	16	$0.25	$0.25	2	$0.15	$0.15
				Supply Chain Impacts (Indirect)	9	$0.31	$1.24	1	$0.04	$0.27
				Induced Impacts	4	$0.10	$0.40	1	$0.03	$0.10
				Total Impacts	**28**	**$0.66**	**$1.90**	**4**	**$0.21**	**$0.52**
Wave	2.4	26.00%	0.6	Onsite Labor Impacts (Direct)	1.06	$0.04	$0.41	0.32	$0.02	$0.04
				Supply Chain Impacts (Indirect)	0.88	$0.03	$0.10	0.07	$0.00	$0.01
				Induced Impacts	1.14	$0.03	$0.12	0.13	$0.00	$0.01
				Total Impacts	**3.08**	**$0.09**	**$0.63**	**0.52**	**$0.02**	**$0.07**
Biomass	135	67.40%	91.0	Onsite Labor Impacts (Direct)	198.89	$7.44	$43.46	125.78	$7.29	$30.26
				Supply Chain Impacts (Indirect)	95.35	$2.77	$11.21	79.67	$2.40	$12.51
				Induced Impacts	111.40	$2.99	$11.99	60.14	$1.61	$6.48
				Total Impacts	**405.64**	**$13.19**	**$66.66**	**265.59**	**$11.31**	**$49.24**
Hydro	35.8	58.40%	20.9	Onsite Labor Impacts (Direct)	42.82	$2.44	$27.65	30.71	$1.67	$2.54
				Supply Chain Impacts (Indirect)	56.27	$1.69	$6.42	5.63	$0.16	$0.66
				Induced Impacts	75.42	$2.02	$8.12	7.06	$0.19	$0.76
				Total Impacts	**174.50**	**$6.15**	**$42.19**	**43.40**	**$2.01**	**$3.96**
Solar*	1.7	13.50%	0.2	Onsite Labor Impacts (Direct)	14.2	$0.74	$1.16	0.1	$5.80	$5.80
*** Earnings and economic output are in thousands of dollars**				Supply Chain Impacts (Indirect)	9.0	$0.26	$0.91	0.0	$0.62	$2.49
				Induced Impacts	4.4	$0.12	$0.50	0.0	$0.40	$1.60
				Total Impacts	**27.7**	**$1.13**	**$0.26**	**0.2**	**$6.82**	**$9.90**
Efficiency	Full			Onsite Labor Impacts (Direct)	48.33	$3.32	$11.50	0.00	$0.00	$0.00
				Supply Chain Impacts (Indirect)	26.66	$0.77	$3.00	7.50	$0.21	$0.90
				Induced Impacts	31.64	$0.85	$3.41	7.12	$0.19	$0.77
				Total Impacts	**106.63**	**$4.94**	**$17.90**	**14.62**	**$0.40**	**$1.67**
Total Impacts (Gross)				Onsite Labor Impacts (Direct)	455	$20.30	$102.33	167	$9.53	$33.41
				Supply Chain Impacts (Indirect)	238	$6.82	$27.15	100	$3.15	$16.49
				Induced Impacts	279	$7.43	$29.83	81	$2.18	$8.76
				Total Impacts	**972**	**$34.55**	**$159.31**	**348**	**$14.87**	**$58.66**
Total Impacts (Net from BAU)				Onsite Labor Impacts (Direct)	196	$7.86	$50.18	93	$5.35	$18.58
				Supply Chain Impacts (Indirect)	125	$3.45	$13.62	38	$0.59	$3.65
				Induced Impacts	140	$3.65	$14.66	37	$0.98	$3.93
				Total Impacts	**461**	**$14.97**	**$78.46**	**168**	**$6.93**	**$26.16**

Source: SERC staff analysis

Table 34: Economic Impacts for Scenario C5

Scenario C_5 - This scenario features a 38% penetration of electric vehicles, a 31% penetration of heat pumps, 98% efficiency, and a 5% increase in BAU cost.					Construction Phase Impacts			Operations Phase Impacts		
Technology	**Total Installed Capacity (MW)**	**Capacity Factor (%)**	**Average Power Production (MW)**	**Impact Type**	**Jobs (FTE)**	**Earnings (millions of 2010$)**	**Output (millions of 2010$)**	**Annual Jobs (FTE)**	**Earnings (millions of 2010$/yr)**	**Output (millions of 2010$/yr)**
Natural Gas	163	19.30%	31.5	Onsite Labor Impacts (Direct)	133	$6.82	$19.05	8	$0.41	$0.41
				Supply Chain Impacts (Indirect)	41	$1.26	$5.18	10	$0.56	$3.12
				Induced Impacts	51	$1.44	$5.79	7	$0.20	$0.80
				Total Impacts	**226**	**$9.52**	**$30.03**	**25**	**$1.17**	**$4.34**
Wind	45.8	29.80%	13.6	Onsite Labor Impacts (Direct)	21	$0.33	$0.33	4	$0.32	$0.32
				Supply Chain Impacts (Indirect)	21	$0.73	$2.96	3	$0.08	$0.61
				Induced Impacts	8	$0.22	$0.89	2	$0.06	$0.23
				Total Impacts	**50**	**$1.28**	**$4.18**	**8**	**$0.45**	**$1.16**
Wave	0.43	26.00%	0.1	Onsite Labor Impacts (Direct)	0.19	$0.01	$0.07	0.06	$0.00	$0.01
				Supply Chain Impacts (Indirect)	0.16	$0.00	$0.02	0.01	$0.00	$0.00
				Induced Impacts	0.21	$0.01	$0.02	0.02	$0.00	$0.00
				Total Impacts	**0.55**	**$0.02**	**$0.11**	**0.09**	**$0.00**	**$0.01**
Biomass	111.8	67.40%	75.4	Onsite Labor Impacts (Direct)	164.71	$6.16	$35.99	104.17	$6.04	$25.06
				Supply Chain Impacts (Indirect)	78.96	$2.29	$9.28	65.98	$1.99	$10.36
				Induced Impacts	92.26	$2.47	$9.93	49.80	$1.34	$5.37
				Total Impacts	**335.93**	**$10.92**	**$55.20**	**219.95**	**$9.36**	**$40.78**
Hydro	37.3	58.30%	21.7	Onsite Labor Impacts (Direct)	44.61	$2.54	$28.81	32.00	$1.74	$2.65
				Supply Chain Impacts (Indirect)	58.62	$1.76	$6.69	5.86	$0.16	$0.69
				Induced Impacts	78.58	$2.11	$8.46	7.36	$0.20	$0.79
				Total Impacts	**181.82**	**$6.40**	**$43.96**	**45.22**	**$2.10**	**$4.13**
Solar	1.1	13.50%	0.1	Onsite Labor Impacts (Direct)	9.2	$477.09	$747.48	0.1	$3.75	$3.75
*** Earnings and economic output are in thousands of dollars**				Supply Chain Impacts (Indirect)	5.8	$171.39	$591.90	0.0	$0.40	$1.61
				Induced Impacts	2.9	$80.47	$323.14	0.0	$0.26	$1.04
				Total Impacts	**17.9**	**$728.95**	**$1,662.53**	**0.1**	**$4.41**	**$6.40**
Efficiency	Full			Onsite Labor Impacts (Direct)	48.33	$3.32	$11.50	0.00	$0.00	$0.00
				Supply Chain Impacts (Indirect)	26.66	$0.77	$3.00	7.50	$0.21	$0.90
				Induced Impacts	31.64	$0.85	$3.41	7.12	$0.19	$0.77
				Total Impacts	**106.63**	**$4.94**	**$17.90**	**14.62**	**$0.40**	**$1.67**
Total Impacts (Gross)				Onsite Labor Impacts (Direct)	421	$19.65	$96.50	148	$8.51	$28.45
				Supply Chain Impacts (Indirect)	232	$6.98	$27.72	92	$3.00	$15.68
				Induced Impacts	265	$7.18	$28.82	74	$1.98	$7.97
				Total Impacts	**918**	**$33.81**	**$153.05**	**313**	**$13.49**	**$52.09**
Total Impacts (Net from BAU)				Onsite Labor Impacts (Direct)	163	$7.21	$44.36	74	$4.33	$13.62
				Supply Chain Impacts (Indirect)	119	$3.62	$14.18	30	$0.45	$2.84
				Induced Impacts	126	$3.40	$13.65	29	$0.78	$3.13
				Total Impacts	**408**	**$14.23**	**$72.19**	**133**	**$5.55**	**$19.60**

Source: SERC staff analysis

Table 35: Economic Impacts for Scenario C5a

Scenario C_{5a} - This scenario features a 37% penetration of electric vehicles, a 38% penetration of heat pumps, 100% efficiency, and a 5% increase in BAU cost (C_5 variation with high wind and low biomass).

Technology	Total Installed Capacity (MW)	Capacity Factor (%)	Average Power Production (MW)	Impact Type	Construction Phase Impacts: Jobs (FTE)	Construction Phase Impacts: Earnings (millions of 2010$)	Construction Phase Impacts: Output (millions of 2010$)	Operations Phase Impacts: Annual Jobs (FTE)	Operations Phase Impacts: Earnings (millions of 2010$/yr)	Operations Phase Impacts: Output (millions of 2010$/yr)
Natural Gas	163	20.60%	33.6	Onsite Labor Impacts (Direct)	133	$6.82	$19.05	8	$0.41	$0.41
				Supply Chain Impacts (Indirect)	41	$1.26	$5.18	10	$0.59	$3.27
				Induced Impacts	51	$1.44	$5.79	7	$0.21	$0.83
				Total Impacts	**226**	**$9.52**	**$30.03**	**26**	**$1.21**	**$4.51**
Wind	67.1	29.80%	20.0	Onsite Labor Impacts (Direct)	23	$0.36	$0.36	4	$0.39	$0.39
				Supply Chain Impacts (Indirect)	31	$1.08	$4.38	4	$0.11	$0.88
				Induced Impacts	11	$0.32	$1.29	3	$0.08	$0.33
				Total Impacts	**65**	**$1.76**	**$6.03**	**11**	**$0.58**	**$1.59**
Wave	0	26.00%	0.0	Onsite Labor Impacts (Direct)	0.00	$0.00	$0.00	0.00	$0.00	$0.00
				Supply Chain Impacts (Indirect)	0.00	$0.00	$0.00	0.00	$0.00	$0.00
				Induced Impacts	0.00	$0.00	$0.00	0.00	$0.00	$0.00
				Total Impacts	**0.00**	**$0.00**	**$0.00**	**0.00**	**$0.00**	**$0.00**
Biomass	102.2	67.60%	69.1	Onsite Labor Impacts (Direct)	150.57	$5.63	$32.90	95.29	$5.52	$22.96
				Supply Chain Impacts (Indirect)	72.18	$2.09	$8.49	60.46	$1.83	$9.49
				Induced Impacts	84.33	$2.26	$9.08	45.62	$1.22	$4.92
				Total Impacts	**307.09**	**$9.99**	**$50.46**	**201.38**	**$8.57**	**$37.37**
Hydro	37.6	58.30%	21.9	Onsite Labor Impacts (Direct)	44.97	$2.56	$29.04	32.25	$1.75	$2.67
				Supply Chain Impacts (Indirect)	59.10	$1.77	$6.74	5.91	$0.17	$0.69
				Induced Impacts	79.21	$2.12	$8.53	7.42	$0.20	$0.80
				Total Impacts	**183.28**	**$6.45**	**$44.31**	**45.58**	**$2.11**	**$4.16**
Solar*	1.1	13.50%	0.1	Onsite Labor Impacts (Direct)	9.2	$477.09	$747.48	0.1	$3.75	$3.75
*** Earnings and economic output are in thousands of dollars**				Supply Chain Impacts (Indirect)	5.8	$171.39	$591.90	0.0	$0.40	$1.61
				Induced Impacts	2.9	$80.47	$323.14	0.0	$0.26	$1.04
				Total Impacts	**17.9**	**$728.95**	**$1,662.53**	**0.1**	**$4.41**	**$6.40**
Efficiency	Full			Onsite Labor Impacts (Direct)	48.33	$3.32	$11.50	0.00	$0.00	$0.00
				Supply Chain Impacts (Indirect)	26.66	$0.77	$3.00	7.50	$0.21	$0.90
				Induced Impacts	31.64	$0.85	$3.41	7.12	$0.19	$0.77
				Total Impacts	**106.63**	**$4.94**	**$17.90**	**14.62**	**$0.40**	**$1.67**
Total				Onsite Labor Impacts (Direct)	410	$19.17	$93.61	140	$8.07	$26.44
				Supply Chain Impacts (Indirect)	235	$7.14	$28.38	88	$2.90	$15.23
				Induced Impacts	261	$7.08	$28.41	70	$1.90	$7.64
				Total Impacts	**906**	**$33.39**	**$150.40**	**299**	**$12.88**	**$49.30**
Total Impacts (Net from BAU)				Onsite Labor Impacts (Direct)	151	$6.73	$41.46	66	$3.89	$11.61
				Supply Chain Impacts (Indirect)	122	$3.78	$14.84	26	$0.35	$2.39
				Induced Impacts	122	$3.30	$13.24	26	$0.70	$2.80
				Total Impacts	**396**	**$13.81**	**$69.55**	**118**	**$4.94**	**$16.81**

Source: SERC staff analysis

Table 36: Economic Impacts for Scenario C5b

Technology	Total Installed Capacity (MW)	Capacity Factor (%)	Average Power Production (MW)	Impact Type	Construction Phase Impacts: Jobs (FTE)	Construction Phase Impacts: Earnings (millions of 2010$)	Construction Phase Impacts: Output (millions of 2010$)	Operations Phase Impacts: Annual Jobs (FTE)	Operations Phase Impacts: Earnings (millions of 2010$/yr)	Operations Phase Impacts: Output (millions of 2010$/yr)
Scenario C_{5b} - This scenario features a 38% penetration of electric vehicles, a 29% penetration of heat pumps, 100% efficiency, and a 5% increase in BAU cost (C_5 variation with high biomass and low wind).										
Natural Gas	163	19.10%	31.1	Onsite Labor Impacts (Direct)	133	$6.82	$19.05	8	$0.41	$0.41
				Supply Chain Impacts (Indirect)	41	$1.26	$5.18	10	$0.55	$3.10
				Induced Impacts	51	$1.44	$5.79	7	$0.20	$0.80
				Total Impacts	**226**	**$9.52**	**$30.03**	**25**	**$1.16**	**$4.31**
Wind	14.1	29.80%	4.2	Onsite Labor Impacts (Direct)	11	$0.18	$0.18	1	$0.10	$0.10
				Supply Chain Impacts (Indirect)	6	$0.22	$0.88	1	$0.03	$0.20
				Induced Impacts	3	$0.07	$0.28	1	$0.02	$0.07
				Total Impacts	**20**	**$0.47**	**$1.34**	**3**	**$0.15**	**$0.38**
Wave	4.9	26.00%	1.3	Onsite Labor Impacts (Direct)	2.15	$0.07	$0.84	0.66	$0.04	$0.09
				Supply Chain Impacts (Indirect)	1.80	$0.05	$0.20	0.14	$0.00	$0.02
				Induced Impacts	2.34	$0.06	$0.25	0.26	$0.01	$0.03
				Total Impacts	**6.29**	**$0.19**	**$1.29**	**1.06**	**$0.05**	**$0.13**
Biomass	121.8	67.40%	82.1	Onsite Labor Impacts (Direct)	179.45	$6.71	$39.21	113.48	$6.58	$27.30
				Supply Chain Impacts (Indirect)	86.03	$2.50	$10.11	71.88	$2.17	$11.28
				Induced Impacts	100.51	$2.69	$10.82	54.26	$1.46	$5.85
				Total Impacts	**365.98**	**$11.90**	**$60.14**	**239.62**	**$10.20**	**$44.43**
Hydro	37.9	58.30%	22.1	Onsite Labor Impacts (Direct)	45.33	$2.58	$29.28	32.51	$1.76	$2.69
				Supply Chain Impacts (Indirect)	59.57	$1.79	$6.80	5.96	$0.17	$0.70
				Induced Impacts	79.84	$2.14	$8.60	7.48	$0.20	$0.81
				Total Impacts	**184.74**	**$6.51**	**$44.67**	**45.95**	**$2.13**	**$4.20**
Solar	1.2	13.50%	0.2	Onsite Labor Impacts (Direct)	10.0	$520.47	$815.44	0.1	$4.09	$4.09
*** Earnings and economic output are in thousands of dollars**				Supply Chain Impacts (Indirect)	6.4	$186.98	$645.71	0.0	$0.44	$1.76
				Induced Impacts	3.1	$87.78	$352.52	0.0	$0.28	$1.13
				Total Impacts	**19.5**	**$795.22**	**$1,813.67**	**0.1**	**$4.82**	**$6.99**
Efficiency	Full			Onsite Labor Impacts (Direct)	48.33	$3.32	$11.50	0.00	$0.00	$0.00
				Supply Chain Impacts (Indirect)	26.66	$0.77	$3.00	7.50	$0.21	$0.90
				Induced Impacts	31.64	$0.85	$3.41	7.12	$0.19	$0.77
				Total Impacts	**106.63**	**$4.94**	**$17.90**	**14.62**	**$0.40**	**$1.67**
Total Impacts (Gross)				Onsite Labor Impacts (Direct)	430	$20.20	$100.87	156	$8.90	$30.60
				Supply Chain Impacts (Indirect)	228	$6.77	$26.82	96	$3.13	$16.20
				Induced Impacts	271	$7.35	$29.50	77	$2.07	$8.32
				Total Impacts	**929**	**$34.32**	**$157.19**	**329**	**$14.10**	**$55.12**
Total Impacts (Net from BAU)				Onsite Labor Impacts (Direct)	171	$7.76	$48.72	82	$4.71	$15.78
				Supply Chain Impacts (Indirect)	115	$3.40	$13.29	34	$0.57	$3.36
				Induced Impacts	133	$3.57	$14.33	33	$0.87	$3.49
				Total Impacts	**419**	**$14.74**	**$76.34**	**149**	**$6.16**	**$22.62**

Source: SERC staff analysis

Table 37: Economic Impacts for Scenario E5

Scenario E5 - This scenario features a 76% penetration of electric vehicles, a 27% penetration of heat pumps, 100% efficiency, and a 5% increase in BAU cost.					Construction Phase Impacts			Operations Phase Impacts		
Technology	Total Installed Capacity (MW)	Capacity Factor (%)	Average Power Production (MW)	Impact Type	Jobs (FTE)	Earnings (millions of 2010$)	Output (millions of 2010$)	Annual Jobs (FTE)	Earnings (millions of 2010$/yr)	Output (millions of 2010$/yr)
Natural Gas	163	37.20%	60.6	Onsite Labor Impacts (Direct)	133	$6.82	$19.05	8	$0.41	$0.41
				Supply Chain Impacts (Indirect)	41	$1.26	$5.18	17	$1.01	$5.14
				Induced Impacts	51	$1.44	$5.79	10	$0.29	$1.15
				Total Impacts	**226**	**$9.52**	**$30.03**	**35**	**$1.70**	**$6.70**
Wind	94.8	29.80%	28.3	Onsite Labor Impacts (Direct)	25	$0.39	$0.39	6	$0.49	$0.49
				Supply Chain Impacts (Indirect)	44	$1.53	$6.23	5	$0.15	$1.22
				Induced Impacts	16	$0.45	$1.80	4	$0.11	$0.45
				Total Impacts	**85**	**$2.37**	**$8.42**	**15**	**$0.76**	**$2.16**
Wave	1.8	26.00%	0.5	Onsite Labor Impacts (Direct)	0.79	$0.03	$0.31	0.24	$0.01	$0.03
				Supply Chain Impacts (Indirect)	0.66	$0.02	$0.07	0.05	$0.00	$0.01
				Induced Impacts	0.86	$0.02	$0.09	0.10	$0.00	$0.01
				Total Impacts	**2.31**	**$0.07**	**$0.47**	**0.39**	**$0.02**	**$0.05**
Biomass	61	67.40%	41.1	Onsite Labor Impacts (Direct)	89.87	$3.36	$19.64	56.83	$3.29	$13.67
				Supply Chain Impacts (Indirect)	43.08	$1.25	$5.07	36.00	$1.09	$5.65
				Induced Impacts	50.34	$1.35	$5.42	27.17	$0.73	$2.93
				Total Impacts	**183.29**	**$5.96**	**$30.12**	**120.01**	**$5.11**	**$22.25**
Hydro	37.9	58.30%	22.1	Onsite Labor Impacts (Direct)	45.33	$2.58	$29.28	32.51	$1.76	$2.69
				Supply Chain Impacts (Indirect)	59.57	$1.79	$6.80	5.96	$0.17	$0.70
				Induced Impacts	79.84	$2.14	$8.60	7.48	$0.20	$0.81
				Total Impacts	**184.74**	**$6.51**	**$44.67**	**45.95**	**$2.13**	**$4.20**
Solar*	1.1	13.50%	0.1	Onsite Labor Impacts (Direct)	9.2	$477.09	$747.48	0.1	$3.75	$3.75
*** Earnings and economic output are in thousands of dollars**				Supply Chain Impacts (Indirect)	5.8	$171.39	$591.90	0.0	$0.40	$1.61
				Induced Impacts	2.9	$80.47	$323.14	0.0	$0.26	$1.04
				Total Impacts	**17.9**	**$728.95**	**$1,662.53**	**0.1**	**$4.41**	**$6.40**
Efficiency	Full			Onsite Labor Impacts (Direct)	48.33	$3.32	$11.50	0.00	$0.00	$0.00
				Supply Chain Impacts (Indirect)	26.66	$0.77	$3.00	7.50	$0.21	$0.90
				Induced Impacts	31.64	$0.85	$3.41	7.12	$0.19	$0.77
				Total Impacts	**106.63**	**$4.94**	**$17.90**	**14.62**	**$0.40**	**$1.67**
Total Impacts (Gross)				Onsite Labor Impacts (Direct)	352	$16.98	$80.91	104	$5.98	$17.31
				Supply Chain Impacts (Indirect)	220	$6.79	$26.94	71	$2.62	$13.61
				Induced Impacts	233	$6.33	$25.43	56	$1.52	$6.11
				Total Impacts	**805**	**$30.10**	**$133.28**	**231**	**$10.13**	**$37.02**
Total Impacts (Net from BAU)				Onsite Labor Impacts (Direct)	93	$4.54	$28.77	30	$1.80	$2.48
				Supply Chain Impacts (Indirect)	107	$3.42	$13.40	9	$0.07	$0.77
				Induced Impacts	94	$2.55	$10.26	12	$0.32	$1.27
				Total Impacts	**295**	**$10.51**	**$52.43**	**51**	**$2.19**	**$4.53**

Source: SERC staff analysis

C.2 US Clean Energy Economy Standard Industrial Classification Codes

Table 38 below is included to show the range of industry sectors that are considered by the Pew Charitable Trusts (2009) to be fully within the "clean energy economy" cluster. A component of this cluster is made up of renewable energy sectors.

Table 38: Standard Industrial Classification Codes for Establishments in the US Clean Energy Economy

8-digit SIC	Description
1810103	Mats, preseeded: soil erosion, growing of
8510102	Reforestation services
13110201	Coal gasification
13110203	Coal pyrolysis
16290505	Waste water and sewage treatment plant construction
17110403	Solar energy contractor
17310202	Energy management controls
17310203	Environmental system control installation
17420204	Solar reflecting insulation film
17819901	Geothermal drilling
17969906	Pollution control equipment installation
17990210	Weather stripping
28210401	Carbohydrate plastics
28210407	Soybean plastics
28690104	Ethyl alcohol, ethanol
28739901	Fertilizers: natural (organic), except compost
28759901	Compost
28999913	Desalter kits, sea water
32110302	Insulating glass, sealed units
32310401	Insulating glass: made from purchased glass
34339904	Solar heaters and collectors
34430304	Economizers (boilers)
35110207	Wheels, water
35239906	Windmills for pumping water, agricultural
35590403	Desalination equipment
35599937	Recycling machinery
35890300	Sewage and water treatment equipment
35890301	Sewage treatment equipment
35890306	Water treatment equipment, industrial
36219909	Windmills, electric generating
36290102	Electrochemical generators (fuel cells)
36740305	Photovoltaic devices, solid state
36740306	Solar cells
36749901	Fuel cells, solid state
37110104	Cars, electric, assembly of
38220000	Environmental controls
38220206	Temperature controls, automatic
38220300	Thermostats and other environmental sensors
38229900	Environmental controls, nec
38229905	Energy cutoff controls, residential or commercial types
38269907	Environmental testing equipment
38290218	Solarimeters
49119908	Hydro electric power generation
49520000	Sewerage systems
49539905	Recycling, waste materials
49539907	Sewage treatment facility
49590300	Toxic or hazardous waste cleanup
49590301	Oil spill cleanup
49590302	Environmental cleanup services
50399912	Soil erosion control fabrics
50740208	Heating equipment and panels, solar
50750103	Air pollution control equipment and supplies
50840706	Pollution control equipment, air (environmental)
50840707	Pollution control equipment, water (environmental)
50849914	Recycling machinery and equipment
50930000	Scrap and waste materials (all related codes)
52110300	Insulation and energy conservation products
52110301	Energy conservation products
52110303	Solar heating equipment
73890201	Air pollution measuring service
73899931	Meter readers, remote
76990304	Thermostat repair
81110208	Environmental law
86419903	Environmental protection organization
87110101	Pollution control engineering
87110403	Heating and ventilation engineering
87119906	Energy conservation engineering
87310302	Environmental research
87340300	Pollution testing
87349911	Water testing laboratory
87449904	Environmental remediation
87489904	Energy conservation consultant
87489905	Environmental consultant
89990703	Natural resource preservation service

Source: Pew Charitable Trusts (2009)