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FINAL PROJECT REPORT

REPOWERING HUMBOLDT WITH COMMUNITY-SCALE RENEWABLE ENERGY

Prepared for: California Energy Commission
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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.

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- Renewable Energy Technologies
- Transportation

RePowering Humboldt with Community-Scale Renewable Energy is the final report for the RePowering Humboldt with Community-Scale Renewable Energy project (agreement number PIR-12-022) conducted by the Redwood Coast Energy Authority. The information from this project contributes to PIER's Renewable Energy Technologies Program.

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ABSTRACT

The RePowering Humboldt with Community-Scale Renewable Energy project examined the design, installation, and operation of a forest-based biomass energy conversion system to provide combined heat and power for the Blue Lake Rancheria, a federally recognized Native American tribe. The project team evaluated system performance and assessed opportunities for system scale-up and replication. In addition, the researchers piloted and evaluated a community-based energy upgrade program in the surrounding community to demonstrate a sustainable model for local clean energy deployment in terms of financing and market deployment.

The biomass energy demonstration project did not result in an operational system, but many valuable lessons were learned to advise future efforts. Mass and energy balance models were developed and used to estimate system performance. Results show the overall energy efficiency and economic viability of the installed system is likely to be poor; a biomass gasification engine-generator configuration shows more promise. Overall the project team found that biomass fueled distributed generation systems are not mature, readily available, cost-effective or practical at this time.

The energy upgrade program used new and existing energy efficiency and renewable energy delivery mechanisms combined with a targeted outreach campaign to promote and incentivize energy saving actions and adoption of solar electric systems. Several site assessments were completed and referrals to participating contractors resulted in several upgrade projects. Goals related to customer engagement, site assessments and upgrade projects were met and the program demonstrated the viability of a targeted campaign with community-focused outreach and social marketing efforts.

Keywords: California, renewable, energy, community, distributed generation, gasification, fuel cell, biomass, Humboldt County, electric vehicles, heat pumps, program design, upgrade, outreach, marketing, financing, site assessments

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EXECUTIVE SUMMARY

Introduction

Humboldt County, on the northern California coast, shows great potential to become a renewable energy secure community. The county is geographically and electricially isolated, with a relatively small electrical demand (170 MW peak), and a wealth of local renewable energy resources, including wind, wave, biomass and small hydro. In addition, Humboldt County boasts a large number of energy savvy early adopters (for example, rooftop solar and hybrid vehicle owners) and has strong community resources with the Redwood Coast Energy Authority (a local Joint Powers energy office) and the Schatz Energy Research Center at Humboldt State University. Humboldt County has demonstrated the interest, expertise, and resource potential to become a renewable energy secure community and developed the *RePower Humboldt Strategic Plan* which outlined a set of strategies expanding local renewable energy resources in the county. The *RePowering Humboldt with Community-Scale Renewable Energy* project explored, verified, and implemented some of the key recommendations from the *RePower Humboldt Strategic Plan.*

Project Purpose

The *RePowering Humboldt with Community-Scale Renewable Energy* project focused on two key elements. The design and installation of a first-of-its-kind forest-based woody biomass integrated gasification fuel cell combined heat and power system for the Blue Lake Rancheria, a federally recognized Native American tribe. The program also developed the Mad River Valley Energy Upgrade Program, a community-based energy upgrade program to engage the local community, promote energy efficiency and distributed generation, and demonstrate a financial and organizational self-sustaining model and can be expanded and replicated throughout California.

The Blue Lake Rancheria served as an ideal host site for the distributed generation (DG) biomass energy project. The Rancheria currently serves as a regional emergency center and requires energy resiliency in the case of extreme events, such as an tsunami. The Blue Lake Rancheria and Serraga Energy, LLC, is a tribally-chartered renewable energy project development company managed the site construction and facility operations. Staff from the Schatz Energy Research Center at Humboldt State University handled project management, engineering, procurement, installation, commissioning, and performance analysis tasks. Several key technology partners provided equipment and services, including Proton Power, Inc., Ballard Power Systems, Xebec Adsorption, Inc., and Applied Compression Systems. In addition, numerous local contractors provided services. These included site and facilities preparation, electrical contracting, biomass feed system design and installation, ventilation system installation, and fire and life safety system installation. Third party contractors also provided safety review services.

The biomass system was installed to the north of the Blue Lake Casino and Hotel complex in two buildings: the gasifier building and the biomass buildingwas to provide electricity for the casino building, offsetting about one-third of its typical electricity use. The average energy use is 480 kW and remains relatively flat regardless of time of day or season of the year.

The Mad River Valley Community Energy Upgrade Program was managed by the Energy Upgrade Program team in collaboration with project partners. Redwood Coast Energy Authority conducted program design and implementation activities, except for heat pump monitoring and assessment, which was conducted by staff from the Schatz Energy Research Center. Key partners included Blue Lake School, Crystal Air Heating, the City of Blue Lake, OurEvolution Energy and Engineering, Robert Colburn Electric, and the Blue Lake Rancheria. These partners acted as site hosts, provided equipment and services, and collaborated on program outreach efforts.

The Mad River Energy Upgrade Program used existing tools and created new, innovated project management and assessment tools to help program implementation. To track customers and project progress, a simple Microsoft Excel database was set-up with Google maps used to identify customer site locations. This allowed a customer to be tagged as qualified for the program if they had not signed up through program-specific outreach and also made certain qualified customers were entered into the tracking database. The existing Energy Watch program used its own scheduling process and customer database. Additional program reference functions were added to the existing database so that program customer assessment information could be safely stored and easily queried for reporting purposes.

Energy assessments culminated in a report of findings that included recommendations for behavioral and no-cost changes; an overview of any no-cost energy efficient technology measures that were installed through the Energy Watch program (e.g. lighting or low-flow showerheads); and recommendations for energy upgrade investments that could be pursued through the Home Upgrade® program or with a solar site survey.

Contractors were recruited to participate in the program by reaching out via mass email solicitations, print advertisements for training opportunities, and by contacting contractors directly through email or by phone. The program also identified financing options for financing program guide and associated outreach materials including bank loan financing Property Assessed Clean Energy (PACE) Financing and PG&E On-bill Financing Program.

Project Results

The biomass energy demonstration project, while not resulting in an operational system, did achieve significant benefits by helping to guide future research and development for biomass fueled distributed generation systems. In addition, many of the lessons learned were documented to help educate others to develop similar biomass fueled distributed generation systems. During this project, an innovative biomass energy system was conceived, designed, procured and installed. In addition, mass and energy balance models were developed and used to estimate system performance. The modeling exercise results identified the potential viability of a biomass gasification fuel cell power system. The biomass gasification fuel cell system was also compared, in terms of efficiency and economic viability, with alternate woody biomass distributed generation systems, and it did not fare well.

Despite a concerted investment of time, money, and effort, the gasifier is not yet operational. The research team concluded that, at this time, biomass fueled distributed generation systems are not mature, readily available, cost-effective or practical, particularly with this combination of technologies. Future work should focus on overcoming the obstacles and challenges with biomass gasification systems, and alternative engine-generator configurations are likely to show more promise. The Blue Lake Rancheria Tribe and Serraga Energy are continuing to support the project financially and operationally, and intend to furnish further updates as they become available.

The successful Mad River Energy Upgrade Program used new and existing energy efficiency and renewable energy delivery mechanisms, combined with a targeted outreach campaign, to promote and incentivize energy savings actions and adoption of solar electric systems. The Redwood Coast Energy Authority engaged stakeholders to promote the program, recruit participants, and advocate the benefits of energy efficiency and renewable energy in their community. The program provided for educational opportunities, including presentations, workshops, one-on-one consultations, and detailed reports of findings, to fill in knowledge gaps regarding energy technologies and the benefits of potential energy and cost savings associated with adoption of these technologies. Several site assessments were completed, resulting in immediate energy savings through the existing Energy Watch program. Referrals to participating contractors resulted in several upgrade projects as well. Goals related to customer engagement, site assessments, and upgrade projects were met and the program also demonstrated the viability of a targeted campaign with community-focused outreach and social marketing efforts.

Benefits to California

The *RePowering Humboldt with Community-Scale Renewable Energy* project has helped to build energy security, create local jobs, and empower the community to take an active role in its sustainable energy future, all while gathering valuable lessons learned and serving as an example for other communities to pursue the development of local renewables.

Demonstrating a biomass integrated gasification fuel cell system achieved significant benefits, primarily for further research and development of biomass fueled distributed generation systems. An innovative DG biomass energy system was conceived, designed, procured and installed, and many lessons were learned in the process. As a result, the project team and future research efforts are left with a better understanding of which system types offer the best opportunities for further development. Analysis conducted as part of this project has provided insight into the costs, component technologies, and complexities associated with installing a biomass gasification system.

The successful Mad River Energy Upgrade Program continues to provide benefits in the form of reduced greenhouse gas emissions from energy efficiency retrofits, electric vehicle charging infrastructure, and a new renewable energy system. Local consumers are also now more aware than ever of efficiency measures that continue lowering their energy use and costs.

CHAPTER 1: Introduction

To meet the state's ambitious goals for developing renewable energy, creating clean energy jobs, and reducing greenhouse gas emissions, individual communities must step forward and demonstrate what can be done. Humboldt County, with tremendous opportunities for renewable energy development, is one of those communities. This community-scale renewable energy implementation project builds on important energy planning work that was completed in March 2013 under the Humboldt County Renewable Energy Secure Community project (PIR-08-034).

A key deliverable from the Humboldt County Renewable Energy Secure Community project was the *RePower Humboldt Strategic Plan* (Schatz Energy Research Center 2013). This strategic plan outlined key opportunities for renewable energy development and energy efficiency in Humboldt County. Specific recommendations were to implement energy efficiency, develop biomass energy resources, pursue opportunities for distributed generation, promote fuel switching with adoption of plug-in electric vehicles and electric heat pumps, and pursue community-based projects that engage local residents, and provide financing mechanisms and programs that address market barriers.

The key goal for the RePowering Humboldt with Community-Scale Renewable Energy project was to begin to implement some of the key recommendations from the *RePower Humboldt Strategic Plan*, to demonstrate their viability, and to set an example for continued implementation efforts. The project featured two key elements: 1) the design and installation of a first-of-its-kind woody biomass integrated gasification fuel cell (BIGFC) combined heat and power system, and 2) a community-based energy upgrade program that engages the local community, promotes energy efficiency and distributed generation, and demonstrates a financial and organizational model that is self-sustaining and can be expanded and replicated throughout the state.

This project will move the *RePower Humboldt Strategic Plan* into action by implementing key recommendations, building energy security, create local jobs, and empower the community to take an active role in its sustainable energy future.

1.1 Problem Statement

The *RePower Humboldt Strategic Plan* outlined a set of strategies for developing local renewable energy resources in Humboldt County. Biomass energy, community-scale distributed generation, energy efficiency, electric vehicles and heat pumps were all identified as key strategies for reducing greenhouse gas emissions, increasing renewable energy use, and providing for local energy security. Identified next steps to move the RePower Humboldt plan forward include implementation of pilot scale projects that successfully demonstrate candidate technologies and programs, overcome perceived barriers and exhibit the economic viability of the RePower Humboldt strategies.

Barriers that distributed biomass energy systems must overcome include technological, market, environmental and cost hurdles. Historically there have not been suitable biomass energy systems for distributed electrical power applications. Traditional stoker boiler and steam turbine systems are typically not efficient enough to be economically viable unless they are sized to primarily meet heating needs. In addition, pollution control for these systems is disproportionately expensive. Biomass gasification systems open up new possibilities, but these systems have not been widely available for distributed energy applications. A BIGFC power system offers substantial increases in efficiency and cleaner operation; however, this technology pairing operating on cellulosic fuel has not yet been demonstrated. The technologies now exist to successfully demonstrate this distributed scale biomass energy system model, and doing so could help open up a substantial new market for these technologies.

Barriers to the successful deployment of energy efficiency technologies, distributed energy systems, and heat pumps have to do mostly with market and cost barriers. To overcome these obstacles, programs can be developed that address cost barriers through financing and bulk purchasing. Market barriers can be addressed through customer outreach, marketing, education and technical assistance. Ultimately, to be successful, such a program must be structured in a way that is self-funding and does not rely on grants or subsidies, except perhaps to overcome start-up costs.

1.2 Goals and Objectives

The goals of this Agreement were to successfully design, install and operate a forest-based biomass energy system that utilized a gasifier and a proton exchange membrane fuel cell to provide combined heat and power for the Blue Lake Rancheria. System performance was to be evaluated and opportunities for system scale-up and replication were to be assessed. In addition, a community-based energy upgrade program was to be developed and implemented in the surrounding community in order to demonstrate a sustainable model in terms of financing and market deployment. Table 1 summarizes the project goals and outlines the metrics against which the goals can be measured.

Table 1: Project Goals and Metrics

Goals	Metrics
Distributed Generation BIGFC CHP System	
Install and operate a biomass gasifier that produces a hydrogen rich syngas	• Syngas composition: > 60% hydrogen by volume
Design, install, and operate a BIGFC CHP system	• Peak output ≥ 175 kW • Capacity factor > 75% • Biomass-to-electricity efficiency of > 25% • Overall energy efficiency, including waste heat recovery, of > 50%
Share results from the BIGFC CHP system and communicate the potential for replication throughout the state	• Publish at least two journal articles documenting results • Present results at one or more conferences • Post project case study information on at least three industry organization web sites
Community Energy Upgrade Program	
Demonstrate a viable community-based energy upgrade model that reaches a substantial number of community members and secures their participation	• Engage the participation of and train at least six local contractors to provide energy services • Conduct workshops reaching at least 100 participants • Conduct 20-60 site assessments • Provide assistance for 5-10 energy upgrade projects
Demonstrate a viable local financing program for energy upgrade projects	• Secure the participation of one or more local lenders • Coordinate financing for 5-10 upgrade projects
Install and quantify the benefits of air source heat pump systems in Humboldt County	• Install and monitor performance of at least two air source heat pump systems
Demonstrate electric vehicle charging stations	• Install and monitor two electric vehicle charging stations • Record at least 100 charging events in a twelve month operating period

Source: RePowering Humboldt Project Team

1.4 Project Team

The project team included the Redwood Coast Energy Authority (a Joint Powers Authority), the Schatz Energy Research Center at Humboldt State University (a university research group), and the Blue Lake Rancheria (a local, federally recognized Indian Tribe).

The Redwood Coast Energy Authority (RCEA) was the prime contractor and also led the Mad River Valley Community Energy Upgrade Program project task. RCEA was formed in 2003 with the purpose to develop and implement sustainable energy initiatives that reduce energy demand, increase energy efficiency, and advance the use of clean, efficient, and renewable resources available in the region. RCEA is a Joint Powers Authority (JPA), representing seven local municipalities (the Cities of Arcata, Blue Lake, Eureka, Ferndale, Fortuna, Trinidad and Rio Dell), the County of Humboldt, and the Humboldt Bay Municipal Water District. RCEA has extensive experience with energy project implementation and engaging the local community and has administered and directly implemented over $6 million of rate-payer-funded energy programs. Recent experience includes completion of a Regional Plug-in Electric Vehicle

Readiness Plan, and a Renewable Energy Secure Community (RESCO) Program project that culminated in developing a strategic plan called RePower Humboldt, which outlines a vision and strategic plan for renewable energy and energy security in Humboldt County.

The Schatz Energy Research Center (SERC) at Humboldt State University was the technical lead for the Distributed Generation Biomass Combined Heat and Power project task. SERC was founded in 1989 with a mission to promote the use of clean and renewable energy resources. SERC and RCEA have worked together since RCEA's inception. SERC was the technical lead on the *RePower Humboldt Strategic Plan* project. SERC has many years of experience designing, installing and operating hydrogen energy systems, including high profile demonstration projects. In addition, SERC has experience operating and testing thermochemical biomass energy systems, including gasifiers, pyrolysis units, and torrefiers. SERC provided project management, design, engineering, procurement, installation, commissioning, and performance analysis services for the project.

The Blue Lake Rancheria (BLR) was the site host for the Distributed Generation Biomass Combined Heat and Power system, and will operate the system for its projected lifetime once the system is in routine operation. Serraga Energy, LLC, is a tribally-chartered renewable energy project development company and served as the major subcontractor. Serraga coordinated site and facilities work, handled associated construction management tasks, and managed the associated budget and accounting on the project. Serraga will manage the ongoing project-related tasks post grant completion, including routine operation of the system.

Key project staffs from each of the entities described are listed in Table 2.

Table 2: Key Project Staff

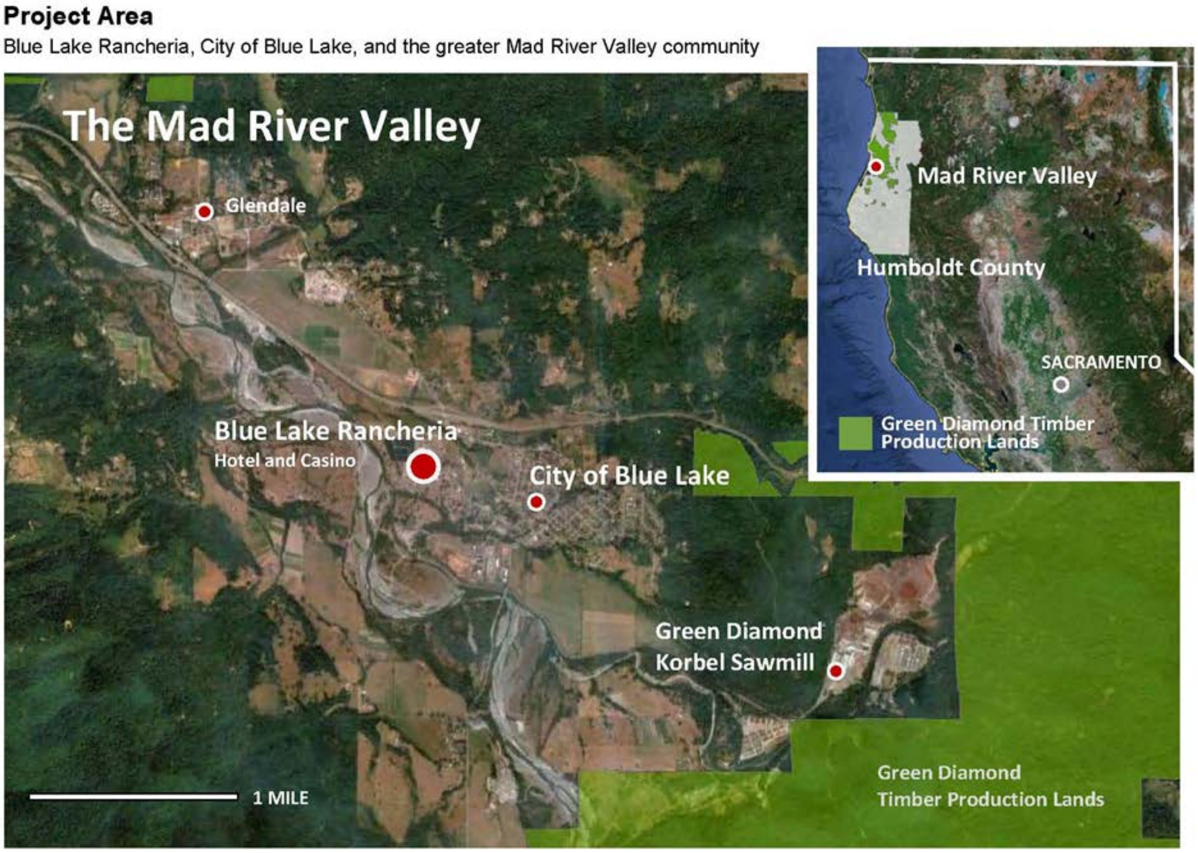
Staff Member	Organization, Title	Role
Matthew Marshall	RCEA, Executive Director	Project oversight
Dana Boudreau	RCEA, Operations Manager	Project management
Lori Biondini	RCEA, Project Manager	Project management
Peter Lehman	SERC, Founding Director	Project design
Jim Zoellick	SERC, Senior Research Engineer	Project management, project design, installation, commissioning and testing
Greg Chapman	SERC, Senior Research Engineer	Project design, installation, commissioning and testing
Marc Marshall	SERC, Research Engineer	Project design, installation, commissioning and testing
Jana Ganion	BLR, Energy Director	Project management
Neil Harris	BLR, Facilities Manager	Project design, installation, commissioning and testing
Bruce Ryan	BLR, Construction Manager	Construction management

Source: RePowering Humboldt Project Team

1.5 Background

The project is located in the Mad River Valley, Humboldt County, California, about five miles inland from the Pacific Ocean along the Mad River and California Highway 299 (the major arterial between California Highway 101 and Interstate 5 at Redding) (Figure 1). The region is rural, geographically isolated, and prone to large earthquakes (CA Seismic Zone 4). The communities served by this project include the City of Blue Lake, the Blue Lake Rancheria Tribal Community, Glendale, and unincorporated areas of Humboldt County.

Figure 1: Project Area



Source: Redwood Coast Energy Authority, Adapted from Google Maps

1.5.1 Distributed Generation Biomass System

There are substantial reasons why the Blue Lake Rancheria (BLR) community was an ideal host site for the central component of this investment, a demonstration of a distributed generation (DG) biomass power system. BLR currently serves as a regional emergency center and therefore has a strong need for energy resiliency. BLR has already implemented numerous energy and resource conservation efforts, and through direct cash investments has promoted innovative clean and renewable energy projects. For this project, both BLR and Serraga substantially leveraged the Tribe's funding, project management, and operational expertise over and above the initial PIER application commitments.

The Humboldt County region relies on the Tribe to serve many local residents in emergency situations. BLR is one of the only local evacuation sites not at direct risk of tsunamis. Severe storms with heavy rains, high winds and flooding are common, as are landslides across major arterials. With local heavy forest cover, wildfires are another threat. Power interruptions/outages are frequent due to technical and natural factors, limited electrical transmission lines, extreme weather, and remote locations. Humboldt County is connected to the larger electric grid via only two 115-kV lines that head east to the Central Valley. Outages can last from several days to several weeks (1964), and create an ongoing safety threat to the region.

Currently the Tribe has the unique ability to use its 1-MW diesel generator to provide backup power during both unplanned outages as well as during demand response events, when they voluntarily disconnect from the larger electric grid. The runtime capacity is 2-5 days, depending upon load and the stored quantity of diesel fuel. With the addition of the distributed generation biomass power system and a 2-4 week supply of biomass fuel stored onsite, the Tribe extends its emergency power capabilities by 1-3 weeks.

The Tribe has demonstrated its ability to operate in emergency situations, including:

- Managing the voluntary evacuation of thousands of people and vehicles fleeing the coast as a result of the 2011 Fukushima earthquake/tsunami;
- Serving as an evacuation site/operations center for people escaping from numerous regional inland wildfires;
- Serving as an emergency evacuation site for the students and staff of a local school district when a natural gas leak was discovered; and
- Operating as shelter in multiple major weather events and power outages.

In addition, BLR is an ideal site for this project because of its commitment to resource conservation and developing cutting-edge clean energy technologies. The Tribe has reduced greenhouse gas emissions, increased energy efficiency, reduced fossil fuel consumption, increased renewable/clean energy use, and enhanced climate preparedness and resilience. Recent accomplishments include:

- Strategic and tactical emergency planning and training, both onsite and regionally, with a wide array of governments and agency stakeholders (City of Blue Lake, Humboldt County, Humboldt Bay Municipal Water District, FEMA, CalEMA, among many others)
- Energy efficiency programs that have reduced GHG emissions by over 150,000 lbs/year
- A community-wide recycling program (70+ tons/year)
- Installation of solar arrays at low-income residences on the Rancheria
- Construction of a biodiesel manufacturing plant which converts waste oil from the Tribe’s kitchens into fuel which powers the Tribe’s transit buses.

And with this project the Tribe added:

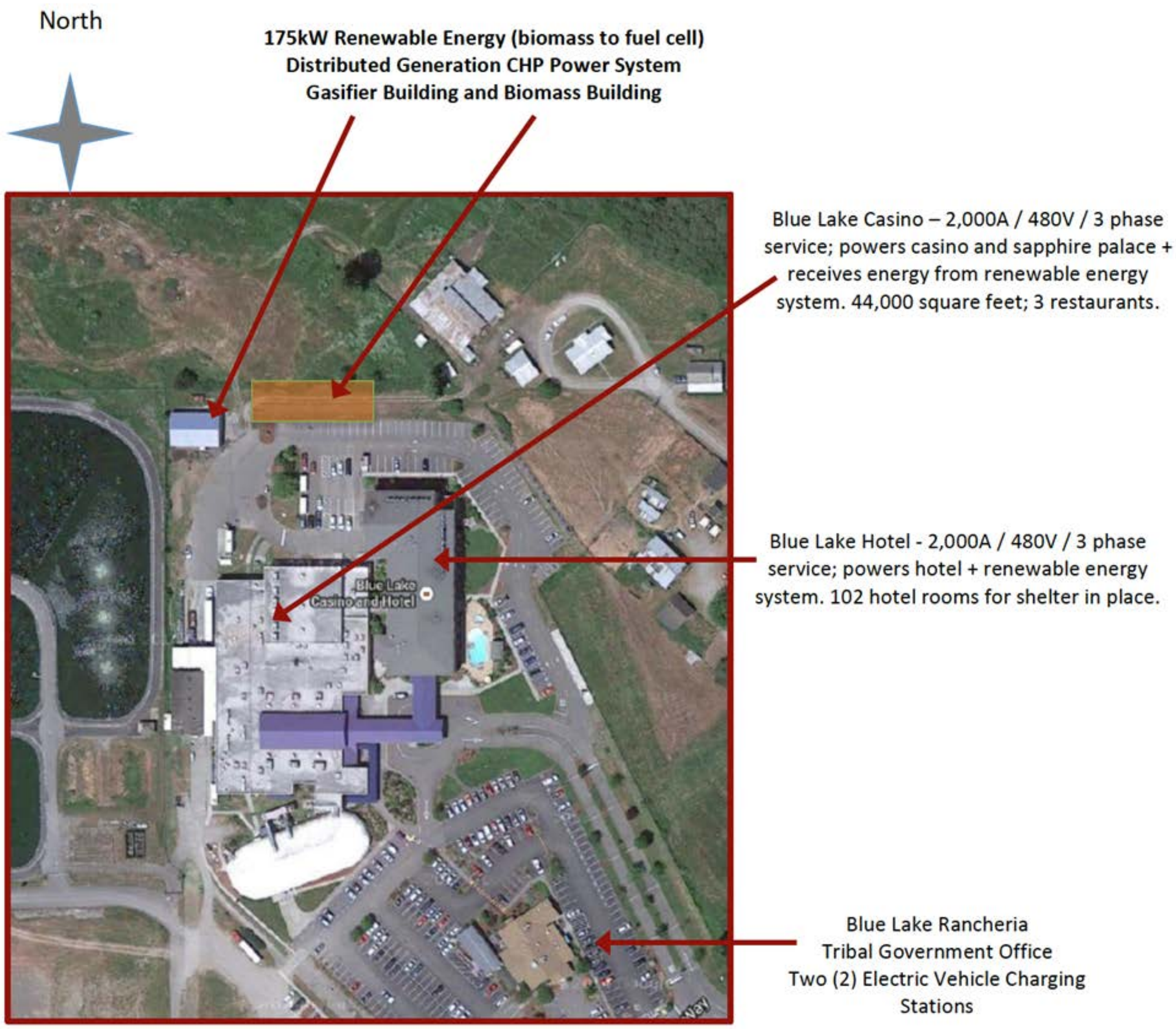
- Installation of electric vehicle charging stations and deployment of plug-in electric vehicles in the Tribe’s fleet
- Numerous energy efficiency upgrades
- Implementation of a 175 kW renewable, biomass-fueled, gasifier/fuel cell power system

For its work, the Tribe was recognized in December 2014 by the White House and the U.S. Department of Energy as a "Climate Action Champion," and with Boston, San Francisco, and Seattle among others, was one of only 16 governments across the nation to be recognized. Extending operability of the Tribe's critical infrastructure as a result of this investment is an extraordinary benefit to the ratepayers of California.

The Tribe's energy goals include reducing greenhouse gas emissions by 40% by 2018, building the ability to operate emergency power in islanded mode for many weeks, exceeding California's renewable energy standards, and ultimately meeting all energy demands on the Rancheria with renewable energy. With this project alone the Tribe will make substantial progress toward meeting these goals. Further, the Tribe has near-term plans to develop a microgrid that will achieve energy cost savings, provide clean-energy demand response capabilities, and provide for critical power needs in extended emergency situations (i.e., for months if necessary).

The DG biomass system was installed just to the north of the Blue Lake Casino and Hotel complex in two buildings: the gasifier building and the biomass building (Figure 2). The DG biomass system will provide electricity to power the casino building, offsetting about 1/3 of its typical electricity use. The energy demands of the casino are very consistent. The average energy use is 480 kW and remains relatively flat regardless of time of day or season of the year. The maximum energy use by the casino at any one time is less than 800 kW, and the minimum is 350 kW. The casino has a small natural gas demand due to a temperate climate and modest heating load.

Figure 2: Blue Lake Rancheria Aerial View



Source: Blue Lake Rancheria Tribe

1.5.2 Community Energy Upgrade Program

The Redwood Coast Energy Watch (RCEW) program offers comprehensive locally-based energy efficiency services to traditionally hard-to-reach market sectors in Humboldt County. RCEW provides a cost-effective, comprehensive approach to accomplishing real energy savings through education, technical assistance, and direct installation services for the public agency, small and medium business, and residential market sectors. RCEW also works with public agencies on a range of strategic initiatives to develop local plans and programs that encourage energy efficiency and promote energy security and reliability. Identified as key strategies in the *RePower Humboldt Strategic Plan*, energy efficiency, distributed energy, electric vehicles, and heat pump adoption are expected to reduce greenhouse gas emissions, increasing renewable energy use, and providing local energy security. RCEA recognized the need to expand services to incorporate these strategies. The development of an innovative and replicable community-based upgrade program was meant to feature key technologies and offer more comprehensive services to the community. Additionally, the demonstration of some of these key strategies, including electric vehicles and heat pumps, was also necessary to verify the local technical and economic benefits of they are anticipated to provide.

CHAPTER 2: Project Approach

The two key goals of the RePowering Humboldt with Renewable-Scale Renewable Energy project were 1) to design, install and operate a woody biomass distributed energy system and 2) to develop and implement, on a pilot basis, a community-based energy upgrade program. The following is a list of project tasks conducted to meet these key goals.

- Task 1: Administration
- Task 2: Install and Demonstrate Distributed Generation Biomass Energy System
- Task 3: Develop and Demonstrate Mad River Valley Community Energy Upgrade Program
- Task 4: Data Collection and Analysis
- Task 5: Technology Transfer Activities
- Task 6: Production Readiness Plan

The project team shared responsibilities on these tasks. SERC was the technical lead on Task 2, working closely with BLR and Serraga staffs to coordinate site work, manage contractors, procure equipment and services, and install and commission all major components. RCEA lead Task 3, and the team shared responsibility on Tasks 1, 4, 5 and 6.

This chapter describes the project team's approach to Tasks 2 through 6.

2.1 Task 2: Install and Demonstrate Distributed Generation Biomass Combined Heat and Power System

One of the findings from the *RePower Humboldt Strategic Plan* was that biomass is a key renewable energy resource in Humboldt County. There are already three traditional Rankine cycle biomass power plants in the region ranging from about 10 to 28 MW in capacity, and there are additional sources of woody biomass that could be utilized. The focus of this task was to develop and demonstrate a smaller, distributed-scale biomass power plant that could provide power to a commercial facility.

There are many potential benefits associated with distributed generation. With regard to biomass power, there further specific benefits associated with smaller, distributed-scale systems. Provided there is a need for heat at the site, distributed-scale systems provide opportunities for combined heat and power applications, which improves system efficiency and economic viability. In addition, there have been some concerns voiced by the environmental community and community at large that the development of new, large-scale biomass power plants will create a need for fuel that will drive forest policy and lead to unsustainable harvest practices. While these concerns may be unfounded in this geographic region where harvest of whole trees for biomass fuel is not likely economically viable, it is nonetheless a community concern. In general, the concern tends to be less significant when dealing with smaller distributed-scale systems because the need for fuel is not as great. It would also typically be easier for a smaller facility that requires smaller quantities of fuel to identify a long-term (i.e., 10 years) sustainable fuel source at an acceptable price; this is recommended before a significant capital investment in a biomass energy facility is made.

The site chosen for this distributed-scale biomass energy technology demonstration was the Blue Lake Rancheria in Blue Lake, CA. The project concept originated with a conversation between Ballard Power Systems and the Schatz Energy Research Center regarding Ballard's interest to demonstrate one of their distributed generation fuel cell generators in an application utilizing woody biomass as a primary fuel source. In February of 2013, Ballard released a White Paper titled "Biomass-to-Fuel-Cell Power… For Renewable Distributed Power Generation" (Ballard 2013). This project aimed to move the concept forward. This type of technology demonstration would be the first of its kind, according to the latest information available to the project team. A woody biomass gasifier that could produce a syngas with very high hydrogen content would be a critical component of the system. Ballard had already identified Proton Power, Inc. of Lenoir City, Tennessee as a possible gasifier vendor.

This array of partners formed a nucleus for the project. This group and other key partners who participated in this task are listed in Table 3 along with a description of their task roles.

Table 3: Distributed Generation Biomass Project Partners

Project Partner	Roles
Schatz Energy Research Center	Project management, engineering, procurement, installation, commissioning, performance analysis
Blue Lake Rancheria and Serraga Energy, LLC	Site host, construction management, facility operator
Proton Power, Inc.	Gasifier vendor, gasifier system installation and commissioning
Ballard Power Systems, Inc.	PEM fuel cell vendor, fuel cell system installation and commissioning
Xebec Adsorption, Inc.	Pressure swing adsorption vendor
Applied Compression Systems Ltd.	Reciprocating compressor vendor

Source: Schatz Energy Research Center

Because of the complexity and breadth of Task 2, the work was divided into the following subtasks:

- DG Biomass System Design
- DG Biomass Interconnection Agreement
- DG Biomass Fuel Supply Contract

- DG Biomass Equipment Procurement
- DG Biomass Site and Facilities Work
- DG Biomass System Installation
- DG Biomass Start-up and Commissioning
- DG Biomass System Test Plan
- DG Biomass Data Collection and Analysis
- DG Biomass Project Evaluation

Each of these subtasks is summarized in the following sections:

2.1.1 DG Biomass System Design

The design process for this project started during the proposal-writing phase. At that time a preliminary design was developed for budgeting and scope of work purposes. The preliminary design was then refined during the project period. SERC was the lead designer, with substantial input, guidance, and approval from BLR staff. SERC also worked closely with the major equipment vendors to solidify the overall integrated system design. The design process was broken down into the ten key areas described below.

2.1.1.1 Overall Process Design and Major Component Selection

The primary objective for the distributed generation system at the Blue Lake Rancheria hotel/casino complex was to provide a substantial fraction of the on-site energy needs. With a rather uniform electrical load averaging about 500 kW, the desired electrical generation size was in the 100 to 500 kW range. The focus for the distributed energy system was electricity production because the energy demands are primarily electrical and the natural gas heating loads do not offer easy retrofit opportunities. Space heating loads are met via packaged units (natural gas furnaces packaged with air conditioners) located on the casino roof. Packaged terminal air conditioners, or PTACs, are used to condition the individual hotel rooms. There is no centralized heating and cooling system. Therefore, heat from a biomass-fired system cannot easily be used to supplant existing fuel sources. In addition, the existing HVAC equipment is relatively new and efficient, making the economic viability of a major retrofit less favorable. With regard to water heating, tank water heaters and on-demand, tankless water heaters are utilized. These loads are modest and again do not lend themselves to an easy retrofit application. There is also a swimming pool, but it is very modest in size with a minimal heating load. Hence, the focus was on electricity generation.

One of the first design options considered was a small Rankine cycle steam power plant. The research team considered both standard grate boilers and close-coupled gasifier boilers for generating steam and looked at condensing turbines because they are the most efficient at producing electricity and, given the discussion above about the HVAC systems, there was no use for process steam at the Rancheria. While the team was able to find a few units available in the size range they were interested in (100 to 500 kW), most steam turbines are larger (1 MW and above). In addition, smaller turbines are typically designed for non-condensing applications where some of the steam is utilized for other energy demands and electrical generation efficiencies are lower. Because the available small steam turbines were fairly expensive and not very efficient (10% efficient), the economics looked poor and it was decided a steam turbine was not a good fit. Interestingly, the estimated costs for a small Rankine cycle steam power system were roughly equivalent to the costs to date for the BIGFC system, in the $3-4 million range. This equivalency provides insight into project pricing for biomass-fueled, distributed generation systems of this size.

The other distributed biomass energy system option considered was a gasification system. Once the biomass is gasified there are various options for generating electricity using the syngas produced. This includes running an internal combustion engine generator, running a combustion turbine, or running a fuel cell electric generator. There are also various gasifier technology options, and each type produces syngas with different characteristics. Gasifier types include updraft or downdraft fixed bed, entrained flow and fluidized bed, moving bed, auto thermal versus allothermal (externally heated), and plasma. Fixed bed, fluidized bed and entrained flow types all utilize partial combustion of the biomass internal to the reactor as a means of generating heat to drive the reaction (autothermal). If air is used as the oxidant there will be a substantial amount of nitrogen in the syngas that will decrease its heating value. Externally heated units must provide the heat needed from and external source[1], but no air is needed within the reactor since combustion is not desired in the reactor. This can allow for production of a syngas with higher energy content, and under the right conditions a syngas with higher hydrogen content. Other parameters that can affect the hydrogen content are reactor temperature, pressure, and water or steam content.

The research team identified and engaged with various technology vendors in an attempt to find a system that would meet their needs. After substantial effort and analysis, it was decided on an externally heated gasifier technology that could produce a syngas with high hydrogen content, and this would be coupled with a fuel cell electric generator. This decision was based largely on the attributes of the technologies, which included the possibility of achieving a high biomass to electricity conversion efficiency. Other decision criteria considered were system functionality and suitability, capital cost, expected operating cost, technology maturity, technology availability, and responsiveness and willingness of the vendor to participate in a grant funded technology demonstration project.

Ballard Power Systems was chosen as the fuel cell vendor. They have been a leading manufacturer of proton exchange membrane (PEM) fuel cells for decades and they stepped forward as a willing partner. PEM fuel cells require pure hydrogen, so this meant that a gasifier that produced a syngas with high hydrogen content would be required. Ballard engineers had identified Proton Power, Inc. as a possible gasifier vendor.

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[1] Externally heated autothermal gasifiers are possible if the pyrolysis and gasification processes are separated and heat generated in the exothermic process is used to drive the enothermic process. One such gasifier has been developed by Cortus Energy.

The team visited Proton Power's manufacturing and testing facilities in Tennessee, as well as their first commercial installation at Wamplers Farm Sausage in Lenoir City, Tennessee. Proton Power's gasifier technology, called Cellulose to Hydrogen Power, or CHyP, is an externally heated (allothermal) pyrolysis gasifier reactor that could purportedly produce syngas with hydrogen content (by volume) of 50% to 60% and 10% to 20% carbon monoxide, with the remainder being carbon dioxide. Their commercially available CHyP gasifier is rated at 750 kWth (250 kWe). Founded in 2005, Proton Power has been developing and testing gasifier technology for over a decade. During site visits to their facilities the team was able to observe their smaller prototype units in operation.

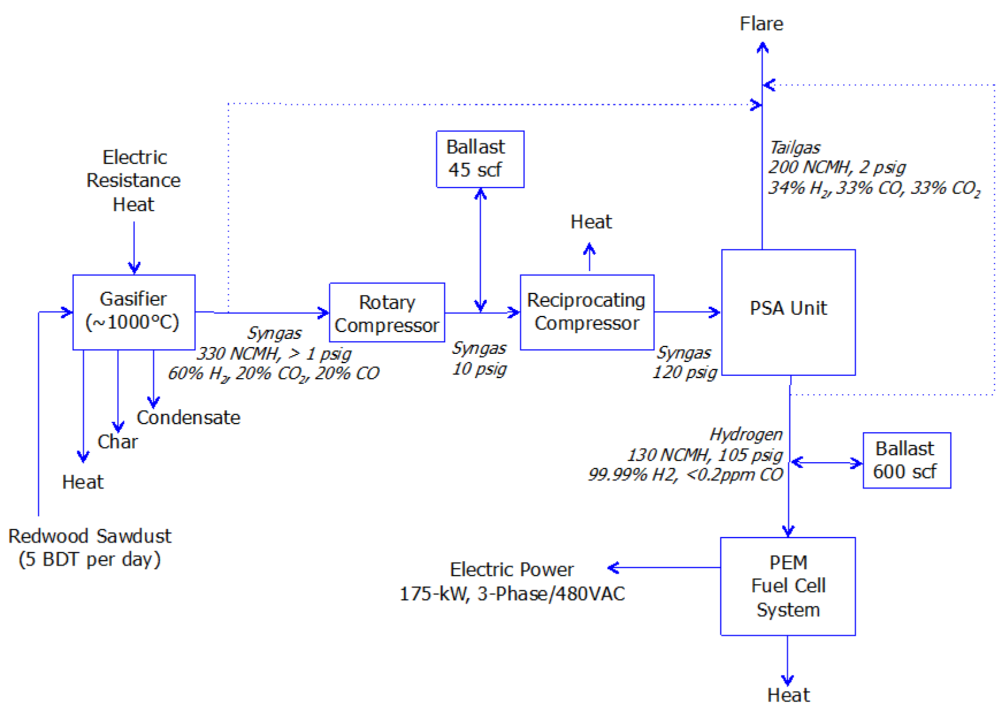
Cortus Energy, based in Sweden was also contacted and visited. Their WoodRoll® technology is another externally heated gasifier technology that produces a syngas with a high hydrogen content. In the end the team decided on Proton Power, as their gasifier system was more fully developed and their U.S. location simplified project coordination. This project became Proton Power's second commercial installation.

The other major components required in the system were determined to be a rotary claw compressor, a reciprocating compressor, and a pressure swing adsorption (PSA) unit.

2.1.1.2 Process Flow

A process flow diagram of the system is shown in Figure 3 and a description follows.

Figure 3: DG Biomass System – Process Flow



Source: Schatz Energy Research Center

Redwood sawdust is deposited into a feed bin in the fuel storage building. Augers at the bottom of the bin move it to a bucket elevator conveyor belt, which lifts it high in the air and delivers it into a hopper. From there it is augered via a covered trough to the adjacent gasifier building where it is transferred into a feed hopper for the gasifier system.

Once in the gasifier system, the feedstock drops through an air-lock rotary valve and then through slide gate valves that keep air from entering the system. The biomass feed is moved via augers into an electrically heated gasifier reactor. The reactor is divided into four zones, with heat provided to each zone controlled by silicon-controlled rectifiers (SCRs). The reactor is heated to about 1100°C during operation.

Char generated in the reactors exits through dual slide gate valves to prohibit air intrusion. The char is dropped into a water-cooled trough where it is cooled while being augered through the system. A second auger then transfers the char out of the gasifier building to a char collection bin, where a dust collector pulls fine char dust out of the system and the larger char particles drop into a metal bin for periodic removal.

The syngas generated in the gasifier reactor flows through the incoming biomass material via a "recapture" box. This serves to partially filter the gas and remove tars that can then be reintroduced to the reactor. This also preheats the biomass. After passing through the recapture box the syngas is cooled in a condenser and then passed through a filter. The syngas generated in the reactor is at only a few inches of water column of gauge pressure, so a rotary claw compressor is used to pull the gas through the filter system and then compress the gas to approximately 10 psig. At this point the gas is delivered to downstream components through a product delivery isolation valve.

The gas delivered by the rotary claw compressor is fed to oil-less reciprocating compressor to boost the pressure to 120 psig. A syngas buffer tank located between the two compressors helps minimize pressure deviations between these components. In addition, the speed of the reciprocating compressor is controlled to maintain a stable suction pressure.

The syngas is delivered at 120 psig to a pressure swing adsorption (PSA) unit for hydrogen purification. The syngas enters the bottom of the adsorption beds and moves upwards through the columns. The hydrogen moves through the beds the fastest and is delivered as product gas with an expected purity of no more than 0.1 to 0.2 ppm carbon monoxide. When a set of adsorption beds nears their available purification capacity, they are back flushed with pure hydrogen in order to regenerate their purification ability. The gas produced during this back flushing process is referred to as tail gas, and is composed primarily of hydrogen, carbon monoxide and carbon dioxide. The tail gas is sent to a flare system. The hydrogen recovery efficiency for the PSA is expected to be about 70% to 80% depending on CO levels, meaning that 70% to 80% of the available hydrogen in the syngas stream will be delivered as pure hydrogen. The remaining 20% to 30% will be discharged in the taigas.

Pure hydrogen delivered from the PSA will be fed to the fuel cell generator. A hydrogen buffer tank located between the PSA and the fuel cell will help maintain a stable pressure between these two devices. When running at full power the fuel cell generator is expected to provide 175 kW of net electrical power while consuming approximately 12 kg/hr of hydrogen.

Note that waste heat from the gasifier system (cooled char auger and gas condensers), reciprocating compressor (suction, interstage and discharge coolers), and fuel cell system will be rejected to the atmosphere via three closed-loop cooling systems. All three systems feature forced convection radiators, and the compressor cooler also includes a refrigeration loop to boost the cooling capacity when ambient temperatures dictate the need. The waste heat rejected from these systems will be measured and opportunities for waste heat recovery will be considered. In addition, waste heat dumped through the flare system will be measured and waste heat recovery opportunities will be assessed.

2.1.1.3 Site and Facilities Design

The DG biomass facility is located on the Blue Lake Rancheria in the northwest corner of the Rancheria adjacent to the hotel/casino complex (Figures 1 and 4).

Figure 4: Location of DG Biomass Facility on Rancheria Property (View From the Southeast)

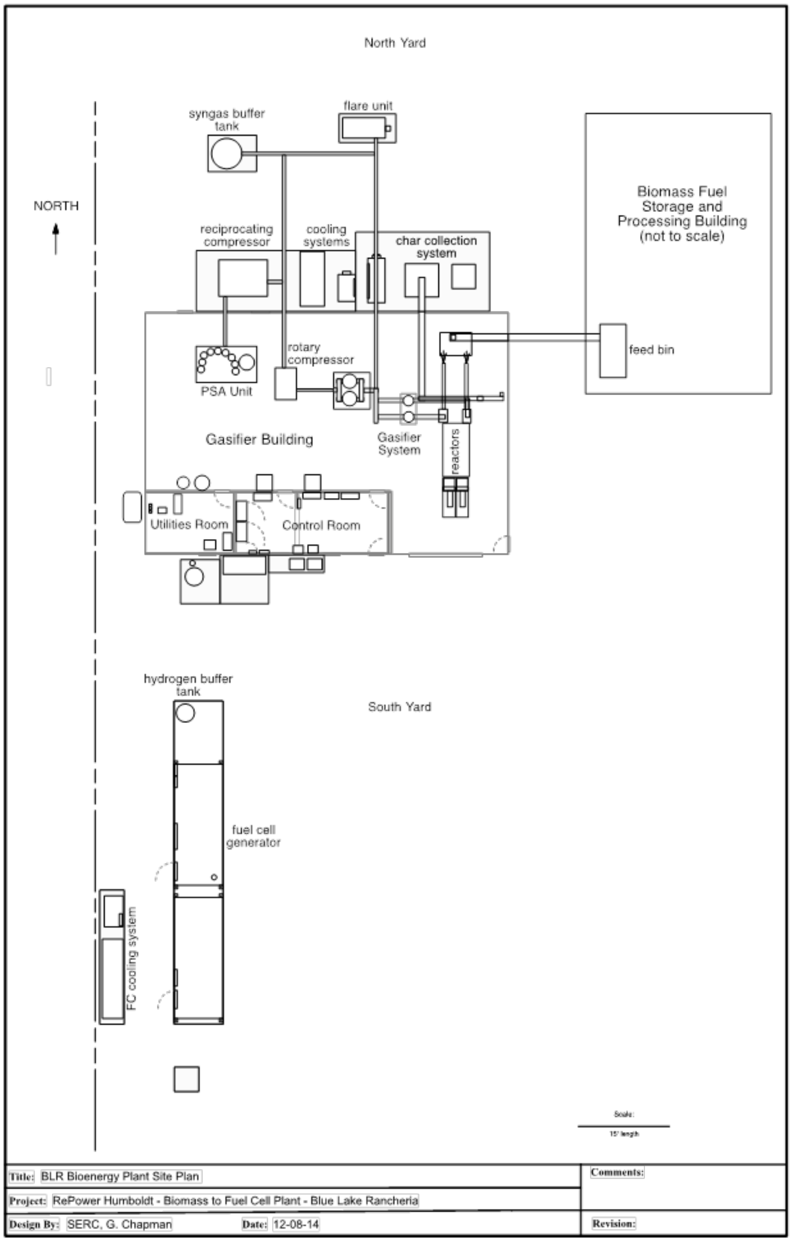
Source: Blue Lake Rancheria Tribe, Photo Credit Toni Ramos

The gasifier building was an existing metal building on the site that was retrofitted to house the gasifier system, PSA, process control system and other auxiliary systems. A pad was poured immediately north of the gasifier building (referred to as the North Yard) where the reciprocating compressor, cooling systems, syngas ballast tank, flare system, biochar collection and dust collection systems are located. A large metal building was erected due east of the gasifier building to store and potentially process biomass fuel. To the south of the gasifier building a concrete pad was poured to support the fuel cell system and associated cooling equipment, as well as the hydrogen ballast tank. This area is referred to as the South Yard. This entire area will be fenced to limit access to authorized personnel only (Figure 5) shows the site layout for the DG biomass facility.

Fuel Storage and Processing Building

The fuel storage and processing building is a prefabricated metal building that was purchased and erected on-site by a local contractor. The building measures 125 feet long x 45 feet wide. It was designed to hold approximately 12-14 days worth of fuel. It features a large roll-up door that allows a live bottom truck to back into the building and dump its load. An area for fuel processing (e.g., screening or other processing if needed) has been provided, but there is currently no fuel processing equipment integrated into the facility.

Figure 5: DG Biomass Facility Site Layout



Source: Schatz Energy Research Center

The biomass feedstock will be redwood sawdust from a local redwood sawmill. Redwood is milled approximately once per week, so deliveries will occur on that basis. The redwood sawdust material, or redwood kerf as it is called, is vacuumed directly off the saw blades, thereby minimizing contaminants. The material is rather consistent in composition with a typical particle size of about 3 millimeters. The moisture content (MC) of the material is about 55% to 60% on a wet basis. The desired MC prior to feeding the material into the gasifier is about 30% to 40%. Methods for drying the material are currently being considered and sources of dryer fuel are being explored.

The sawdust material is dumped on the building's concrete floor and then pushed into a storage area inside the building. When needed, a front-end loader is used to scoop up a load of sawdust and dump it into the feed bin.

Gasifier Building

The gasifier building measures 40 feet wide by 60 feet long and houses the gasifier, the PSA unit, the electrical/control room, the utilities room, and other various auxiliary components. It is a metal building with high ceilings (15 feet plus) that had previously been used for storage and office space. It was retrofitted for use as the gasifier building. Modifications included new electrical systems, explosion proof lighting, and an industrial ventilation system.

North Yard

The north yard area is located immediately to the north of the gasifier building. A concrete pad was poured in this area to support the various system components. This area houses the reciprocating compressor, syngas storage tank, flare system, char bin, dust collection system, and cooling systems for the gasifier and compressor.

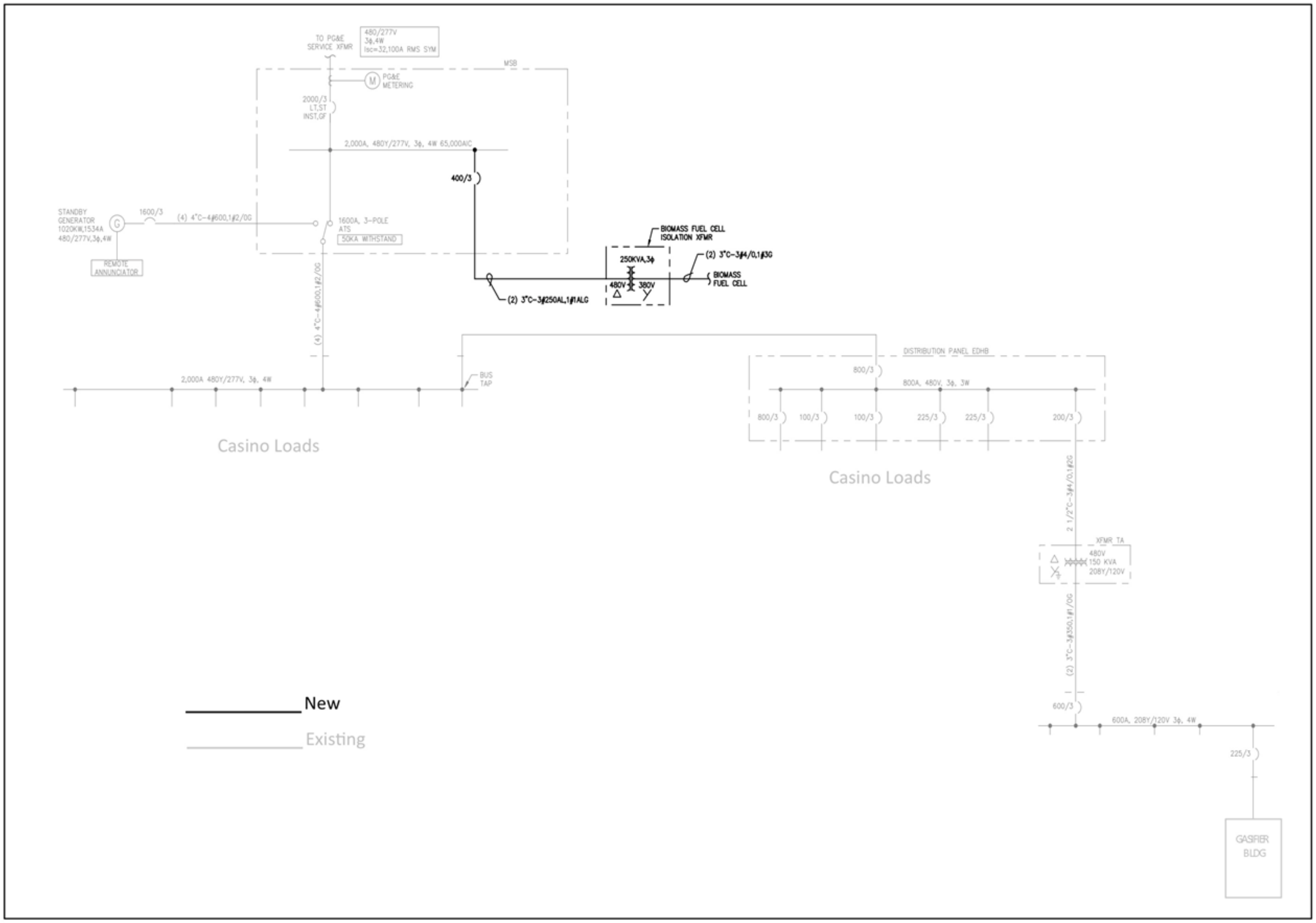
South Yard

The south yard is located to the south of the gasifier building along the west edge of the Rancheria property. The south yard consists of a concrete pad that supports the hydrogen ballast tank and the fuel cell generator. The fuel cell generator is packaged in two ISO shipping containers. The fuel cell module houses the fuel cell stacks and associated gas conditioning and delivery equipment. The power conditioning module holds the inverter, electrical switchgear and control panels.

2.1.1.4 Electrical Systems

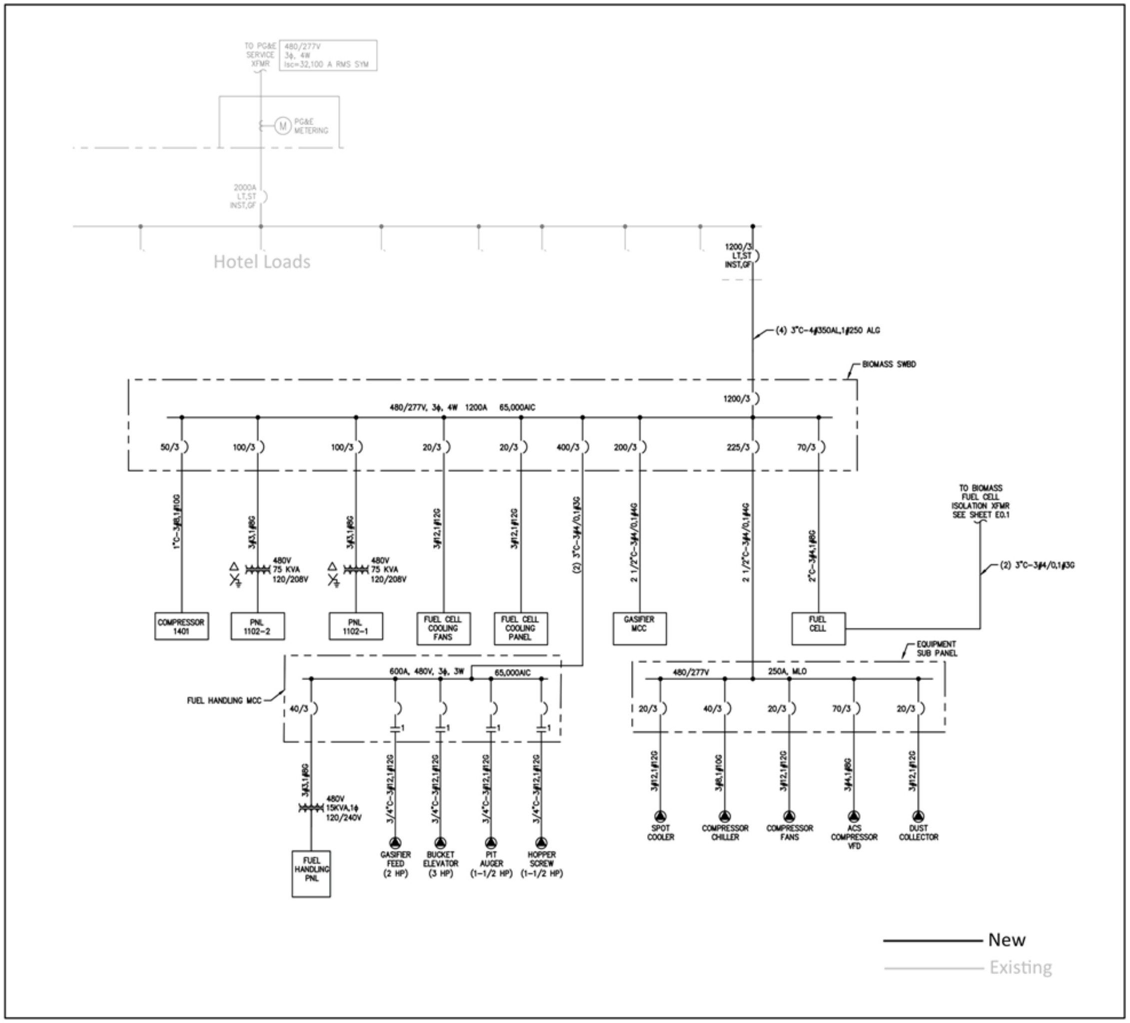
The DG biomass facility is served by a 225A, 120/208VAC, 3-phase service and a 1200A, 277/480VAC, 3-phase service. These electrical services provide the power needed to operate the equipment associated with the DG biomass facility. The power generated by the fuel cell generator is delivered at 380VAC, 3-phase. The voltage on this circuit is boosted to 480VAC via a pad mounted transformer located adjacent to the fuel cell power conditioning module. All power circuits are designed to meet Class 1, Division 2 classified electrical area requirements where necessary. Where required, circuits are run in rigid conduit, though most of the circuits within the gasifier building utilize cable trays. Figure 6 and 7 show the single line electrical diagrams for the DG biomass facility for casino service and the hotel service, respectively. Table 4 provides an electrical load schedule for the DG biomass facility.

Figure 6: Biomass Facility Casino One-Line Diagram



Source: Schatz Energy Research Center

Figure 7: Biomass Facility Hotel One-Line Diagram



Soure: Schatz Energy Research Center

Table 4: DG Biomass Facility Electrical Load Schedule

Ckt#	480VAC/3-Phase/60Hz Loads	Voltage (V)	Circuit breaker rating (A)	Phase
Main	Main breaker	480	1000	3
1	Gasifer System - SCR heater CHyP 0301, PNL-1102 (PPI)	480	100	3
2	Gasifer System - SCR heater CHyP 0302, PNL-1102 (PPI)	480	100	3
3	Gasifer System - motor control panel PNL-1101 (PPI)	480	200	3
4	Instrument Air Compressor CMP-1401 (PPI)	480	50	3
6	(3) Fuel Cell Radiator Fans (Dry Cooler)	480	20	3
7	Fuel Cell Radiator Pump (Dry Cooler)	480	20	3
12	Fuel cell auxiliary power	480	70	3
29	Dust Collector	480	PNL-1101	3
30	Biochar auger	480	PNL-1101	3
31	Fuel handling MCC (fuel storage bldg)	480	400	3
32	Gasifier bldg 480V sub-panel	480	225	3
	480V Sub-Panel			
5	High Press Compressor (Applied Compression Systems)	480	70	3
8	Syngas System Radiator Fans (Dry Cooler)	480	20	3
8	Syngas System Cooling Water Pump (Dry Cooler)	480		3
10	Compressor Chiller / Pump	480	40	3
11	Compressor Radiator	480	20	3

Ckt#	120/208 VAC Loads	Voltage (V)	Circuit breaker rating (A)	Phase
Main	Main breaker	208	225	3
13	PSA Unit (Xebec)	120	20	1
14	Instrument Air Dryer DRY-1401-01 (PPI)	240/208	40	2
15	Nitrogen Generator NGN-1404 (PPI)	120	20	1
16	Gasifier operator panel PNL-1105 (PPI)	120	20	1
17	Syngas analyzer panel PNL-1901 (PPI)	120	20	1
18	Water Softener and Reverse Osmosis System (Columbia)	120	20	1
19	DIW pump/level control (Columbia)	120	20	1
20	Conductivity meter panel (Columbia)	120	20	1
21	Central computer control/DAQ system & trasnducer power supplies	120	20	1
34	Safety system	120	20	1
22	PSA product gas CO monitor	120	20	1
23	Lights_1 (gasifier room)	120	20	1
24	Lights_2 (utility & electrical rooms)	120	20	1
25	Misc. plug loads	120	20	1
26	Telecommunications system	120	20	1
27	Flare blower (1.5 HP)	120/208	20	1/3
28	Gas gen bldg main exhaust fans (2)	208	20	3
33	High Press Compressor (Applied Compression Systems)	120	20	1
35	Gas gen bldg ridgeline exhaust fan + two intake fans	120/208	20	1

Source: Schatz Energy Research Center

Low Voltage Signal and Control Circuits

Low voltage signal and control circuits provide control and monitoring capabilities between individual components and their automated control systems, as well as between the central control system and the overall system. Most signal and control circuits are 24VDC, though a few circuits are 120VAC (e.g., solenoid valves, alarm lights). All signal and control circuits are designed to meet Class 1, Division 2 classified electrical area requirements where necessary. Where required, circuits are run in rigid conduit, though most of the circuits within the gasifier building utilize cable trays. Section 2.1.1.6 discusses the control systems.

2.1.1.5 Mechanical Systems

Mechanical systems include the following:

Solids Conveyance:

- Biomass Feed System
- Biochar Discharge System

Gas Systems:

- Syngas (expect approximately 50%-60% H_2, 10-20% CO, remainder CO_2), pressure ranges from inches of water column in gasifier reactor to about 10 psig out of the rotary claw compressor to 120 psig out of the reciprocating compressor, 45 scf of storage at 10 psig
- Tail gas from PSA (approximately 25% H_2, 10% CO, and 65% CO_2, depends on syngas composition), pressure ranges from 0-25 psig
- Hydrogen, pressure ranges from about 80-105 psig, 600 scf of storage at 100 psig
- Nitrogen (for combustible gas system purging and pneumatic valve/device operation), pressure ranges from 5-90 psig
- Compressed air system for plant air, pressure up to 120 psig
- Natural gas for flare burner package, pressure is approximately 8 inches of water column

Liquid Systems:

- Municipal water
- Deionized water system
- Water/glycol coolant systems
- Syngas condensate system

2.1.1.6 Control Systems

A simplified system wide piping and instrumentation diagram describes the basic control logic for the system (Figure 8). The DG biomass system is designed to be an automated system that can run unattended, though it will require frequent monitoring and interaction to add fuel, remove char, and generally make sure the system is running smoothly. The DG biomass system has been designed with modular control functions, meaning that most subsystems are independently controlled and capable of running as stand-alone devices. There is some amount of handshaking that must occur between the integrated systems, and there is a central control system that serves to monitor the entire system and perform rudimentary control functions. Figure 9 shows the system control system architecture.

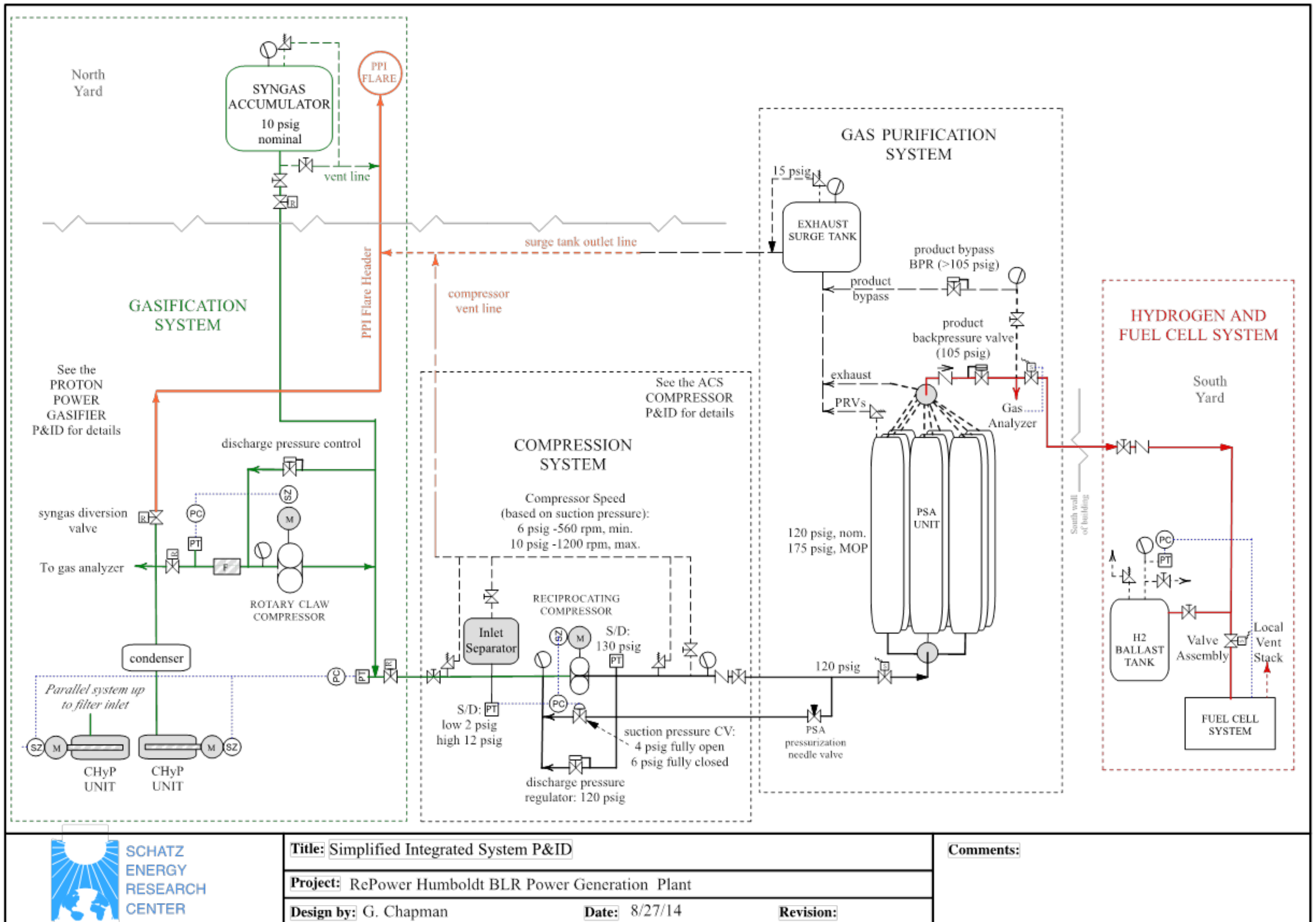
The system wide P&ID starts with the gasifier CHyP units shown in the bottom left corner of the diagram. The gasifier can be operated with a fixed biomass feed auger speed for stable gas generation rate or with a varying feed auger speed to generate sufficient syngas to maximize fuel cell power output. The gas analyzer on the outlet of the condenser will monitor generated syngas composition to ensure the carbon monoxide (CO) concentration is below the maximum allowable for gas purification. If the CO level is greater than 20%, the syngas will be diverted to the flare until CO level returns to an acceptable level. The generated syngas is pulled through the system by the rotary claw compressor and is delivered to the syngas accumulator. A pressure control loop is used to monitor gasifier system pressures and control the speed of the claw compressor to maintain a target pressure. A recycle regulator is located on the outlet, and it will spill gas back to the suction side of the compressor to prevent over pressurization of the discharge system. Operation of all the equipment shown in the dashed gasifier box on the diagram is accomplished by the Proton Power gasifier control system.

The reciprocating compressor is an independently controlled unit that boosts the syngas pressure up to approximately 120 psi for delivery to the PSA gas purification unit. The reciprocating compressor is equipped with both a variable speed drive system (primary flow control) and a recycle control valve for final trim control. Both devices take their control signals from the suction pressure transmitter. The discharge pressure regulator will spill back gas when discharge pressure is too high (e.g. when the compressor discharge valve is closed during PSA pressurization).

The PSA unit pressure will be determined by the set point of the product back-pressure valve (minimum of 105 psig). A carbon monoxide gas analyzer will continuously monitor the outlet hydrogen gas stream and if CO levels rise above 0.1 ppm the PSA outlet solenoid valve will be closed. PSA outlet line pressure will then increase until the unit's pressure reaches the product bypass valve set point (>105 psig), at which time product gas will be diverted to the flare. Gas monitoring will continue during diversion and when the CO level in the hydrogen product gas drops below 0.1 ppm the solenoid will reopen and gas will once again be delivered to the hydrogen ballast tank.

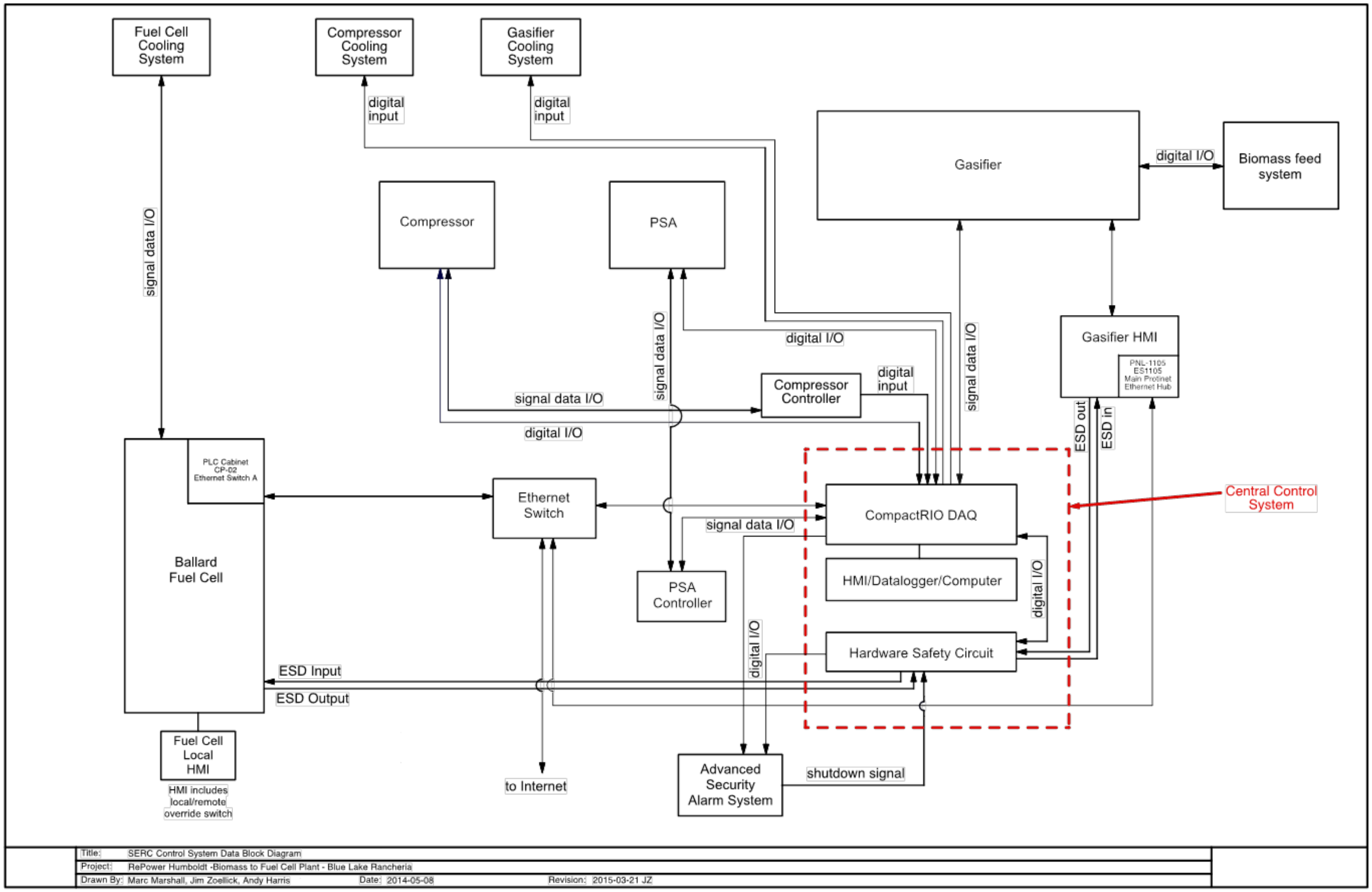
The fuel cell power level will be determined depending on the amount of hydrogen gas available. The ballast pressure control system will adjust the FC power to maintain a target pressure (e.g. 95 psig) in the ballast. The minimum recommended ballast pressure is 80 psig to ensure proper purging of the fuel cell stacks.

Figure 8: Simplified System P&ID With Control Logic



Source: Schatz Energy Research Center

Figure 9: DG Biomass Facility Control Architecture



Source; Schatz Energy Rsearch Center

Central Control and Monitoring System

The central control system is composed of a National Instruments CompactRIO control and monitoring system running a compiled version of custom program written in LabView software. The central control system provides supervisory control functions between the various system components (Figure 9). For example, the central controller has the ability to trim the syngas production rate up or down by 10% from its internal set point. Similarly, the central controller can specify the fuel cell power generation level between 40% and 100% of its maximum output, thereby also affecting the fuel cell hydrogen consumption rate. The central controller provides all control functions for the PSA system, including solenoid valve control and rotary valve speed. It also provides on/off control of product gas delivery from the gasifier, on/off control of the reciprocating compressor, on/off control of product gas delivery from the PSA, and on/off control of the gasifier and reciprocating compressor cooling systems. The central controller also monitors system status for most components in the system.

The central control system also features a hardware safety circuit that monitors the emergency shutdown button circuit, initiates emergency shutdowns for individual components, and provides ventilation control functions. These safety related functions are integrated with the fire and life safety alarm panel, which was installed by a local fire alarm provider.

Finally, the central control and monitoring system provides data monitoring and data logging capabilities to allow monitoring and evaluation of system performance. The central control system connects via Ethernet link to both the Ballard fuel cell system and the Proton gasifier system and can access operational data from both of these systems. In addition, there are numerous individual transducers integrated into the central control and monitoring system that allow collection of system operating parameters. These include system gas pressures, temperatures and flows, component electrical power consumption values, and cooling water flows and temperatures. Monitoring of these parameters allows mass and energy flows to be analyzed. Additional parameters are also monitored to provide additional safety and diagnostic features, such as ventilation airflows, ambient contaminant gas concentrations (hydrogen and carbon monoxide), and emergency stop button positions. A complete I/O list for the central control system is provided in Appendix A.

Individual Component Control Systems

Many of the major system components have their own logic controllers as noted below:

- Biomass feed system (programmable logic controller)
- Proton Power Gasifier System (Siemens SIMATIC PCS 7)
- Flare System (Honeywell controller)
- Applied Compression Systems Reciprocating Compressor (Centurion™ C4 Series Configurable Controller from Murphy by Enovation Controls)
- Ballard Power Systems Fuel Cell System (Allen Bradley programmable logic controller)

- DryCooler Cooling System (Yokogawa Temperature Controller, Carel pCO5 Controller)

2.1.1.7 Major Equipment Specifications

A list of the major equipment procured for the DG biomass facility is included in Section 2.1.4. Specification sheets for major components are included in Appendix B.

2.1.1.8 Fire Alarm and Life Safety Systems

The DG biomass facility features a robust fire alarm and life safety hazard detection and alarm system. Advanced Security Systems, a regional alarm company, provided a UL listed Notifier fire alarm panel to meet the project specifications. The system includes fire alarm pull stations, heat detectors, smoke detectors, CO detectors, and a hydrogen flammable gas detector. In addition, the system will accept inputs from the central control system and the Proton gasifier system to initiate system wide shutdowns when deemed necessary. The alarm system features multiple alarm levels, notification protocols, and system responses as outlined in Table 5. In addition, the alarm panel controls status beacons, alarm strobes and audible horns that will alert personnel if there is a hazardous situation and will provide an indication of system status (Figure 10).

Table 5: Fire and Life Safety Alarms

Alarm Level	Alarm Triggers	Alarm Indication	Alarm Notification	Alarm Action
Level 1 – Fire	Pull box, heat detector, smoke detector, fire sprinklers	Clear strobe light and horn per NFPA	Fire department, local personnel	Shutdown DG biomass system, shutdown ventilation if fire detected gasifier building
Level 2 – Severe Hazard	CO detection (PPM), H_2 detection (% LFL), Emergency shutdown button	Red strobe light and distinct horn tone	Local personnel	Shutdown DG biomass system
Level 3 - Supervisory	Low hazard level system fault	Amber strobe light	Local personnel	N/A
Normal Operation	Normal operation	Green steady light	N/A	N/A

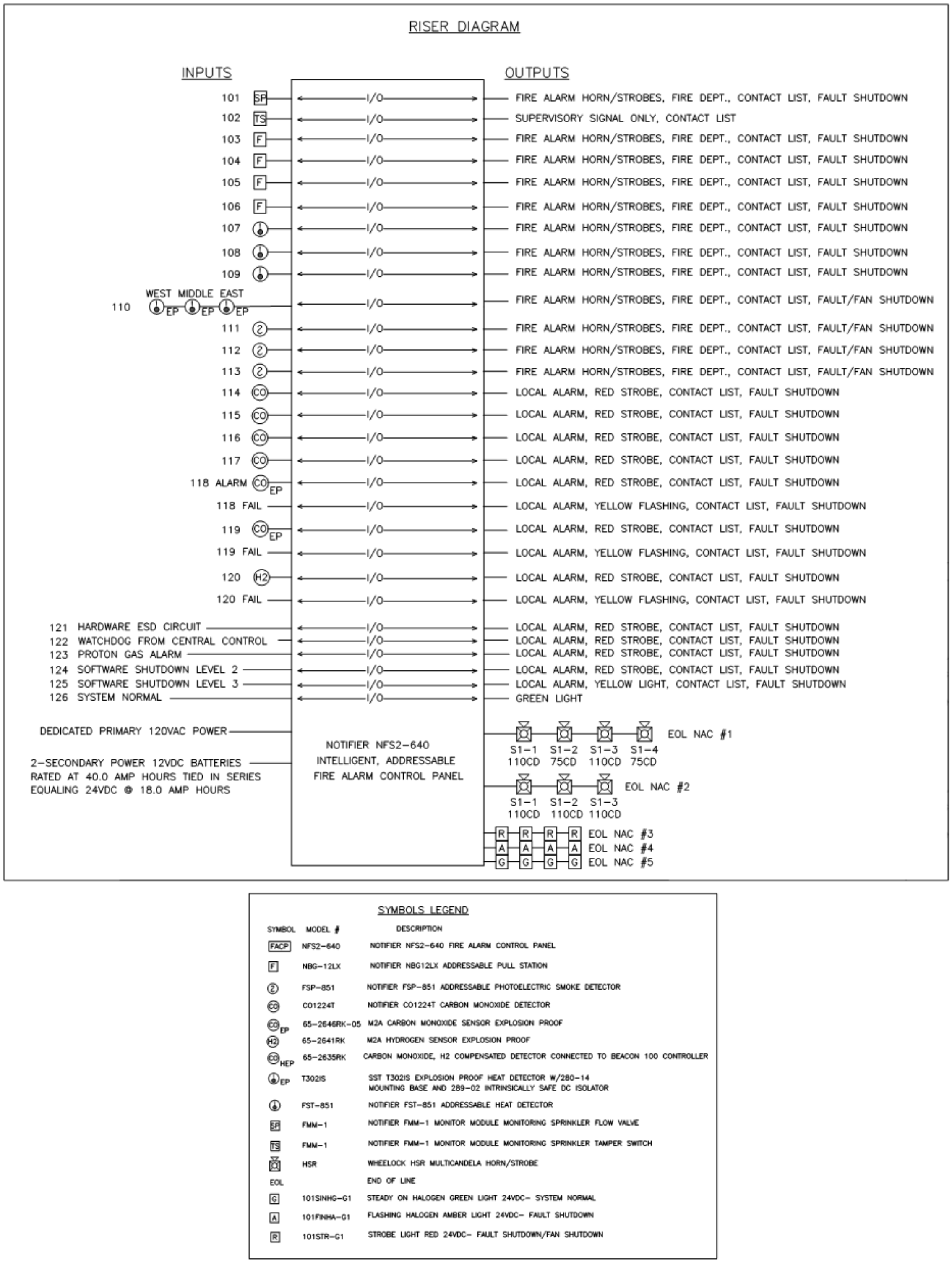
Source: Schatz Energy Research Center

A ventilation system was designed for the gasifier building and installed by a local contractor. The system is designed for six air changes per hour and uses a 3800 cfm wall mounted upblast centrifugal ventilator. A second identical fan is activated if combustible or toxic gas is detected in the space, raising the airflow to 7600 cfm and 12 air changes per hour. The exhaust fans are centrally located high on the north wall of the building, and intake vents are locate at floor level around the south, east and west walls. This draws fresh air in low to the ground and sweeps it across the equipment before rising and exhausting high on the north wall. By using exhaust fans it is certain the building will be maintained at a negative pressure, thereby ensuring that a gas leak inside the building will not be uncontrollably forced out of the building. This will also ensure that combustible or toxic gases are not forced into the electrical/control room. The electrical/control room and the utility room both feature intake fans that will bring in fresh air and slightly pressurize these spaces, again ensuring that toxic or flammable gases are not forced into these areas. Louvers on electrical/control room doors will exhaust air into the gasifier room.

The ventilation system was designed using the CONTAM Building Model (NIST 2015) obtained from the National Institute of Standards and Technology. CONTAM is a multi-zone airflow and contaminant transport analysis software. The model assessed the impact of various contaminant leak scenarios and the effectiveness of various ventilation designs. A smoke test in the building was performed to assess the effectiveness of the chosen design, and then made modifications based on empirical observations.

Additional safety features include a fire sprinkler system in the fuel storage building, housekeeping procedures to minimize dust build-up in the fuel storage building, fire extinguishers, and a fire hydrant located immediately adjacent to the fuel storage building and the biochar bin. In addition, a security fence will limit site access to authorized personnel only. No smoking will be allowed on the site.

Figure 10: Fire Alarm Riser Schematic



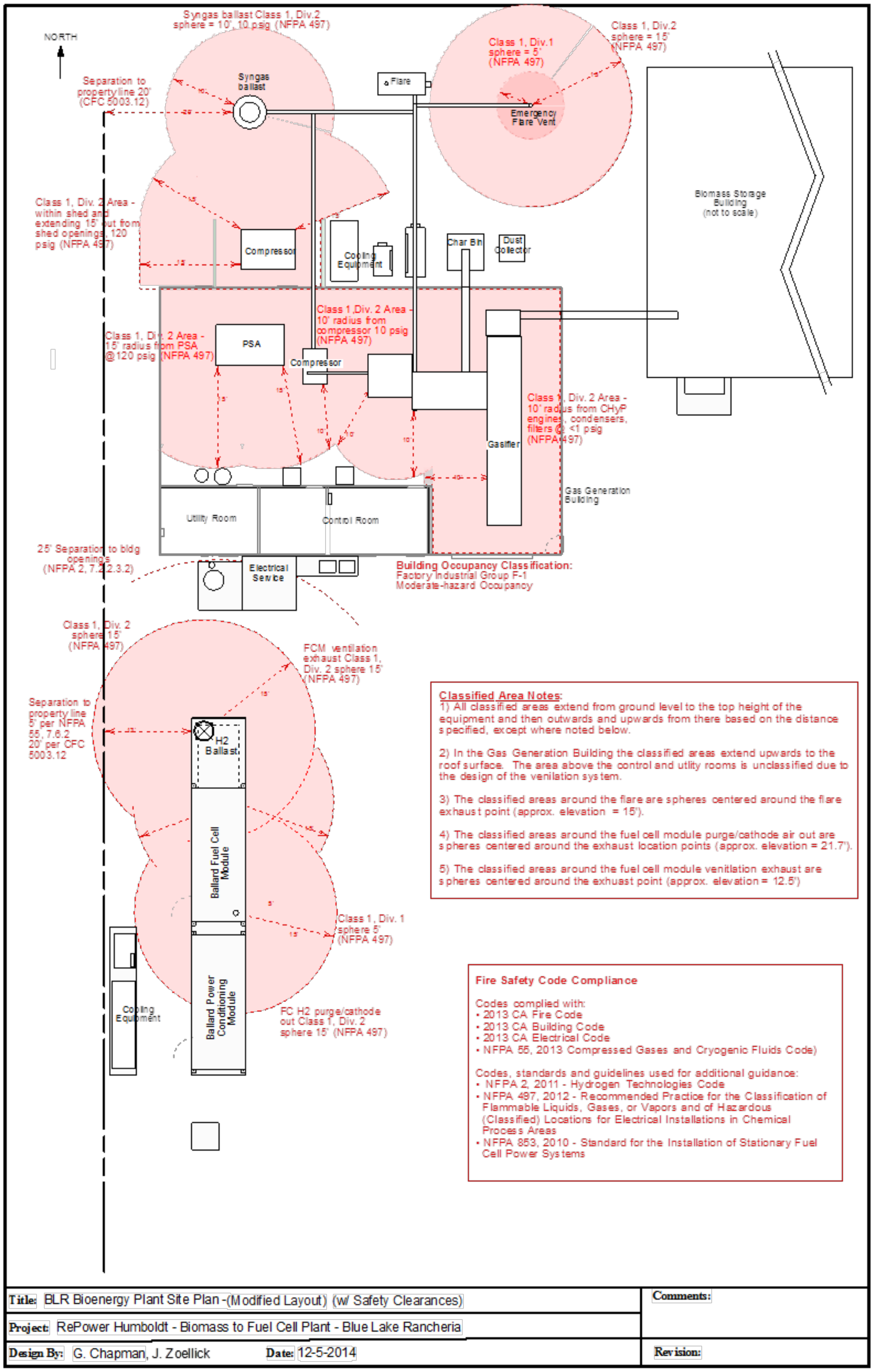
Source: Schatz Energy Research Center and Advanced Security Systems

2.1.1.9 Codes and Standards Compliance

The DG biomass facility meets all applicable building and fire codes. The permitting authority for the DG biomass facility is the Tribal Business Council of the Blue Lake Rancheria, California, a federally recognized Native American tribal government. The Business Council receives permit requests and authorizes any and all construction projects on reservation lands. The Tribe adopts building codes and standards that are consistent with or more current than other local municipal/state entities, and has service professionals design to those adopted codes and standards. This project was designed to comply with the 2013 California Building Codes, including the California Fire Code, California Electrical Code, California Building Code, California Mechanical Code and California Plumbing Code.

A formal plan submittal, review and approval process concerning applicable codes and standards with regard to building occupancy classification, hazardous area electrical classification and separation distances, ventilation, wall coverings, sprinkler system, explosion control and deflagration venting, CO classification, flammable dust hazard, and gasifier security barriers was required and performed by SERC, local fire jurisdiction, and equipment manufacturers. Hazardous electrical classifications and required setbacks are shown in Figure 11. In addition, both metal buildings include stamped drawings and are designed to Seismic Zone 4 and sustained wind loads up to 80 mph. A licensed California Structural Engineer designed and approved all of the hold down systems for the gasifier equipment as per Seismic Zone 4. The fire sprinkler plans, underground fire line and appurtenances were submitted to the local fire jurisdiction (Blue Lake Fire Department- Ray Stonebarger, Chief) and any required changes were integrated into the plans. The Tribe maintains current static and residual pressure readings on the main fire line. The fire system was designed based on available fire line pressure and specified fire-flow requirements according to building type and occupancy.

Figure 11: Classified Electrical Areas and Required Setbacks



Source: Schatz Energy Research Center

2.1.1.10 Safety Review

Two third party safety reviews were conducted for the DG biomass facility in November of 2014. David Kahn of RSSI Consulting, LLC conducted the first review. A Process Hazard Analysis study (PHA) of the BIGFC process was conducted at the project site using the Hazard Identification (HAZID) methodology. SERC engineers and BLR staff provided a site tour and a project overview and provided all required background materials. Engineers from Proton Power were on-site to participate in the HAZID review. Technical representatives from all other major component vendors also participated via phone and Internet. This included representatives from Ballard Power Systems, Applied Compression Systems (reciprocating compressor), and Xebec Adsorption, Inc. (PSA).

The HAZID review examined each major part of the process, as well as more general site level safety issues. The topic areas covered included:

- Biomass Storage
- Gasification System
- Reciprocating Compressor
- Pressure Swing Adsorption Unit
- Fuel Cell Generator
- Flare System
- Project Wide Safety Issues

During the review a list of follow-up recommendations was developed to address various safety issues that were raised. These items were considered and addressed where warranted.

Two consultants who were under contract to the US Department of Energy conducted a second safety review. The Blue Lake Rancheria Tribe requested technical assistance from the US Department of Energy (DOE) Office of Indian Energy Policy and Programs for technical support to perform a safety review of the facility. DOE's Bioenergy Technologies Office (BETO) was contacted for advice, and as a result, two experienced safety professionals, Ed Skolnik (Energetics Incorporated) and Robert Davidson (Davidson Code Concepts, LLC) were chosen to conduct a site-visit to provide the requested safety assessment.

SERC engineers and BLR staff provided a site tour and a project overview, and provided all required background materials. Potential safety issues were identified and discussed during the site tour and ensuing discussion. The safety review team then prepared and submitted a report outlining observations and recommendations. The project team reviewed the observations and recommendations and addressed identified safety issues where warranted.

2.1.2 DG Biomass Interconnection Agreement

Prior to the Notice of Proposed Award, the Blue Lake Rancheria Tribe (BLR) informed their local utility, Pacific Gas and Electric Company (PG&E) that they were pursuing a DG biomass system and would eventually seek an interconnection agreement. PG&E representatives provided feedback on the process. Serraga Energy, working with BLR, SERC and the electrical engineer contacted PG&E's interconnection group. An interconnection application was prepared for submittal under the Expanded Net Metering program, NEMEXP (PG&E Form 79-974). This was allowed because the fuel cell is to be fueled with renewable biomass fuel. This provided BLR with a more favorable interconnection process (fewer fees) than they would have experienced under the NEMFC agreement for non-renewable powered fuel cells. A corresponding interconnection agreement, the "Interconnection Agreement for Net Metering for a Renewable Electrical Generation Facility of 1,000 Kilowatts or Less, Except Solar or Wind" (PG&E Form 79-1137) was prepared. The agreement required significant insurance coverage, including but not limited to $2 million for each occurrence if the gross nameplate rating of the generating facility is greater than 100 kW, and PG&E had to be named as additional insured. This required BLR to have its entire policy rewritten and subjected to underwriting.

2.1.3 DG Biomass Fuel Supply Contract

During the application process for this grant opportunity, the Blue Lake Rancheria staff conducted initial investigations into biomass fuel availability, specifically local sawdust with certain characteristics -- <¼" in size, ~40% moisture content, in quantities sufficient to supply ~5 tons per day. A prior Woody Biomass Resource Supply Study conducted by the Humboldt State University Department of Forestry guided Tribal Staff in its outreach to local mills and other vendors. There are several mills in the area that have sufficient supplies of sawdust, but only one – Humboldt Redwood Company (HRC) – had just invested in operational upgrades that included vacuuming "kerf" sawdust directly from the saw blades. This upgrade ensures a source of clean and uniform sawdust fuel. Further, HRC is Forestry Stewardship Council certified for its environmentally sustainable forest management practices.

BLR staff reached out to HRC to explore the opportunity of securing redwood sawdust for the DG biomass facility, and HRC was found to be a willing supplier. HRC provided many samples of different kinds of sawdust (Douglas Fir, Redwood, planer shavings, kerf) for testing at the Proton Power gasification test lab in Tennessee. Further, HRC was the first major forestry company in the region to achieve certification from the Forestry Stewardship Council for exceptional forest management practices. Lastly, HRC's price per ton for fuel was competitive with other area vendors. Accordingly, Serraga has written agreements with HRC for as much redwood kerf sawdust as needed to run the plant for as long as needed. HRC is also willing to work with Serraga and BLR to provide different types of fuel as needed for ongoing fuels testing. Serraga also has an agreement with an independent local trucking company for hauling the fuel using a live-bottom truck bed that will reduce dust and contaminants by unloading material directly into the building storage area.

2.1.4 DG Biomass Equipment Procurement

All equipment, supplies, materials and services for the DG biomass facility were procured through Serraga Energy LLC, the Blue Lake Rancheria's energy business entity. The SERC engineering team was tasked with specifying most items associated with the process systems. BLR staff specified site and facilities related items, as well as the biomass feed system. The major items procured for the process systems in the DG biomass facility are listed in Table 6. See Appendix B for detailed specifications of the major components.

Table 6: DG Biomass Facility Process Systems Procurement

Item	Model	Vendor
Biomass feed system		O&M Industries, Screw Conveyor Corp., Rick Tyson Controls
Gasifier system (including feed system, reactors, biochar discharge system, condensers, filters, rotary claw compressor, flare system, syngas storage)	500 kW CHyP Unit	Proton Power, Inc.
Reciprocating compressor	VLRG-9	Applied Compression Systems
Pressure swing adsorption unit	H-3200	Xebec Adsorption, Inc.
Fuel cell generator	175 kW ClearGen™	Ballard Power Systems
Hydrogen storage tank	MB-729-B	Roy E. Hanson Jr. Mfg.
Cooling systems	Gasifier: LS-2000-NF air-cooled pump station Compressor: Omni-Chill PAC-104 chiller and pump station with an Aqua-Vent AVR-25 heat exchanger Fuel Cell: CleanLOOP CSX-200-120-ST-MP pump station with an Aqua-Vent AQR-32 heat exchanger	DryCoolers, Inc.
Nitrogen supply system	Series 3 N[2]	Nano Purification Solutions
Compressed air system	SSR UP Series 20-150	Ingersoll Rand
Air dryer	D-Series[2]	Nano Purification Solutions
Dust collection system	Downflo® Oval DFO-3-6	Donaldson Torit
De-ionized water system	MATC-15M-1 Twin Alternating Softener System and a MRO-1500-2.5 DLX Reverse Osmosis System	Marlo Inc.
Central control and monitoring system	CompactRIO and LabView software	National Instruments
Fire and life safety alarm system	Notifier, NFS 640 fire alarm control panel with custom smoke, heat and gas detectors	Advanced Security Systems
Ventilation system	Fumex WFX10B & WFX14B centrifugal exhausters and Nailor Industries Inc. louvers	O&M Industries

Source: Schatz Energy Research Center

2.1.5 DG Biomass Site and Facilities Work

All site and facilities work at the Rancheria was managed and coordinated by Serraga staff, including construction and facilities management. SERC engineering staff assisted where appropriate. Local contractors conducted most work under the direction of Serraga staff and SERC engineers. The major site and facilities work topic areas and the parties responsible for the work are listed in Table 7.

Table 7: DG Biomass Facility Site and Facilities Work

Item	Work Performed By
Grading	Kernen Construction
Trenching	Kernen Construction
Concrete pad construction	Kernen Construction
Metal building installation	Kernen Construction (Varco-Pruden supplied building)
Gasifier building retrofits	Serraga Energy, LLC Staff
Electrical utilities	Colburn Electric
Water utilities	Serraga Energy, LLC Staff
Natural gas utilities	Serraga Energy, LLC Staff
Communication utilities	Blue Lake Rancheria Staff
Fire and life safety alarm system	Advanced Security Systems
Ventilation system	O&M Industries

Source: Schatz Energy Research Center

2.1.6 DG Biomass System Installation

The installation of all DG biomass facility process systems was managed and coordinated by Serraga staff with assistance from SERC engineering staff. Local contractors, SERC engineers, Proton Power engineers and technicians, and Blue Lake Rancheria staff installed all system components. Table 8 lists the major items installed and the responsible parties who installed the items.

Table 8: DG Biomass Facility Process Systems Installation

Item	Installed By
Biomass feed system	O&M Industries, Rick Tyson Controls
Gasifier system (including feed system, gasifiers, biochar discharge system, condensers, filters, rotary claw compressor, flare system, syngas storage)	Proton Power, Inc.
Reciprocating compressor	SERC
Pressure swing adsorption unit	SERC
Fuel cell generator	Ballard Power Systems
Hydrogen storage tank	SERC
Cooling systems (gasifier, reciprocating compressor, fuel cell generator)	SERC
Nitrogen supply system	Proton Power, Inc.
Compressed air system, air dryer	Proton Power, Inc.
Dust collection system	Proton Power, Inc.
De-ionized water system (water softener, reverse osmosis)	Marlo Inc.
Central control and monitoring system	SERC
All electrical system circuits	Colburn Electric

Source: Schatz Energy Research Center

2.1.7 DG Biomass Start-up and Commissioning

Start-up and commissioning activities for all major system components were conducted by Serraga staff, SERC engineers, and in some cases product vendor staff. Commissioning activities for major components are listed inTable 9.

Table 9: DG Biomass Facility Commissioning Activities

Item	Responsible Party	Commissioning Activities
Biomass feed system	O&M Industries, Serraga Energy, LLC staff	Convey biomass through feed system, drop out of chute between buildings, set speed
Gasifier system (including feed system, gasifiers, biochar discharge system, condensers, filters, rotary claw compressor, flare system, syngas storage)	Proton Power, Inc.	Pressure test system, test and confirm all data I/O, test and confirm operation of all valves, test and confirm operation of all sensors, test all auger motors for proper rotation and function, heat reactors without fuel, heat up flare system and test temperature feedback loop, test rotary claw compressor with air, test and set pressure regulators, test safety shutdown systems and faults
Reciprocating compressor	SERC	Pressure test system, test motor rotation, test system operation including motor speed control and low suction pressure spillback control
Pressure swing adsorption unit	SERC	Pressure test system, test and confirm operation of all valves, test rotary valve motor operation including VFD speed control, check regulator set points
Fuel cell generator	Ballard Power Systems	Pressure test system, test and confirm all data I/O, test and confirm operation of all valves, test and confirm operation of all sensors, test all motors for proper rotation and function, test and set PRVs, test safety shutdown systems and faults
Hydrogen storage tank	SERC	Pressure test system
Cooling systems (gasifier, reciprocating compressor, fuel cell generator)	SERC	Flush systems, fill with glycol water mixture, leak test, confirm proper rotation of motors, confirm thermostat set points
Nitrogen supply system	Proton Power, Inc.	Pressure test system, test and confirm operation
Compressed air system, air dryer	Proton Power, Inc.	Pressure test system, test and confirm system operation
Dust collection system	Proton Power, Inc.	Test and confirm system operation
De-ionized water system	Marlo Inc.	Pressure test system, test and confirm system operation
Central control and monitoring system	SERC	Test and confirm all data I/O, test and confirm operation of all sensors and control points, test safety shutdown systems and faults
Fire and life safety alarm system	Advanced Security Systems	Test and confirm all data I/O, test and confirm operation of all sensors and control points, test safety shutdown systems and faults
Ventilation system	O&M Industries	Test motor rotation, confirm air flow specifications, balance ridgeline duct system

Source: Schatz Energy Research Center

2.1.8 DG Biomass System Test Plan

A DG Biomass System Test Plan was developed to assess the performance of the BIGFC system. The objectives of the proposed tests were to evaluate the performance of the gasifier, PSA, and fuel cell subsystems individually, as well as of the integrated system as a whole. System performance measures were to include energy conversion efficiency, subsystem power consumption, system availability, and system capacity factor. The technical approach was to prepare a mass and energy balance for each subsystem individually as well as for the integrated system. In addition, and economic analysis was to be performed that includes initial capital costs as well as ongoing operation and maintenance costs. Emissions from the PSA taigas flare were to be evaluated based on manually collected samples analyzed by a third party commercial laboratory.

The DG Biomass System Test Plan is presented in Appendix C.

2.1.9 DG Biomass Data Collection and Analysis

The goal of this task was to operate the DG biomass system and collect operating data for a 30 to 180 day period. Data were to be analyzed to assess the performance of the DG biomass system according to the DG Biomass System Test Plan described in Section 2.1.8.

2.1.10 DG Biomass Project Evaluation

The goal of this task was to assess opportunities for replication and scale-up based on the economic viability of the technology. This was to include an identification of the required parameters for successful scale-up and replication (system performance, fuel costs, energy costs, capital costs, by-product value, etc.) and an identification of the required improvements for successful scale-up and replication, as appropriate.

2.2 Task 3: Develop, Implement and Evaluate Mad River Valley Community Energy Upgrade Program

The *RePower Humboldt Strategic Plan*[2] developed in 2012 outlines a set of strategies for developing local renewable energy resources in Humboldt County. Energy efficiency, distributed energy, electric vehicles, and heat pumps were identified as key strategies for reducing greenhouse gas emissions, increasing renewable energy use, and providing local energy security. The purpose of the Mad River Valley (MRVC) Energy Upgrade Program was to design and implement a pilot program that would be guided by these key strategies, and to evaluate its success in helping to achieve RePower goals. Program design focused on scalability, adaptability, and effectively targeting high-priority locations for renewable energy and energy efficiency upgrades in homes, businesses, and local-government facilities. Program outreach focused on social visibility, opinion leadership and allowed for adaptable approaches to individual energy-use context. Cost and market issues have been identified as common barriers to the successful deployment of energy efficient technologies and distributed energy systems.

[2]Zoellick, Jim. (Schatz Energy Research Center, Humboldt State University). 2013. Humboldt County as a Renewable Energy Secure Community: Analysis and Strategic Planning. California Energy Commission. Publication number: CEC-500-2010-057.

The program attempted to address these barriers through strategic customer outreach, marketing, education, and technical assistance, and by assisting customers in identifying rebates and financing options for implementing upgrades.

The main objective of Task 3 was to develop and implement an innovative, community-based energy upgrade program in the Mad River Valley community that would demonstrate a sustainable model for financing and market deployment. Specific goals included:

- Recruiting contractors and building professionals to participate in training to become qualified to perform home upgrades.
- Engaging the participation of at least six local contractors to provide energy services.
- Conducting outreach and marketing in the target community to garner interest in the program services.
- Developing a financing program consisting of participating lenders who would provide financing options specifically for energy upgrades.
- Securing the participation of one or more local lenders in a local energy upgrade financing program and provide loans to 5-10 participants.
- Performing site assessments and delivering detailed reports of the results to customers.
- Assisting homeowners with projects through the Energy Upgrade California Home Upgrade® (Home Upgrade®) program to get rebates for efficiency upgrades.
- Secure a robust participation of at least 20-60 site assessments and 10-20 upgrade projects.
- Additional objectives for Task 3 included:
- Demonstrate and verify the localized technical benefits and economic viability of air source heat pump systems in Humboldt County.
- Demonstrate and verify the localized technical benefits and economic benefits of electric vehicle charging stations in Humboldt County.

2.2.1 MRVC Program Design and Setup

The MRVC Upgrade Program was designed to engage businesses and individuals in the Mad River Valley in actions that would result in reduced energy consumption, specifically by adopting energy-efficiency measures and renewable energy systems. A one-stop-shop approach was used to provide customers with information, technical assistance, project support, and assistance in obtaining rebates and other incentives, to help guide adoption from start to finish. The program also offered an adaptive approach to serve customer's unique energy-use context (e.g. renters versus homeowners, types of facilities), and multiple avenues to access information and support. The program utilized the local utility's energy savings program to promote no-cost behavioral changes and efficiency measures, and the state Home Upgrade® program to promote deeper energy upgrades as long-term investments. Customers were encouraged to consider switching from high-carbon fuels to renewable alternatives in their building systems where appropriate, and offered no-cost technical assistance and project support when considering solar energy systems. With this approach, the team increased the perceived value of energy upgrades; fill in information gaps about energy-efficient technologies and renewable energy systems, while building professional capacity to support the emerging energy services market. Increasing the perceived value of upgrades, modeling actual costs and savings, and a well-defined and supported pathway through the Home Upgrade® rebate program were some of the strategies deployed to address some of the barriers to adopting energy efficiency measures and renewable energy systems.

2.2.1.1 Target Area

The Mad River Valley Community includes the City of Blue Lake, the Blue Lake Rancheria, and surrounding areas. Efforts to promote energy efficiency in this area previously occurred through the Redwood Coast Energy Watch program. Lighting "sweeps" have provided upgraded lighting technology and water savings measures to many homes and businesses over the past several years.

2.2.1.2 Customer Segments and Eligibility Requirements

The targeted customer segments within the Mad River Valley included homeowners and business owners, facility managers, and community stakeholders. Adaptability was necessary to customize engagement based on specific energy-use context, but all home and business facilities within the program area were eligible to participate and receive services prior to the funding end date. Existing programs that were leveraged have their own eligibility requirements that were communicated to customers and used to guide participants to the best course of action for their unique situation. Eligibility requirements for existing programs are discussed in section 2.2.1.7 Implementation Strategy.

2.2.1.3 Contractor Guidelines and Participation Protocols

With input from local contractors and other topic experts, contractor guidelines and participation protocols to be used in trainings were established for quality assurance and verification requirements for upgrade projects. Established guidelines and protocols for existing programs were leveraged to seamlessly incorporate those services within the comprehensive program offerings and avoid superfluous training or certifications.

2.2.1.4 Tools and Resources

This task involved identifying and setting up required tools and resources, participation forms, site assessment forms, software programs, customer report templates, and project management templates. Leveraging existing programmatic tools and resources as much as possible was key to cost-effectively creating a streamlined program that could easily coordinate with existing programs. Identifying ways that existing programs would be leveraged, where the programs overlapped, and where there were gaps helped identifying the necessary components. Tools were either adopted, modified to meet the MRVC program needs, or developed or set-up to address the gaps of in existing resources.

2.2.1.5 Marketing and Outreach Materials

Initial program materials were developed for marketing and outreach to target contractors, high-priority installations, and relevant community stakeholders early on during the program design phase. These materials included informational packets and a presentation.

2.2.1.6 Implementation Strategy

Implementation of the program involved coordinating with existing programs and strategizing to recruit and prioritize customers through multiple avenues. This ensured that every visit produced at least modest energy savings through leveraged programs, while creating opportunities for customers to learn about and pursue more comprehensive upgrade projects through the program.

Existing programs that were anticipated to be leveraged included trhe following:

- **Redwood Coast Energy Watch**: implemented by RCEA and has existing capacity for completing site assessments, program management, and administration. Provides no-cost efficiency measures through the local utility incentive program.
- **Energy Upgrade California Home Upgrade®**: a whole-house rebate program focused on performance based retrofits. Provides for energy modeling to project energy savings and assist homeowners in choosing appropriate upgrade projects.
- **California Solar Initiative**: a program that offers information about available solar incentives, and provides a database of solar contractors and installers.
- **GRID Alternatives**: a non-profit organization that assists low-income households in obtaining solar electric systems by offering significant rebates. This program was recently opened up to tribal lands.

New Services were also developed and incorporated into program offerings:

- **Solar Site Surveys**: a site assessment utilizing new and existing solar tools and resources to determine the solar radiation potential of proposed solar locations, and analyze the facility's economic potential for solar.
- **Heat Pump Informational Brochures**: to promote heat pumps as an energy-efficient technology and fuel-switching strategy. Identify high-priority locations and analyze the facility's economic potential for savings.
- Customer engagement involved multiple contacts, including a pre-visit application process, scheduling the site assessment, conducting the site assessment, delivering the assessment reports, and follow-up regarding any additional requested services. Customers were also invited to attend workshops. Reaching out to multi-family and industrial and business park property owners provided an avenue to schedule multiple assessments at once and discuss opportunities for completing large renewable energy projects that would serve multiple uses or customers, and pursuing upgrade projects in bulk.

2.2.2 MRVC Financing Program Development

The goal of this task was to develop a locally-customized energy upgrade financing model that can be aligned with and implemented as a component of the energy upgrade program and the RePower Humboldt vision. The objectives for the task included identifying and engaging lenders and financing programs and developing processes and resources to engage customers and facilitate their participation in the available programs.

2.2.3 MRVC Contractor Recruitment and Training

The goals of the RePower Humboldt plan include creating local jobs and empowering the community to take an active role in shaping a sustainable energy future. Because there are constraints on the services that RCEA can offer, recruiting others, including private sector contractors, to help guide and lead market changes is essential to addressing both community engagement and service gaps. Contractors were to be engaged in two ways: to provide feedback in the program design phase to ensure the program would be successful in meeting their business needs and the RePower goals; and recruiting contractors to participate in the program by completing training, obtaining the required certifications, and enrolling. The goal of this task was to identify, recruit, and train local contractors qualified to complete the high-priority residential and commercial renewable energy and energy efficiency upgrade projects identified in the MRVC Program Implementation Plan.

2.2.4 MRVC Outreach, Marketing and Workshops

The goal of this task was to promote the MRVC Energy Upgrade Program to customers in the City of Blue Lake, the Blue Lake Rancheria, and the broader surrounding Mad River Valley to maximize participation by high-priority residential, commercial, industrial, and government stakeholders. Specific tasks included developing workshop materials, conducting targeted marketing and outreach activities via print, online and radio channels, participating in relevant community events, and conducting workshops. The materials were to be focused on helping local energy consumers identify cost-effective renewable energy and energy efficient upgrade options specific to their needs. Activities would encourage local participation and support for the program, workshops and training opportunities.

2.2.5 MRVC Site Assessments

The main component of the program was to provide detailed renewable energy and energy efficiency site assessment of homes, businesses, and municipal facilities that would result in energy upgrade projects. Interested customers were asked to submit a completed application for services, and were prioritized by either having been engaged through outreach activities, or having an immediate interest in obtaining an energy audit or Home Upgrade® program initial assessment to be evaluated for deeper energy retrofit opportunities.

Site assessments were to include detailed renewable energy and energy efficient resource evaluations and comprehensive energy performance assessments. Assessments were to include an analysis of the economic potential for a solar electric system, heat pumps and energy efficient technologies; technical system performance estimates including total capacity installed, expected operational lifetime, and lifetime energy generated or saved by each system; and cost analysis of the overall investment needed to install and maintain identified systems, including payback and return on investment.

The anticipated outcome of the site assessments included:

- Increased comprehensiveness for each project to include multiple measures or technologies, including deeper retrofits. This is achieved by helping participants navigate behavioral change, low-cost measures, major energy upgrades and adoption of renewable technologies. Success also depends on overcoming cost barriers through multiple financing avenues, including rebate programs, loan products, grant funding, and community support.
- Follow-up engagement with customers. Securing relationships with customers requires multiple points of engagement, including site visits, workshops, presentations, and follow-up consultations.
- Reduced time obligation through turn-key and combined services. Combining multiple services, including energy assessments and solar site surveys into one visit, reduces the time obligation for customers resulting in increased participation. Providing turn-key services that include contractor pre-qualification and selection and energy modeling provided through RCEA's HERS II Rater services provides similar advantages for completing upgrade projects.

2.2.6 MRVC Energy Upgrade Project Assistance

The program aimed to provide hands-on implementation assistance and start-to-finish project management support to participants who opted to proceed with an energy upgrade project. This included assistance with contractor selection and referral to participating contractors suited to complete their project, and helping with the necessary documentation and paperwork for processing rebates and other incentives. It also included providing project quality assurance through post-project inspection and testing of work completed.

2.2.7 MRVC Heat Pump Installation and Assessment

2.2.7.1 Overview

The *RePower Humboldt Strategic Plan* concluded that using heat pumps in Humboldt County in place of natural gas fired furnaces would be a cost-effective means to reduce greenhouse gas emissions in the County. This was based on assumptions about the cost and efficiency of air source heat pump systems and about the performance of natural gas fired furnaces. The goal of Task 3.7 is to demonstrate and verify the technical benefits and economic viability of using air source heat pump systems in Humboldt County.

The approach of this study was to install two mini-split air source heat pumps, outfit them with data monitoring equipment, and evaluate their actual performance in the field. Accordingly, two Daikin mini-split heat pump systems (FTXS36LVJU indoor unit, RXS36LVJU outdoor unit) were installed in two separate classroom buildings at the Blue Lake Elementary School in Blue Lake, CA in July of 2014. The heat pumps were used in place of the existing natural gas furnaces in these classrooms.

The heat pumps in these classrooms and the existing natural gas fired furnaces in two other separate, but similar classrooms were then fitted with a complement of sensors and data loggers in order to collect data over several months of normal heating season operation. These data were then analyzed to determine the operating characteristics of the various units under real-world circumstances and assess whether or not the assumptions and conclusions of the *RePower Humboldt Strategic Plan* are indeed correct.

Note that the heat pump units were programmed by RCEA staff to automatically run in heat-only mode during school hours, Monday through Friday. The units do not run at night or on weekends. This is also true for the gas furnaces which are hard-wired to wall mounted programmable thermostats.

2.2.7.2 Heat Pump Test Plan

A detailed Heat Pump Test Plan was developed to guide the study activities (see Appendix D). The test plan was based heavily on the guidelines presented in the National Renewable Energy Laboratory's Field Monitoring Protocol: Mini-Split Heat Pump Systems (NREL 2011). The key questions were:

- How do heat pumps compare with natural gas furnaces in terms of energy efficiency, cost to operate, installation cost, and greenhouse gas emissions?
- Is it cost-effective for a building owner to install a heat pump instead of a natural gas furnace, and how does this economic viability differ in a "replace on burn-out" scenario versus an "early replacement" scenario?
- We were also interested to determine the difference in economic viability and environmental benefit when replacing a standard efficiency furnace with a heat pump versus replacement of a high efficiency furnace with the same heat pump.

The data collected were used to help answer these questions. The approach was to log the amount of useful heat delivered to each room, as well as the energy consumed by each heating device in the process.

The temperature, humidity, and airflow were monitored for both supply and return air and thereby determined the heat delivered by each unit. Simultaneously, the total energy consumed (natural gas or electricity) by each device was also monitored. The total energy consumed by the heat pumps was determined using Watt-hour meters. Total energy consumed by the natural gas furnaces was determined based on measurements of electrical fan energy using a Watt-hour meter and natural gas flow using a gas flow meter. The team assumed constant electrical power to the fixed speed furnace fans and constant natural gas flow to the single stage gas control valves on the furnaces. This allowed us to simply monitor when the furnaces were on and thereby determine how much energy they consumed.

Airflow was not measured directly during the test period due to the high cost of airflow transducers and other practical difficulties. Instead, alternate parameters easily monitored were identified and established empirical relationships between these alternate parameters and airflow. The furnaces have fixed speed fans, so when they are on the flow is essentially constant.

This fact allowed us to monitor when the fan was on and then assume the flow was constant during that period. Fan operation was determined by measuring current flow to the fan motor.

The heat pumps utilize variable speed fans that operate at a set of fixed speeds based on the unit's controller. The airflow for each of the fixed fan speeds was determined. Flow was measured using a Minneapolis Duct Blaster with an inflatable plenum constructed from a plastic trash bag. The team then monitored the current signal delivered to the fan controller to determine which speed it was running at.

2.2.8 MRVC Electric Vehicle Charging Infrastructure

The goal of the task was to demonstrate and verify the local technical and economic benefits of electric vehicle charging stations in Humboldt County. Electric vehicle supply equipment (EVSE) or was purchased and installed at two facilities in the Mad River Valley. Use of these charging stations was monitored, evaluated, and used to verify the cost-effective greenhouse gas savings suggested by the RePower Humboldt study.

2.2.9 MRVC Program Evaluation and Scale-up

Evaluating the pilot program results was important to determine program cost-effectiveness and opportunities for expansion. This was accomplished through keeping and compiling records of program activities and results in customer databases and tracking tools developing during the program design, and compiling estimates of program costs. Developing a detailed plan for ongoing, sustainable implementation across the county was completed by evaluating opportunities for program expansion, recognizing what didn't work and observing what did work in the pilot program, and applying those lesson learned.

2.3 Task 4: Data Collection and Analysis

The goals of this task were to collect operational data and analyze the data for economic and environmental impacts. Specifically, the approach was to develop a plan for evaluating the energy savings and estimated cost savings, greenhouse gas reductions, and other non-energy benefits attributable directly or indirectly to the project. This analysis was also to provide estimates of potential job creation, market potential, economic development, as well as an estimate of the project's potential statewide energy savings and other benefits once full market potential has been realized.

2.3.1 DG Biomass System

The data collection and analysis plan for the DG biomass system is described in Section 2.1.9.

2.3.2 Community Energy Upgrade Program

Several types of data were collected for the program, including:

- Paper based field data: sign-up sheets, customer intake forms, audit records, participation agreements, usage data releases, completion forms, inspection forms, customer reports, work orders, and contracts.
- Electronic field data: photographs, test equipment logs.

Wherever possible data was directly entered into digital tools, including software programs, customer databases, and data loggers. All data was organized by customer or project and retained in archives for issue resolution. Customer contact and project progress tracking tools were developed for project assistance and for querying program results.

2.4 Task 5: Technology Transfer Activities

The goal of this task was to develop a plan to make the knowledge gained and experimental results and lessons learned available to key decision-makers, and to disseminate the project results to facilitate replication in other communities. Outreach tools for the DG biomass project were to include:

- A project case study for the DG Biomass project
- Two journal articles documenting results of the DG Biomass project
- A conference presentation for the DG Biomass project
- A webinar presentation for the DG Biomass project

Outreach tools for the Energy Upgrade project were to include an Energy Upgrade replication package that features program materials, best practices and protocols. The Energy Upgrade replication package and other program information and data would be made freely available and easily accessible through RCEA’s website and other channels. The Energy Upgrade program model and results would be promoted through local government networking events and the Statewide Energy Efficiency Collaborative.

2.5 Task 6: Production Readiness Plan

The goal of the Production Readiness Plan was to assess the production readiness of the technologies demonstrated and evaluated in this project. In addition, the plan was to outline steps that could lead to the manufacturing of the technologies or to the commercialization of the project’s results.

CHAPTER 3: Project Outcomes

3.1 Task 2: Install and Demonstrate Distributed Generation Biomass Combined Heat and Power System

The DG biomass energy system at the Blue Lake Rancheria has been designed, all site and facilities work has been completed, and all system components have been procured and installed. Most of the major components have been fully or partially commissioned. However, the gasification system is not yet operational. In this section the program progress to date is discussed and the challenges encountered. Using the best data and information available estimates of system performance were developed and opportunities assessed for moving forward to complete a fully functioning system.

3.1.1 DG Biomass Interconnection Agreement

Due to delays in getting the gasifier system fully operational, execution of a DG biomass interconnection agreement with PG&E was temporarily placed on hold. At that time all interconnection application and agreement documents were complete and PG&E had provided assurance that the interconnection would be approved.

In the meantime, the Blue Lake Rancheria pursued and is now developing a community-scale microgrid on their property (funded by the Energy Commission under agreement EPC-14-054). The microgrid will include 432 kW of solar electricity and a 500 kW/950 kWh battery storage system. These distributed generators will be interconnected with the PG&E grid. The interconnection process for the entire microgrid is currently underway and approval is expected by spring/summer of 2016.

Once the interconnection agreement is signed by PG&E and all inspections are complete, an executed agreement will be returned to BLR. Once the agreement is fully executed, the required pre-parallel inspection to allow the generation facility to parallel with PG&E's distribution system will be scheduled. Upon acceptance of the pre-parallel inspection, a written authorization will be provided that will allow the parallel operation of the generation facility.

3.1.2 DG Biomass Fuel Supply Contract

Serraga has secured a long-term fuel supply with sufficient quality and quantity to run the system at full power, including related sawdust hauling services. Once the system is operational, Serraga will test different kinds of locally available biomass sawdust fuels to examine effects on system performance. Parameters that will be tested include tree species, particle size, composition, moisture content, and impurities/contaminants. Serraga and HRC have preserved flexibility in agreements to adjust the commitments across various types of materials.

3.1.3 DG Biomass Site and Facilities Work

All site and facilities work has been completed. Photos documenting the completed site and facilities work are shown (Figures 12-19).

Figure 12: Fill and Grading for Biomass Storage Building

Heavy equipment is used to prepare the site for the new biomass storage building.

Photo Credit: Toni Ramos

Figure 13: Trenching for Electrical Service

Trenching from the Blue Lake Hotel to the DG biomass power system and laying electrical lines and conduit.

Photo Credit: Toni Ramos

Figure 14: Fuel Cell Concrete Pad Construction

Fuel cell concrete pads are poured and finished. The small pad in the foreground is for the 380 VAC to 480 VAC step-up transformers.

Photo Credit: Toni Ramos

Figure 15: Fuel Cell Installation

Fuel cell containers are set into place using a crane. Two containers were set side-by-side; one contains the process module and one contains the power conditioning system.

Photo Credit: Toni Ramos

Figure 16: Metal Building Installation

Metal framing is erected for the biomass storage and handling building.

Photo Credit: Neil Harris

Figure 17: Completed Biomass Storage Building

Completed biomass storage building. Roll-up door in right corner allows moving bed truck to unload biomass directly into the building.

Photo Credit: Jim Zoellick

Figure 18: Electrical Retrofits in Gasifier Building Mezzanine

An existing storage and office building was retrofitted to house the gasifier and required substantial upgrades, including extensive electrical work suitable for both hazardous and non-hazardous classified areas per the electrical code.

Photo Credit: Neil Harris

Figure 19: Completed Retrofits to Gasifier Building

Retrofits to the gasifier building included a new electrical service located in building extension in the left corner, as well as new transformers at the center of the building. Ventilation louvers were also added around the base as shown on either side of the roll-up door.

Photo Credit: Jim Zoellick

3.1.4 DG Biomass System Installation

All major components for the DG biomass system have been successfully installed. Documentation of the DG Biomass System Installation is shown (Figures 20-34).

Figure 20: Front Loader Ready to Move Biomass

A small front loader was purchased to move biomass in the storage building and to load the hopper feed system.

Photo Credit: Jana Ganion

Figure 21: Biomass Feed System in Fuel Storage Building

The biomass feed system features a hopper with “overs” screen, bucket elevator, and auger feed system that carries biomass to the adjacent gasifier building.

Photo Credit: Jana Ganion

Figure 22: Gasifier Reactors

Redwood sawdust from the fuel storage building is fed to the gasifier unit. Fuel enters at the rear of the system and is augered through the system and eventually to the electrically heated gasifier reactors shown in the front right portion of the photo. Product syngas is delivered through the large overhead piping to the condensers shown on the left side of the photo.

Photo Credit: Jim Zoellick

Figure 23: Gasifier System

A rear view of the gasifier system shows the water-cooled char auger and char lift auger that carry char to the storage bin in the north yard. Also shown are the condensers and condensate drum with recirculation pump. Condensate is designed to be reintroduced into the incoming biomass.

Photo Credit: Jim Zoellick

Figure 24: Rotary Claw Compressor

The rotary claw compressor pulls syngas through the gasifier system and then delivers it to the syngas ballast and reciprocating compressor at a pressure of 10 psig.

Photo Credit: Jim Zoellick

Figure 25: Gasifier Building Interior

This is a view of the gasifier building looking from the PSA back toward the rotary claw compressor and gasifier system.

Photo Credit: Jim Zoellick

Figure 26: Reciprocating Compressor

The reciprocating compressor increases the pressure of the syngas delivered by the gasifier system from 10 psig to 120 psig for delivery to the PSA.

Photo Credit: Jana Ganion

Figure 27: Pressure Swing Adsorption Unit

The pressure swing adsorption unit produces pure hydrogen for delivery to the fuel cell generator; waste tail gas from the PSA is sent to a flare.

Photo Credit: Jim Zoellick

Figure 28: Equipment in the North Yard

The north yard houses the reciprocating compressor, cooling equipment; syngas buffer tank, char bin, dust collection system, and tail gas flare.

Photo Credit: Jim Zoellick

Figure 29: Syngas Buffer Tank and Flare

The syngas buffer tank on the left stores gas at 10 psig and helps ensure that slight mismatches in throughput between the two compressors does not cause excessive cycling of equipment. The flare on the right is used to burn the waste taigas.

Photo Credit: Jim Zoellick and SERC

Figure 30: Cooling Systems

These cooling systems serve to dump waste heat from the gasifier condensers and water cooled char auger, as well as waste heat from the reciprocating compressor.

Photo Credit: Jana Ganion

Figure 31: Fuel Cell and Hydrogen Ballast

The fuel cell system is housed in two shipping containers. The one on the right houses the fuel cell stacks and process equipment and the one on the left houses the power conditioning equipment and control system. The hydrogen ballast stores hydrogen fuel at a pressure of about 105 psig and helps balance the flow between the PSA and the hydrogen fuel cell generator.

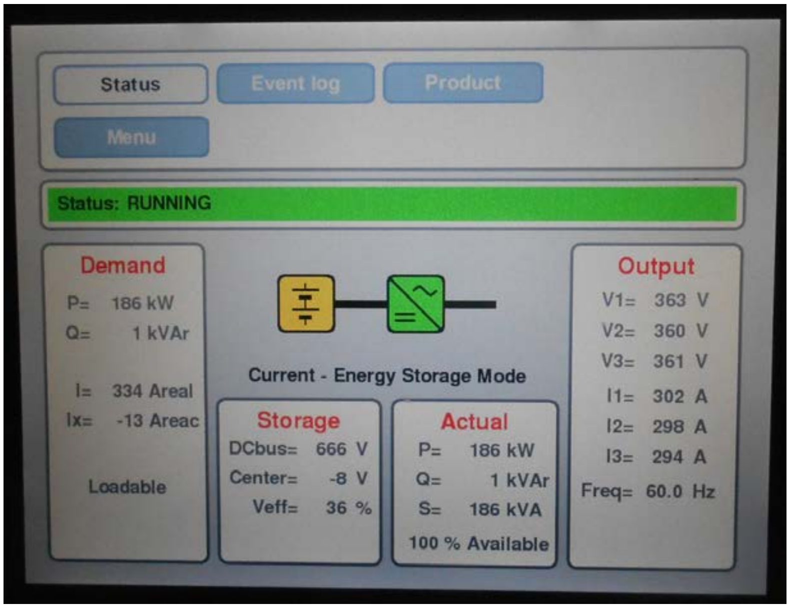
Photo Credit: Jim Zoellick

Figure 32: Fuel Cell with Doors Open

The fuel cell process module the container doors open. The fuel cell stacks are housed in the three vertical enclosures in the center of the container.

Photo Credit: Neil Harris

Figure 33: Human Machine Interface (HMI) for the Fuel Cell Generator



This is a screen shot of the HMI for the fuel cell generator during commissioning at the factory.

Photo Credit: Neil Harris

Figure 34: Deionized Water System

The deionized (DI) water system includes a water softener, a reverse osmosis unit and a polishing DI resin bed to produce high quality water for the fuel cell system. The DI water is used to humidify the supply hydrogen and incoming air to ensure proper hydration of the fuel cell stack membranes.

Photo Credit: Neil Harris

3.1.5 DG Biomass Start-up and Commissioning

Table 10 documents the status of the DG biomass facility start-up and commissioning tasks. Start-up and commissioning activities are complete for most process systems. However, problems with the gasifier system were experienced, and the unit at the Blue Lake Rancheria site has not yet produced syngas. Issues have included problems with feedstock conveyance and difficulty in meeting syngas composition specifications. Because the gasifier is not yet capable of producing syngas, the major components down stream of the gasifier that rely on a throughput of syngas to operate have not been fully commissioned either. This includes the pressure swing adsorption unit and the fuel cell generator. However, the fuel cell has been partially commissioned at the BLR site, and, in addition, has been run at Ballard's manufacturing facility in British Columbia where it passed factory acceptance testing. Ballard has provided run time data from the factory acceptance test for the analyses.

With regard to the gasifier conveyance issues, there were attempts by Proton staff to move moist biomass (approximately 50% moisture content on a wet basis) through the auger systems at BLR. On two occasions augers jammed and biomass was tightly compacted in the conveyance system. These augers had to be removed, cleaned and re-installed. Contributing issues could be that the biomass feedstock was too moist and that feed rates were set too high. Additional work needs to be done to determine the impact of feedstock moisture content, conveyance speeds, auger properties and gasifier performance. Proton will test auger performance at its testing facility in Tennessee as a part of its ongoing work on this project. Current recommendations from Proton to eliminate conveyance problems are that the feedstock moisture content should not exceed approximately 40%.

In addition to feedstock conveyance issues, Proton has had serious difficulties achieving a syngas composition that meets their contractual performance specification. The contractual performance specifications are shown in Table 11.

The main issue is that CO levels are much too high, in the range of 35% to 40% by volume. The overall DG biomass system design requires CO concentrations below 20% by volume; higher CO levels will overburden the PSA's ability to deliver hydrogen with a suitable purity. CO levels in the hydrogen delivered to the fuel cell must be no higher than 0.1 to 0.2 ppm.

In an effort to reduce CO levels below 20% by volume Proton Power has been working with a gasifier at their facility in Rockwood, TN that is comparable to the unit at the Blue Lake Rancheria. Initially they tried to adjust biomass moisture content, feed rates and reactor temperatures in an attempt to reduce CO levels. They have reported they were able to reach lower levels of CO using their smaller prototype gasifiers (their website lists 5% CO by volume), but to date they have not provided us with any evidence indicating they can reproduce those results.

Table 10: DG Biomass Facility Commissioning Status

Item/System	Commissioning Activities	Status
Biomass feed	Convey biomass through feed system, set speed	Complete
Gasifier	Pressure test, test and confirm all data I/O, test and confirm operation of all valves, test and confirm operation of all sensors, test auger motors for proper rotation and function, heat reactors without fuel, heat up flare system and test temperature feedback loop, test rotary claw compressor with air, test and set PRVs, test safety shutdown systems and faults, generate syngas, tune system, meet syngas acceptance test criteria	Partially complete, full start-up with syngas generation, tuning and acceptance testing have not been completed
Reciprocating compressor	Pressure test system, test motor rotation, test system operation including motor speed control and low suction pressure spillback control	Complete
Pressure swing adsorption unit	Pressure test system, test and confirm operation of all valves, test rotary valve motor operation including VFD speed control, check regulator set points	In process
Fuel cell generator	Pressure test system, test and confirm all data I/O, test and confirm operation of all valves, test and confirm operation of all sensors, test all motors for proper rotation and function, test and set PRVs, test safety shutdown systems and faults, test fuel cell voltages, test power generation and tune systems	In process, mostly complete except for generating power on-site and tuning systems, full factory acceptance test completed
H_2 storage tank	Pressure test system	Complete
Cooling systems	Flush systems, fill with glycol water mixture, leak test, confirm proper rotation of motors, confirm thermostat set points	Complete
Nitrogen supply	Pressure test, test and confirm system operation	Complete
Compressed air/dryer	Pressure test, test and confirm system operation	Complete
Dust collection	Test and confirm system operation	Complete
DI water	Pressure test, test and confirm system operation	Complete
Central control and monitoring	Test and confirm all data I/O, test and confirm operation of all sensors and control points, test safety shutdown systems and faults	Complete
Fire and life safety alarm	Test and confirm all data I/O, test and confirm operation of all sensors and control points, test safety shutdown systems and faults	Complete
Ventilation	Test motor rotation, confirm air flow specifications, balance ridgeline duct system	Complete

Source: Schatz Energy Research Center

Table 11: Gassifier Acceptance Test Criteria

Parameter	Allowable Range
Syngas hydrogen content	≥ 60% (by volume)
Syngas carbon monoxide content	≤ 10% (by volume)
Hydrogen flow rate in delivered syngas	≥ 16 kg/hr
Syngas delivery pressure	≥ 10 psig

Source: Schatz Energy Research Center

As of this writing Proton has decided that they will condition the syngas after gasification in order to meet the contracted syngas composition. Their current approach is to add a tar reformer and a water-gas shift reactor after the gasifier. These technologies are discussed briefly in Appendix E. The water-gas shift reactor will steam with the CO in the syngas, producing CO2 and H2. Proton has begun working on this solution, but they do not have any results to show at this time. With steam to CO molar ratios of 2 to 3 it is expected that they might attain CO conversion efficiencies near 80%. This would convert the generated syngas that is 45 Mol% H2 and 35 Mol% CO and produce a conditioned gas that is about 57 Mol% H2 and 5 Mol% CO. This conditioned syngas would be well suited to this application. Proton is working on development and testing of a tar reformer and water-gas shift reactor, and expects to have further results by July of 2016.

In addition to reducing the CO content of the syngas, it must also ensure that certain minor impurities are not present at unacceptable levels in the syngas. These impurities will be tested for once syngas production consistently meets the required specifications for the bulk constituents (CO and H2). Minor impurities that must be eliminated and will be tested for include tar vapors, hydrogen sulfide, ammonia, hydrogen cyanide, chlorine compounds (including hydrogen chloride), and sulphur compounds. These impurities at even trace levels could poison the adsorbent beds in the PSA. Table 12shows the maximum impurity levels allowed in the syngas to be sent to the PSA.

Table 12: Gas Composition Requirements for PSA

Chemical Formula	Chemical Name	Max% Composition
H_2	Hydrogen	100%
CO_2	Carbon Dioxide	40%
CO	Carbon Monoxide	20%
CH_4	Methane	20%
C_2H_6	Ethane	5%
C_2H_4	Ethene	% levels acceptable
C_3H_8	Propane	5%
N_2	Nitrogen	5%
H_2O	Water	saturated, no liquid
	Tar Vapours	< 10 ppm
BTX	Benzene, Tolulene, Xylene	< 50 ppm
H_2S	Hydrogen Sulphide	max of 5 ppm, or 0.005 psi partial pressure,
NH_3	Ammonia	< 10 ppm
HCN	Hydrogen Cyanide	< 1 ppm
CH_3OH	Methanol Vapour	< 0.2%, no liquid
C_2H_5OH	Ethanol	< 0.1%
Cl Compounds (including HCl)	Chlorine Compounds (including Hydrogen Chloride)	< 1 ppm
	Mercaptans	< 5 ppm
NO_X	Nitrogen Oxides	< 10 ppm
SO_X	Sulphur Oxides	< 1 ppm
R_2SiO	Siloxanes	< 10 mg/m3
	Particulates	< 0.5 micron
	Amines	< 50 ppm, no mist or liquid

Source: Xebec Adsorption Inc

Next steps moving forward are as follows. Proton will continue to develop the tar reformer and water gas shift reactor systems, test and validate these systems, and integrate them into their gasifier process train. These tasks will be undertaken at their Rockwood, TN facility. Once they can demonstrate a system that consistently generates syngas with CO levels below 10 Mol%, the team will be ready to modify the process train at the Blue Lake Rancheria facility and add the tar reformer and water-gas shift reactor. In addition, third party gas analysis will be required to test the conditioned syngas product for the presence of unacceptable trace impurities.

Once a system capable of producing acceptable syngas is ready, the team will begin generating syngas at the BLR facility. This will allow us to fully commission the gasifier and other downstream components, including the PSA and fuel cell generator. In addition, the complete BIGFC system must be commissioned. The Blue Lake Rancheria Tribe and Serraga continue to support this work financially and operationally.

3.1.6 DG Biomass System Test Plan

The DG Biomass System Test Plan was developed assuming the installation and commissioning of a fully operational BIGFC system would be complete and would operate and test the system for a prolonged period of time. The BIGFC system was outfitted with data monitoring equipment that would allow us to collect operating data, including mass and energy inputs to and outputs from the system. With these data the team would be equipped to calculate energy and mass balance relationships and assess component and overall system efficiencies and performance. In turn, system economics can be assessed. While the test has been commissioned and some key individual components of the system are operational, to date the team has not been able to achieve a fully functioning system. This has severely hampered the ability to complete an evaluation of system performance, including the estimation of system efficiencies and economic viability.

In the next section the best effort to use the information gathered to develop rough estimates of system performance assuming the full system becomes operational. Note that the original test plan aimed to collect date over time for a system operating at steady-state conditions and then determine average performance parameters. This would ensure that peculiar transient behavior did not overshadow performance estimates. However, because for the most part the team does not have real operating data collected over time to work with, they have developed performance estimates based on the best available data. This includes real run-time data from the fuel cell generator, instantaneous run time data for parasitic loads, manufacturer design parameters (based on bench-top testing and design modeling) for the PSA, manufacturer operating data, anecdotal data and system performance estimates for the gasifier, and manufacturer performance estimates for the gas conditioning systems (tar reformer and water-gas shift reactor).

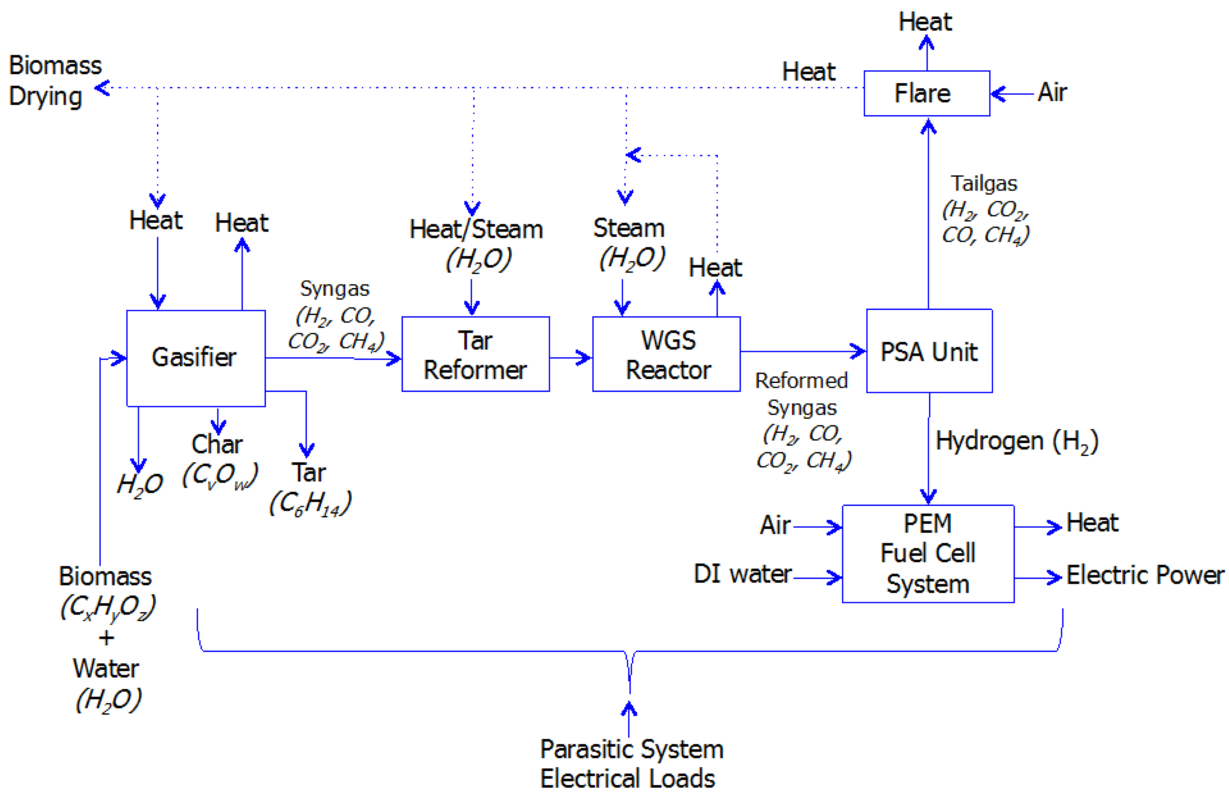
3.1.7 DG Biomass Data Collection and Analysis

The BIGFC system was assessed according to the test plan outlined in Appendix C, with adjustments to the plan as mentioned above. The team discusses which data were measured directly. Where direct measurements were not available, how data were estimated is described. The focus of this section is to assess the expected performance of the BIGFC system, including component efficiencies and overall system efficiency. In addition, economic parameters are assessed to ascertain whether or not a system of this type could be economically viable. Key parameters needed for this assessment included biomass feedstock characteristics and feed rates, parasitic electrical loads, and performance characteristics of the gasifier, PSA and fuel cell.

3.1.7.1 Mass and Energy Balance Models of BIGFC System Performance

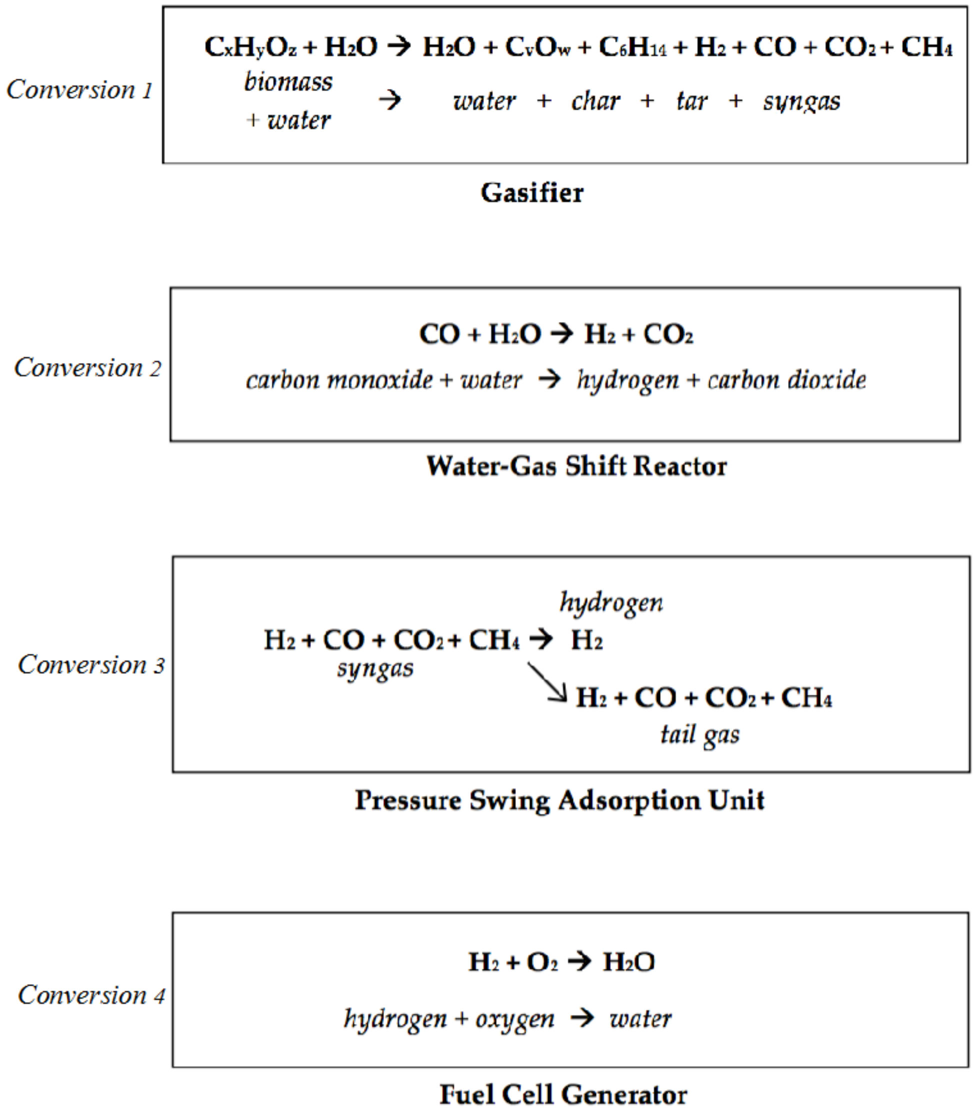
The final design for the BIGFC system is a modified version of the original design as described in Section 2.1.1.2. This modified design includes a tar reformer and a water-gas shift (WGS) reactor and is discussed in Section 3.1.7.5. A simple mass and energy balance model was developed to characterize all of the major components in the modified BIGFC system and to track mass and energy inputs and outputs. The mass and energy balance model is described and the approach used to analyze the system. Figure 35 shows the mass and energy balance model with the key inputs and outputs identified. Figure 36 shows the major chemical conversions taking place in the system; these conversions were used to track inputs and outputs and ensure that mass was conserved. Note that these are not balanced equations, but instead are intended as flow diagrams. Model results showed that mass was conserved within a few percent. Tar was modeled as hexane (C6H14) and char as a carbon-oxygen compound (CvOw). Energy was also conserved, with any unaccounted for "excess" energy assumed to be discharged as heat to the environment.

Figure 35: BIGFC System Mass and Energy Balance Model



Source: Schatz Energy Research Center

Figure 36: BIGFC System Mass Flow Conversions



Note that these are not balanced equations, but are instead intended as mass flow diagrams.

Source: Schatz Energy Research Center

3.1.7.2 Biomass Fuel Analysis

This section presents results of the fuel characterization activities. Biomass moisture content, ultimate analysis and heating value were key information needed for the system performance assessment.

We obtained multiple loads of fuel from the designated fuel provider for this project, Humboldt Redwood Company in Scotia, CA. The fuel obtained was redwood sawdust that was vacuumed right off the saw blades (called kerf). The material was primarily 1/4 "minus in size and very moist (i.e., 50-60% MC, wet basis). The high moisture content is due primarily to water that is sprayed on the saw blades during the milling process to keep the blades cool and to lubricate the process.

As discussed in Section 3.1.5, problems with biomass jamming the augers in the conveyance system were experienced, and it is suspected that this was largely due to the biomass being too wet. In retrospect, Proton Power recommended moisture contents no greater that about 40%. Potential drying options are discussed below in Section 3.1.7.3.

Table 13 presents measured and literature values that were used in this BIGFC system analysis. Moisture content was measured by drying biomass in an oven at 105°C until sample mass was constant. Loose density was determined by measuring the mass of biomass needed to loosely fill a 1.7 cubic foot box. Bulk density was measured using a five-tap method where the box was loosely filled, then lifted five feet in elevation and dropped five consecutive times. Afterwards final volume and weight were measured. The proximate analysis was conducted using a thermogravimetric analyzer (TA Instruments, Q50) with the following temperature program: under a nitrogen purge gas, heat to 95°C at a ramp rate of 80°C/min then to 105°C at a ramp rate of 10°C/min and hold for 10 minutes; heat to 685°C at a ramp rate of 80°C/min then to 700°C at a ramp rate of 10°C/min and hold for 25 minutes; switch the purge gas to air and hold at 700°C for three minutes. Gross calorific value (higher heating value) was measured in a bomb calorimeter (Parr Instruments Model 1241). Lower heating value was estimated based on the measured HHV, and the corresponding LHV was estimated assuming a 16% drop in heating value. This drop in heating value was based on estimates for forest species in Portugal where LHV was calculated at constant pressure based on H, O and N content, and then compared with corresponding measured values for HHV (Telmo, C. and J. Lousada 2011). Values for the ultimate analysis for redwood were found in the literature (Jenkins, B. & J. Ebeling 1985).

Table 13: Redwood Sawdust Feedstock Characteristics

Parameter	Units	Value
Moisture and Density		
Moisture content (delivered)	% (wet basis)	55-65
Moisture content (air dried)	% (wet basis)	30-35
Loose density (63% MC, wet basis)	lb/ft3	292
Bulk density (63% MC, wet basis)	lb/ft3	108
Loose density (oven dried)	lb/ft3	400
Bulk density (oven dried)	lb/ft3	148
Proximate Analysis		
Volatile matter	% by weight (dry basis)	81.2
Ash content	% by weight (dry basis)	0.4
Fixed carbon	% by weight (dry basis)	18.4
Heating Value		
Higher heating value	MJ/kg	20.12
Lower heating value	MJ/kg	17
Ultimate Analysis		
Carbon	% by weight (dry basis)	50.64
Hydrogen	% by weight (dry basis)	5.98
Oxygen	% by weight (dry basis)	42.88
Nitrogen	% by weight (dry basis)	0.05
Sulfur	% by weight (dry basis)	0.03
Chlorine	% by weight (dry basis)	0.02
Residue	% by weight (dry basis)	0.40

Source: Schatz Energy Research Center, except Ultimate Analysis from Jenkins, B. & J. Ebeling, 1985

Figure 37 shows an image of the redwood sawdust used in the project.

Figure 37: Redwood Sawdust Sample

This is a picture of the ¼" minus redwood sawdust fuel supply for the BLR DG biomass system. This material is called "kerf" and is vacuumed straight off the saw blades at the mill.

Photo Credit: Jim Zoellick

3.1.7.3 Biomass Drying Analysis

Delivered biomass moisture content was 55-65% on a wet basis. Most biomass gasification systems need relatively dry biomass. The Proton Power gasifier can handle biomass with higher moisture contents, and in fact higher moisture is desired to increase the hydrogen concentration in the syngas. However, biomass moisture contents greater than about 40% become problematic with the Proton gasifier due to conveyance problems and decreased reactor performance. For this reason, the redwood sawdust source that was secured from Humboldt Redwood needed to be partially dried before gasification.

At the Blue Lake Rancheria site biomass piles were spread out on the concrete floor of the biomass storage building to a depth of about 6 to 12 inches and fans were placed at one end of the building to blow air across the piles. Piles were turned periodically. The effectiveness of this technique was highly dependent on climatic conditions. When ambient humidity levels were low for the coastal climatic zone (days without excessive fog or precipitation), the sawdust could be dried over a number of days to moisture levels of about 30-40% (wet basis). These moisture levels would be acceptable for the Proton Power gasifier.

However, this drying technique would not be practical for full-scale operation when approximately 5 bone-dry metric tons per day will be needed to fuel the gasifier. Various options have been considered for drying the biomass, including belt driers, rotary kiln driers and flash driers. Flash dryers appear to be the most suitable based on their cost, efficiency and effectiveness for materials such as sawdust. It may be possible to fuel a flash drier with a portion of the waste taigas that is generated and sent to the flare. There is more than enough energy in the taigas for this purpose. This is discussed further in Section 3.1.7.8.

3.1.7.4 Parasitic Electrical Loads Analysis

The main purpose of the BIGFC system is to produce on-site renewable electricity for the Blue Lake Rancheria facility by converting biomass fuel into electrical power. However, in order for the BIGFC system to function there are many electrical loads that must be powered. These are referred to as parasitic electrical loads, and for this system they are substantial. These include electrical loads to: convey the biomass, run gasifier auger motors, heat the gasifier reactor, run compressor motors, run cooling system motors, support auxiliary loads for the fuel cell system (pumps, motors, fans, etc.), and power a myriad of additional balance of system loads, including control systems, lighting, ventilation, communications equipment and other various loads.

Table 14 presents the best estimate of BIGFC system parasitic loads. Where possible, electric loads were directly measured. In some cases loads were estimated based on equipment ratings and familiarity with equipment duty cycles. The parasitic loads in Table 14 assume the BIGFC system is operating at full capacity (175 kW net AC power from the fuel cell). The reciprocating compressor load is based on a modeled compressor horsepower versus flow curve.

Note the added load for the tar reformer and water-gas shift (WGS) reactor in Table 14. It is expected these components will be required to reduce syngas CO levels to acceptable levels. Power consumption for these units is based on estimates provided by Proton Power, steam generation requirements for the WGS unit, and an assumption that the heat released from the exothermic reaction in the WGS reactor will be fully utilized to preheat make-up water and thereby assist with steam generation. It is assumed that energy needed beyond that captured from the exothermic reaction will be provided via electric heaters. In Section 3.1.7.8 the possibility of using waste heat from other processes (i.e., from the flare) was examined to lower these parasitic load requirements.

Table 14: BIGFC System Parasitic Loads

Electric Load Description	Load (kW)	% of Total Parasitic Load	Notes	Source
Fuel handling	3.2	3%	measured unloaded, adjusted for loading of equipment	on-site measurement
Gasifier heaters	35.7	28%	measured	off-site measurement, Proton
Gasifier auger motors	5.8	5%	estimated	Proton
Gasifier cooling system	4.7	4%	measured	on-site measurement
Misc gasifier system loads	9.6	8%	estimated	Proton
Rotary claw compressor	12.5	10%	estimated	Proton
Reciprocating compressor	20.4	16%	Modeled BHP vs. flow, estimated kW	modeled values, Applied Compression Systems
Reciprocating compressor cooling	5.2	4%	measured	
Fuel cell auxiliary loads	14.0	11%	measured	off-site measurement, Ballard Power Systems
Fuel cell cooling	5.2	4%	measured	on-site measurement
Balance of system	9.9	8%	measured	on-site measurement
Total parasitic load	**126.1**			
Additional load for tar reformer and water-gas shift reactor				
Tar reformer & WGS	36		estimated	Proton, SERC

Source: Schatz Energy Research Center, Blue Lake Rancheria, Proton Power Inc., Applied Compression Systems, and Ballard Power Systems

3.1.7.5 Gasifier Performance Assessment

As discussed in Section 3.1.5, the gasifier at the Blue Lake Rancheria project site is not yet operational. The data and estimates in this section are based on the mass and energy balance model results.

Gasifier system performance was assessed according to the system's First Law energy efficiency which was calculated as usable energy output divided by required energy input (Equation 2, Appendix C). Energy inputs to the gasifier system are redwood sawdust fuel and electricity. If a tar reformer and water-gas shift reactor are added, they will require additional electrical power. Energy outputs from the gasifier are in the form of syngas fuel, heat, and tar condensate. Estimates of biomass fuel and electricity inputs and syngas fuel output were developed and an energy balance was performed to make sure that output energy did not exceed input energy. Mass balance calculations were also conducted to track mass inputs and outputs. Mass inputs included biomass feedstock, water in the biomass, and water added as steam in the water-gas shift reactor. Mass outputs included syngas, char and both tar and water condensate.

3.1.7.6 Syngas Composition

We shipped a few truckloads of redwood sawdust to Proton Power in Tennessee to use for gasifier testing. Proton provided us with limited, but useful information. Proton Power provided typical gas composition data for syngas generated from their gasifier units operated at their fabrication and testing facilities in Tennessee. This was based on gas samples from both their smaller prototype units, as well as one sample from a full-scale (750 kWth) commercial unit. The full-scale unit, referred to as the P8, is comparable to the unit at BLR. The team's best estimates of syngas composition data are presented in Table 15.

Note that hydrogen concentrations are high, as was expected, but not as high as Proton Power committed to in their sales contract ($\geqslant$ 60% by volume). There is flexibility to accept lower hydrogen concentrations, though efficiency of the system would be reduced. However, the CO concentrations are also very high, at 35-40% by volume. Proton Power originally estimated CO concentrations would be about 5% by volume, and committed to $\leqslant$ 10% by volume in their sales contract. The gas purification system (i.e., the PSA) is designed to handle no more than 20% CO by volume, and less CO is better as the PSA can operate more efficiently with lower CO concentrations. For these reasons, the syngas compositions shown in Table 15 are not acceptable for this application.

The research team continues to work with Proton Power, and they understand the importance of the syngas composition. As of this writing they are committed to meeting the syngas composition specifications they agreed to. They are currently in the process of developing a tar reformer and water-gas shift reactor, which they had mentioned as a possibility early on in the project, but had expected would not be necessary. A tar reformer and water-gas shift reactor will add complication, expense, and parasitic load to the system, but it is a logical next step and it offers the benefit of increased hydrogen concentrations as a result of converting CO to CO2.

Table 15: Syngas Composition Test Results for Proton Power Gasifier

Date	1/30/14	1/30/14	8/8/14	3/28/16	?
Test Lab	Core Laboratories	Test America	Proton (3rd party?)	Proton (micro-GC)	?
Gasifier Unit	P4 prototype	P4 prototype	P4 prototype	P8 full-scale	P8 full-scale
Feedstock	redwood sawdust	redwood sawdust	hardwood	mix[1]	redwood sawdust
Gas concentrations (Mol%)					
Hydrogen (H_2)	49.27	46	45.18	45.5	42.3[2]
Oxygen (O_2)	0.04		0.08	1.3	
Nitrogen (N_2)	0.3		0.48	5.5	
Methane (CH_4)	5.86	5.6	9.01	4.9	
Carbon Monoxide (CO)	35.91	41	35.13	35.1	
Carbon Dioxide (CO_2)	8.04	8.6	8.41	7.3	
Ethylene	0.24		1	0.2	
Ethane	0.01		0.27	0.0	
Hydrogen Sulfide	<0.01		0.0	0.0	
Propane	<0.01		0.07	0.0	
Propylene	<0.01		0.01	0.1	
Isobutane	<0.01		0.04		
n-Butane	0.2		0.07		
trans-2-Butene	<0.01		0.01		
1-Butene	<0.01		0.01		
Isobutylene	<0.01		0.01		
cis-2-Butene	<0.01		0.01		
1,3-Butadiene	<0.01		0.01		
Isopentane	<0.01		0.03		
n-Pentane	<0.01		0.04		
(Hexanes plus @ 0.12 mol%):	0.13				
Naphthalene 70%			0.08		
Anthracene 15%			0.02		
Phenanthrene 15%			0.02		

Table 15 notes: (1) Average of three runs, each with different feedstock mix, including switch grass, mixed hardwood, and crumbled oak. (2) Average of three runs using redwood sawdust feedstock. H2 concentrations of 38%, 44% and 45%.

Source: Schatz Energy Research Center, Proton Power Inc.

Estimated major gas constituent concentrations after the water-gas shift reaction are shown in Table 16 for various reactor conversion efficiencies. In the rest of the analysis of the WGS reactor it was assumed 80% conversion efficiency[3], a 2.6-to-1 steam-to-carbon ratio, and a parasitic electrical load of approximately 36 kW. As noted above, this assumes that the exothermic energy from the water-gas shift reaction can be utilized to offset some of the power required to generate steam for the reaction.

Table 16: Estimated Syngas Composition Following Water-Gas Shift Reaction

CO Conversion Efficiency		100%	90%	80%	70%
	Raw syngas (Mol%)	Treated syngas (Mol%)	Treated syngas (Mol%)	Treated syngas (Mol%)	Treated syngas (Mol%)
H_2	45	59	58	57	56
CO	35	0	3	5	8
CO_2	8	32	30	28	26
CH_4	9	7	7	7	7
Remainder	3	2	2	2	2

Source: Schatz Energy Research Center, Proton Power Inc.

Note that the gas composition results shown in both Table 15 and Table 16 are critical with regard to both major gas constituents and minor trace impurities. As shown in a previous table, the PSA can only tolerate certain ranges of major gas constituents and very low levels (i.e., parts per million) of certain trace impurities. A review of these tables indicates that although the major gas constituent concentrations will not present an issue following water-gas shift and most of the trace impurities do not appear to present a problem either, there is uncertainty with regard to some of the trace impurities. In particular, tar vapors could present a problem. Proton Power is proposing a tar reformer along with the water-gas shift reactor. This tar reformer will need to be very efficient, as the PSA cannot handle more than 10 ppm tar vapors and 50 ppm benzene, tolulene and xylene. In addition, hydrogen sulfide concentrations could pose a problem since they must be less than 5 ppm. Other potential problem contaminants include hydrogen cyanide, acetonitrile, and carbonyl sulphide. If these trace impurities prove to be a problem, a guard bed would be needed to remove them before the syngas enters the PSA.

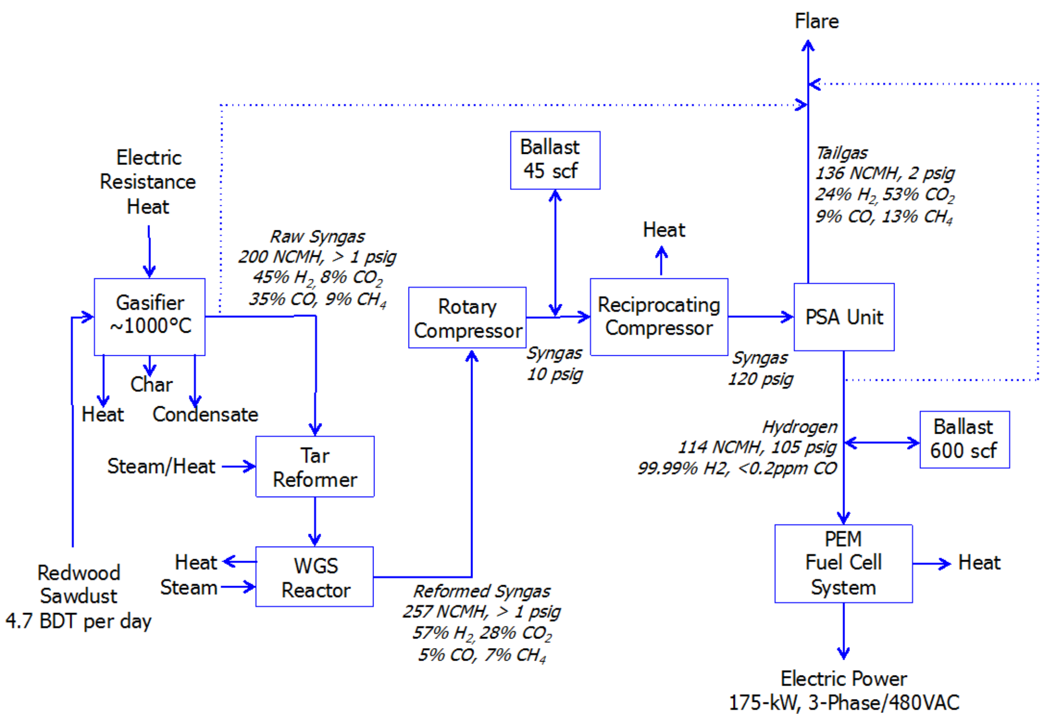
According to Proton Power, both tar reforming and WGS reactors will be designed to operate at atmospheric pressure. As such, some reaction efficiency, particularly for the WGS reactor, will be compromised in order to achieve a simpler system. The reactors are expected to run at slight negative pressure, as a downstream compressor drawing on the gas stream will control gas

[3] A CO conversion efficiency of 80% implies that two water-gas shift reactors will be required (Grol, E. & W. Yang 2009). If only one shift reactor is utilized a maximum 75% CO conversion efficiency is expected.

flow. Reactor geometries will be designed to limit pressure drop through each bed to approximately 1.0 psig.

Proton Power has provided a preliminary system schematic showing the proposed tar reformer (850°C) and low-temperature water-gas shift reactor (400°C). These units would be on the immediate output of the gasifier reactors, with the tar reformer receiving the hot, low-pressure (inches of water column) gases as they leave the gasifier reactor and pass through a silicon carbide filter. The existing rotary claw compressor would be used to pull the syngas through the filter, tar reformer, water-gas shift reactor, and downstream condenser/dryer. The rotary claw compressor would then deliver the conditioned syngas at 10 psig to the existing reciprocating compressor. An adapted process flow diagram showing the modified system with tar reformer and water-gas shift reactor is shown in Figure 38.

Figure 38: BIGFC System – Modified Process Flow With Tar Reformer and Water-Gas Shift Reactor



Source: Schatz Energy Research Center.

3.1.7.7 Gasifier Mass and Energy Balance and Efficiency Estimate

Proton Power provided the following information to help determine the biomass feed rate to be used in the mass and energy balance models: "Assuming a good feedstock, optimally presented with not an atom lost, you could generate 185 kWe with a 46% efficiency for about 1.95 bone dry tonnes/day. It is suggested that for calculation purposes 20 bone dry tonnes/day per continuous MWe is needed. The 185 kWe would therefore be 3.7 tonnes/day." This was the best information obtained by the researchers. Note that Proton markets their gasifier for use with an internal combustion gas engine-generator, and this feed rate information should be interpreted in that context. Using the assumption of a feed rate of 1.95 BDT/day with a moisture content of 30% (wet basis) and a gas genset electrical efficiency of 36% for a GE Jenbacher J208 330 kWe (GE Power 2016), it was estimated approximately 194 kWe output from the genset. Researchers generally agreed on the mass balance, although they ended up with about 14% of the oxygen unaccounted for. In addition, the energy output from the gasifier was overestimated by about 25-30%. This was expected due to an underestimate of the energy inputs to the gasifier and perhaps a gas composition that is not possible for the defined conditions. Nonetheless, this provides a decent agreement with the information received from Proton.

If the biomass feed rate was increased to 3.7 BDT/day (an increase of almost a factor of two), the team ends up with very good agreement in the mass balance, and the energy balance is plausible (less energy out than energy in). Under these conditions, they predicted a high production rate of char, equivalent to about 20% of the incoming mass. According to Proton, it is expected about 5% of the incoming mass will be converted to char. The estimated gasifier efficiency under these conditions, calculated as syngas energy output divided by biomass fuel and electrical energy input, is about 70%.

For the Blue Lake Rancheria BIGFC system configuration the gasifier energy and mass balance models were modified to include a water-gas shift reactor. It was assumed a steam-to-carbon ratio in the water-gas shift reactor of 2.6 and CO conversion efficiency in the reactor of 80%. This agrees well with testing conducted at the National Carbon Capture Center (NCCC 2012). The objective was to produce enough hydrogen in the syngas to operate the fuel cell at full power (175 kWe net); this corresponds to 10.7 kg/hr of hydrogen.

To produce sufficient hydrogen in the conditioned syngas the team estimated a required biomass feed rate of 4.7 BDT/day (this is consistent with the estimates provided by Proton Power) and assumed 10% of the total carbon ended up forming tars and char production was equivalent to 15% of the incoming biomass mass. In this case both the energy and mass balance were very good. The estimated gasifier efficiency under these conditions is again about 67%. The reformed syngas flow rate was 257 NCMH.

3.1.7.8 Pressure Swing Adsorption Performance Assessment

The PSA is required to produce pure hydrogen for the proton exchange membrane fuel cell. The PSA must produce product gas with a very high level of purity; namely, it must reduce the CO content of the product hydrogen gas to less than 0.2 PPM. Xebec Adsorption Inc. provided estimates of PSA hydrogen recovery efficiency for three syngas composition scenarios (Table 17). A log-log mathematical model was fit to this relationship, allowing the team to predict recovery efficiency as a function of CO content. Note that Xebec performed bench top laboratory tests to inform their design models before providing these estimates. Using estimates of hydrogen recovery efficiency allowed the researchers to predict the amount of product hydrogen and the composition and flow rate of the tail gas that will be discharged from the PSA. The taigas is the result of back flushing of the adsorbent beds, a process that is required in order to recharge the beds for repeated use.

Table 17: Estimated PSA Hydrogen Recovery Efficiency

Syngas CO Content (Mol%)	Hydrogen Recovery Efficiency (%)
5	78
10	>72
20	>68

Source: Xebec Adsorption Inc.

With a syngas flow of 257 NCMH into the PSA, a hydrogen content of 57 Mol% and a carbon monoxide content of 5 Mol%, the PSA will produce about 10.7 kg/hr of pure hydrogen that can be sent to the fuel cell. In addition, the PSA will discharge a taigas at a flow rate of 136 NCMH with a composition of 53 Mol% CO_2, 24 Mol% H_2, 13 Mol% CH_4, and 9 Mol% CO. As currently designed, this tail gas will be sent to a flare to be cleanly burned, converting the CO, CH_4 and H_2 to CO_2 and water. However, there is a substantial amount of energy in this taigas (estimated at 339 kWth), and it could be possible to recover this energy and use it to decrease the required energy inputs to the overall system. This is discussed further in Section 3.1.7.9.

PSA energy efficiency was assessed according to Equation 3, Appendix C. The electrical power input to the PSA is insignificant, so the efficiency for the unit, assuming no use of the energy in the taigas, is a function of the hydrogen energy output divided by the syngas energy input. The PSA energy efficiency is 51%; if the taigas were utilized this efficiency would increase substantially.

3.1.7.9 Fuel Cell System Performance Assessment

A performance evaluation was conducted to determine the electrical efficiency and total efficiency (electrical and waste heat) of the fuel cell power system according to Equations 4 and 5, Appendix C. These efficiencies were calculated for full power output (175 kW AC net) using both the lower heating value (LHV) and the higher heating value (HHV) of hydrogen gas. Values of the inverter efficiency and parasitic loads were also computed and compared to the manufacturer's product specifications.

The Ballard 175 kWe ClearGen™ Fuel Cell Generator has only been partially commissioned at the Blue Lake Rancheria site. Full commissioning and operation will require a steady supply of hydrogen, and this in turn will depend on a fully functioning gasifier system and PSA. However, prior to procurement and shipment of the fuel cell generator to BLR, Ballard engineers set-up and operated the unit at their facility in Burnaby, BC, Canada. Data collected during this testing period show that the fuel cell was operated at two power levels, 135 kW and 163 kW net AC power output. Extrapolation of data beyond these operating points was required to complete an analysis for full power output.

It should be noted that net AC power output was not measured directly; it is calculated within the Ballard data acquisition system. Ballard estimates the required auxiliary power, or parasitic loads, as a percentage of system power output. The parasitic power includes all system loads within the Ballard power control module and fuel cell module, with the exception of the electrical loads in the cooling water system. The net AC power is calculated by subtracting the subsystem parasitic loads from the gross AC power output as measured by the system inverter.

The methodology used for calculating the FC electrical efficiency and the FC total efficiency using the given data set is presented below.

1. Determine the % parasitic load using net AC power and gross AC power

Result: The parasitic load is 7.4% of the gross AC power output, resulting in 14 kW at full power operation. The Ballard manual states that the maximum auxiliary power is 15 kW (excluding the cooling system).

2. Determine the PCS efficiency using DC power and gross AC power

Result: The PCS efficiency was calculated at 96.1%; Ballard manual specifies 97%.

3. Plot IV Curve for the fuel cell stacks using IFC and VFC with a trend line and equation

Result: The fuel cell operating points are along the ohmic region of the IV curve, therefore the trend line and equation are somewhat linear and do not capture the downward portion of the curve associated with limitations of mass transport.

4. Use the IV Curve equation, the inverter efficiency and the parasitic power loss to determine the stack current and voltage operating point that will produce the necessary DC power to output 175 kW net AC power output

Result: DC power = 197 kW, gross AC power = 189 kW, net AC power = 175 kW. Note that this extrapolation assumes that full power operation exists within the ohmic region of the IV curve.

5. Plot H2 flow vs. net AC power and use trend line equation to approximate the H2 flow rate at 175 kW net AC power

Result: H2 flow rate at full power is approximated at 10.7 kg/hr.

6. Calculate the hydrogen input power to the fuel cell using the LHV and HHV and the approximated H2 flow rate at full power calculated above.

Result: H2 input (LHV) = 344 kW, H2 input (HHV) = 408 kW

7. Calculate FC electrical efficiencies for 175 kW net AC power using H2 input power

Result: FC electrical efficiency (LHV) = 50.8%, FC electrical efficiency (HHV) = 42.9%

The Ballard manual states an electrical efficiency (HHV) at full power = 40%

8. Calculate the total efficiency (electrical and waste heat) of the fuel cell power system using the above result and the value for waste heat as stated in the Ballard manual

Result: FC total efficiency (LHV) = 94.4%, FC total efficiency (HHV) = 79.7%

3.1.7.10 BIGFC System Analysis

BIGFC System Efficiency Analysis

The BIGFC system efficiency was estimated according to Equations 6 and 7 in Appendix C as net energy output divided by total biomass fuel energy input. The modified process flow diagrams presented in Figure 39 and Figure 40 document the energy inputs and outputs from the system. Multiple system configurations with various degrees of waste heat recovery were evaluated.

In Case 1, the researchers evaluated a system where no waste heat is recovered, not even for biomass drying. In this case it is assumed biomass is obtained at 30% moisture content. In Case 2 and all subsequent cases, they assume biomass received at 60% moisture content is dried to 30% using waste heat from the flare. In Case 3 they also used waste heat from the flare to heat the steam for the tar reformer and water-gas shift reactor. In Case 4 the researchers also heat the gasifier reactor using waste heat from the flare. In Case 5 all available heat from the flare was used, and in Case 6 all available waste heat, including the lower grade heat being dumped by the gasifier, reciprocating compressor and fuel cell cooling systems was used. Assumptions used in the modeling for all of these configurations are shown in Table 18. Table 19 show estimated system efficiencies and component efficiencies under the various scenarios. Efficiencies are all based on lower heating values.

Figure 39 shows the distribution of total system energy for scenario Case 1. The majority of the system energy is lost due to PSA losses, gasifier losses, and fuel cell losses. Gasifier reactor heater losses and WGS and tar reformer losses are broken out separately since these losses can be averted by using the waste heat from the flare tail gas. Note that this pie chart assumes no waste heat recovery. There is substantial high quality heat available in the tail gas that could be used to offset a portion of the parasitic loads and to dry the biomass. In fact, essentially all of the PSA losses are due to the heat being dumped via the flared tail gas. If this waste heat source is utilized the PSA efficiency will improve substantially. The pie chart clearly shows the trivial amount of net power out of the system compared to total system energy.

Figure 40 shows the available waste heat in the flared tail gas and the proposed use of this waste heat source.

Table 18: BIGFC System Modeling Assumptions

Parameter	Value
Biomass feed rate	4.7 MT/day (dry)
Biomass moisture content, received (wet basis)	60%
Biomass moisture content to gasifier (wet basis)	30%
WGS CO conversion efficiency	80%
WGS steam-to-carbon ratio	2.6
Syngas flow rate (post WGS)	257 NCMH
Syngas composition, pre-WGS (Mol%)	H_2, CO, CH_4, CO_2 45%, 35%, 9%, 8%
Syngas composition, post-WGS (Mol%)	H_2, CO, CH_4, CO_2 57%, 5%, 7%, 28%
PSA H_2 recovery efficiency	78%

Source: Schatz Energy Research Center

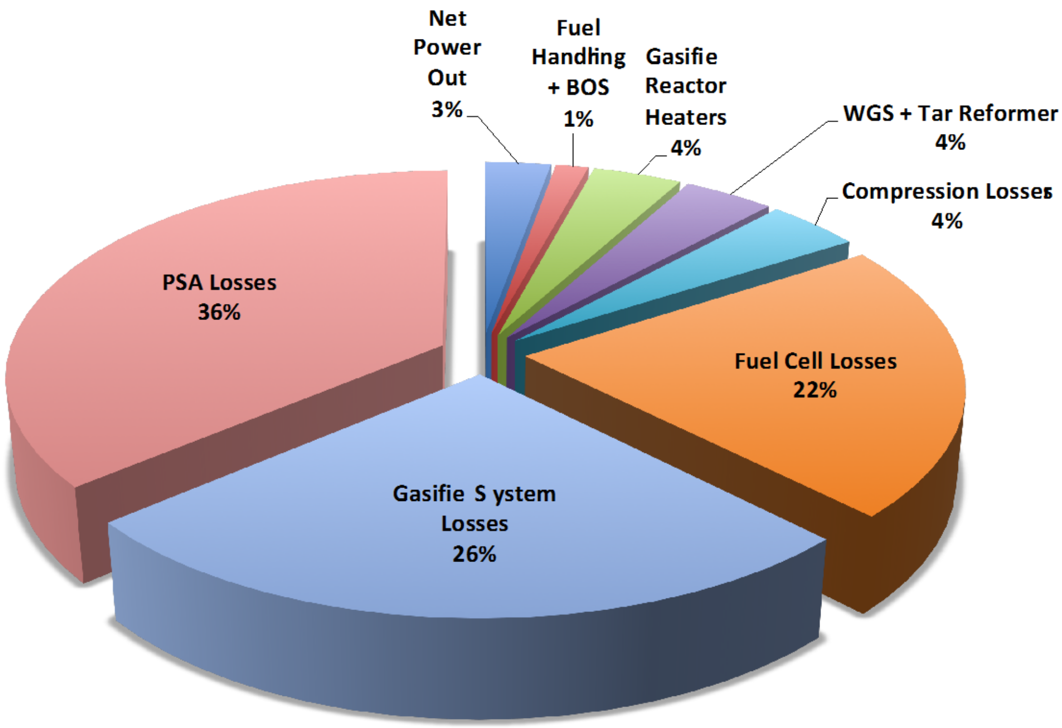
Table 19: BIGFC System Performance Estimates

Scenario	Waste Heat Recovery	Gasifier System Efficiency* (%)	PSA Efficiency (%)	Fuel Cell Efficiency (%)	Waste Heat Recovery (%)	System Efficiency (%)	Net Electric Power Output (kW)
Case 1	None**	68	51	51	0	2.9	26
Case 2	From flare to dry biomass	68	73	51	24	2.9	26
Case 3	From flare to dry biomass + for WGS and tar reformer	70	78	51	30	6.8	63
Case 4	From flare to dry biomass + for WGS, tar reformer & gasifier reactor	73	83	51	36	10.7	99
Case 5	All heat from flare	73	100	51	55	23.4	99
Case 6	All available waste heat	73	100	51	100	54.0	99

*Gasifier system includes tar reformer and WGS reactor. **Assumes biomass obtained at 30% moisture content.

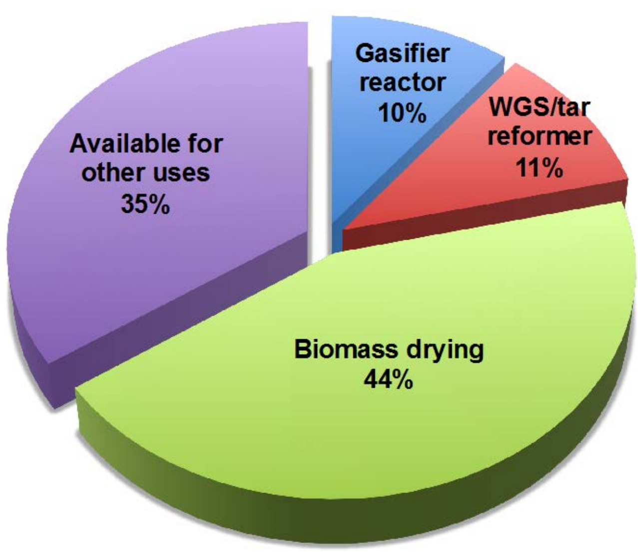
Source: Schatz Energy Research Center

Figure 39: Distribution of Total System Energy – Case 1



Source: Schatz Energy Research Center

Figure 40: Proposed Allocation of Waste Heat from Tail Gas Flare



Source: Schatz Energy Research Center

BIGFC System Economic Analysis

Cases 2, 3 and 4 were evaluated for economic viability. Note that this economic evaluation provides only a very rough estimate, as many of the costs are highly uncertain. This includes the capital cost of the gasifier system, which is still in early commercial development stage, and well as the water-gas shift reactor and tar reformer, fixed system O&M costs, and variable system O&M costs. The latter two cost parameters were estimated based on biomass and fuel cell plant O&M cost estimates from Klein et.al. 2007. Economic parameters assessed included fuel cost, operation and maintenance cost, capital recovery cost and life cycle cost of energy. A system capacity factor of 80% and a real discount rate of 5% were assumed. Table 20 presents results of the economic analysis.

Table 20: BIGFC System Cost Analysis

Scenario	Biomass Fuel Cost ($/kWh)	Non-Fuel O&M Cost ($/kWh)	Total O&M Cost ($/kWh)	Capital Recovery Cost ($/kWh)	Total Life Cycle Cost of Energy ($/kWh)
Case 2	0.52	0.30	0.82	2.03	2.85
Case 3	0.22	0.16	0.38	0.85	1.23
Case 4	0.14	0.13	0.27	0.54	0.81

Source: Schatz Energy Research Center

For scenarios 2 through 4, total operating costs, not including amortized capital costs, range from about $0.27/kWh to $0.82/kWh. For comparison purposes, the current cost of electricity for the Blue Lake Casino is about $0.13/kWh to $0.14/kWh. When amortized capital costs are factored in, the life cycle cost of energy ranges from $0.81/kWh to $2.85/kWh. Clearly the BIGFC system is not competitive with the cost of grid power.

Another economic measure is to compare the cost of operating the BIGFC system to the cost of operating BLR's 1-MW back-up diesel generator. At a dyed-diesel price of $3.50/gal, the cost to operate the diesel generator is estimated at $0.35/kWh, and at a $3/gal the cost drops to $0.30/kWh. Consequently, from an economic standpoint the BIGFC system could potentially be a viable alternative to running the diesel generator if the waste heat from the flare were used to offset the parasitic loads associated with the gasifier reactor heaters and the steam generators for the tar reformer and water-gas shift reactor.

However, the BIGFC system is not well suited to meet the needs of this application. The diesel generator is currently used to provide back-up power when there are local power outages on the electric utility grid or when BLR participates in demand response programs. In both of these situations the diesel generator needs to be started rapidly. The BIGFC system is not capable of being started from a cold state in rapid fashion. Instead, the gasifier reactor needs to be slowly heated to operating temperature over about an eight-hour period. In addition, the 1-MW diesel generator is capable of carrying the entire load at BLR, where as the BIGFC system could only carry a portion of the load (i.e., no more than about 25%).

Opportunities for substantial cost reductions that could make the BIGFC system competitive with PG&E power are not likely. For operating costs, it is estimated more than half of the total amount is due to fuel costs. Table 21 shows the operating cost assumptions that were used in this analysis and includes a breakdown of costs by category for Case 4.

Table 21: BIGFC System Operating Costs

Cost Parameter	Cost per Unit	Cost** ($/kWh)	Percent of Total Operating Cost**
Fuel	$30/ton (50% MC wet basis)	$0.14	52%
Labor	$120/day***	$0.06	24%
Operations & Maintenance	$0.065/kWh	$0.07	24%
Total Operating Cost		**$0.27**	

* Numbers shown are the Case 4 where all heat energy needed for the gasifier reactor, the tar reformer and the water-gas shift reactor are met using the waste heat from the flare.

** Assumes a capacity factor or 80%.

*** Assumes 8 person-hours per day.

Source: Schatz Energy Research Center

The capital costs associated with the BLR DG biomass facility are listed in Table 21 and broken out by major categories. While most of the costs are for commercially mature "off-the-shelf" equipment, there are some exceptions. Specifically, the Proton Power CHyP gasifier system is in a very early-stage of commercial development, and is still undergoing technology development. Pricing for this unit is therefore uncertain, including the price for gas conditioning and cleanup equipment such as the tar reformer and water-gas shift reactor. While this type of gas cleanup equipment may be mature in some applications, it is not currently mature technology for DG biomass energy systems.

Note that Table 21 loosely categorizes costs across major cost categories and shows that the total project cost, including both grant and match funds, was about $3.4 million. However, there was some additional cost share that was not counted. In addition, Case 4 is evaluated, which includes a tar reformer and water-gas shift reactor. It is estimated these additional costs bring the total project cost to $3.9 million. Note that design, engineering and management costs are not included in the stated costs.

Table 22: DG Biomass Facility Capital Costs (Millions)

Item/Cost Category	CA Energy Commission Funds ($)	Match Funds ($)	Total ($)
Major Equipment	0.60	1.80	2.40
Materials/Supplies	0.10	0.03	0.13
Minor Subcontractors	0.40	0.50	0.90
Total	1.10	2.33	3.43

Source: Schatz Energy Research Center

BIGFC System Greenhouse Gas Emissions Analysis

One of the objectives of installing the BIGFC system was the opportunity to reduce greenhouse gas emissions. In this section the research team assessed the CO2e reduction potential for the Case 4 scenario. Assuming a capacity factor of 80%, the BIGFC system will generate 691,080 kWh per year. This equates to a reduction of 134 MT CO2e using PG&E's emissions factor of 0.194 kg CO2e/kWh (PG&E 2015). Note that it is assumed the biomass fuel for the BIGFC system is carbon neutral because it is a mill waste product that would result in CO2 emissions if it were not used as a biomass fuel. The incremental cost associated with running the BIGFC system would be about $88,000 per year, resulting in an excessive carbon reduction cost of $630/MT CO2e. The California Carbon Dashboard (calcarbondash.org 2016) shows current carbon prices to be only about $12 to $13/MT CO2e, so this is clearly not a cost effective measure.

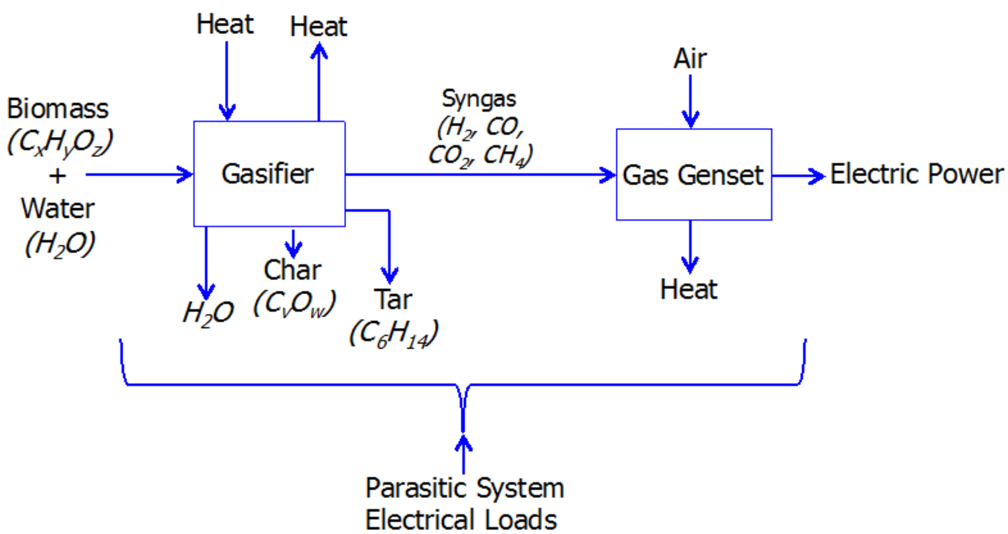
3.1.7.11 Alternate DG Biomass System Configurations

An alternate design for the DG biomass system was assessed that consisted of the biomass gasifier integrated with a gas engine genset. This is a somewhat simpler design. It means that the tar reformer, water-gas shift reactor, rotary claw compressor, reciprocating compressor, PSA and fuel cell can all be eliminated and replaced by a gas engine generator. The result is a substantial reduction in capital costs; it is expected the capital cost for a 250 kWe system (gross system output) to be about $2.4 million. In addition, dropping the gas compression and conditioning equipment listed above will substantially reduce the parasitic loads and simplify the system. The issues the researchers faced with an unacceptable gas composition due to too much CO would no longer be an issue as the CO, H2 and CH4 can all be burned in the IC engine. Gas gensets, like the GE Jenbacher unit, are well proven operating on biogas fuels and are being used in limited applications coupled with biomass gasifiers.

A modified mass and energy balance model was developed to assess the expected performance of this alternate system and to compare performance characteristics with the original system design. Figure 41 shows the mass and energy balance model with the key inputs and outputs identified. Figure 42 shows the major chemical conversions taking place in the system; these relationships were used to ensure that mass and energy were conserved.

The results show that a biomass gasifier coupled with a GE Jenbacher genset is likely to be substantially more efficient than the fuel cell based system, and therefore much more likely to be economically viable. Table 23 shows an efficiency comparison between these two systems, and Table 24 shows an economic comparison. Clearly the gas genset solution is preferable, though the life cycle cost of this option still doesn't compete with the price of electricity from PG&E.

Figure 41: DG Biomass Gasifier-Genset Mass and Energy Balance Model



Source: Schatz Energy Research Center\

Figure 42: DG Biomass Gasifier-Genset Mass Flow Conversions

Conversion 5

$$C_xH_yO_z + H_2O \rightarrow H_2O + C_vO_w + C_6H_{14} + H_2 + CO + CO_2 + CH_4$$

biomass + water → *water + char + tar + syngas*

Gasifier

Conversion 6

$$H_2 + CO + CO_2 + CH_4 + O_2 \rightarrow H_2O + CO_2$$

hydrogen + carbon monoxide + carbon dioxide + methane + oxygen → *water + carbon dioxide*

Gas Engine Generator

Note that these are not balanced equations, but instead are intended as mass flow diagrams.

Source: Schatz Energy Research Center

Table 23: Performance Comparison Between Gasifier-Fuel Cell System and Gasifier-Genset System

Scenario	Biomass Feed Rate (MT/day-dry)	Waste Heat Recovery	Gasifier System Efficiency (%)	PSA Efficiency (%)	Generator Efficiency (%)	Waste Heat Recovery (%)	System Efficiency (%)	Net Electric Power Output (kW)
Gasifier-Fuel Cell System, Case 4	4.7	From flare to dry biomass + for WGS, tar reformer & gasifier reactor	73 (includes WGS & tar reformer)	83	51 (fuel cell)	36	10.7	99
Gasifier-Genset System	4.5	None	72	N/A	36 (IC engine generator)	0	19.0	168

Source: Schatz Energy Research Center

Table 24: Cost Comparison Between Gasifier-Fuel Cell System and Gasifier-Genset System

Scenario	Biomass Fuel Cost ($/kWh)	Non-Fuel O&M Cost ($/kWh)	Capital Recovery Cost ($/kWh)	Total Life Cycle Cost of Energy ($/kWh)
Gasifier-Fuel Cell System, Case 4	0.14	0.13	0.54	0.81
Gasifier-Genset System	0.07	0.10	0.20	0.37

Source: Schatz Energy Research Center

3.1.8 DG Biomass Project Evaluation

In this section project results are discussed and evaluated on how well the DG biomass project goals and objectives were met. The DG biomass project assessed the effort, evaluated outcomes, and explored options for moving forward. This includes a brief assessment of other DG biomass technology options.

3.1.8.1 Evaluation of Project Goals, Objectives and Results

The goals for the DG biomass project are shown in Table 25 and are compared with corresponding project accomplishments. The stated metrics for success included installing and operating a gasifier that converts sawdust into syngas with hydrogen content of 60% or greater (by volume). In addition, the gasifier was to be integrated with a proton exchange membrane (PEM) fuel cell and operated to produce a peak power output of at least 175 kW, a capacity factor of 75% or better, a biomass-to-electricity efficiency of 25% or greater, and an overall energy efficiency, including waste heat recovery, of at least 50%.

Table 25: DG Biomass Project Accomplishments vs. Project Goals

Goals	Metrics	Accomplishments
Install and operate a biomass gasifier that produces a hydrogen rich syngas	• Syngas composition: > 60% hydrogen by volume	• Syngas generated with 40% to 50% hydrogen by volume (offsite)
Design, install, and operate a BIGFC CHP system	• Peak output ≥ 175 kW • Capacity factor > 75% • Biomass-to-electricity efficiency of > 25% • Overall energy efficiency, including waste heat recovery, of > 50%	• Fuel cell tested at factory, produced 175 kW net output • BIGFC system was installed and partially commissioned, has not been operated, no measure of capacity factor, estimated biomass-to-electricity efficiency of only 3-10%, estimated overall efficiency with maximum theoretical heat recovery = 51% • Assessed alternate system design replacing fuel cell with gas genset, estimated system electrical efficiency of 19%
Share results from the BIGFC CHP system and communicate the potential for replication throughout the state	• Publish at least two journal articles documenting results • Present results at one or more conferences • Post project case study information on at least three industry organization web sites	• Delivered project presentations at over 20 workshops, conferences and meetings (see Table 35). • Substantial media coverage via web and other mediums

Source: Schatz Energy Research Center

While many of the stated goals of the DG biomass project were not met, much was accomplished and learned through the course of the project. The key setback for the project was that the biomass gasifier was never made fully operational and at this time is not capable of meeting the required syngas specification. This, in turn, has prevented the full commissioning, operation and testing of the rest of the system. Proton Power, the gasifier manufacturer, has been working to resolve the problem, but has not yet succeeded.

The key problem is that the gasifier produces a syngas with too much CO (i.e., ~35% by volume). While Proton Power reported syngas production with lower CO concentrations using their prototype units, they have not been able to replicate this for the project. Still looking to achieve their intended goals, Proton is currently attempting to develop and test a tar reformer and a water-gas shift reactor to rectify the problem. These gas cleanup systems will be installed immediately downstream of the gasifier reactor. The water-gas shift reactor will react steam with CO in the syngas, producing CO2 and H2. If the water-gas shift reactor works as planned it could allow full operation, testing and commissioning of the system at some future date. However, it has been shown through system modeling that even if the system can be made operational via use of a water-gas shift reactor, it is unlikely that it can be operated at a cost that will be competitive with grid electricity.

As was stated above, although the operational goals were not met, much has been accomplished. An innovative DG biomass energy system was conceived, designed, procured and installed, and many lessons were learned in the process. Many of the lessons learned are described in Section 4.2. In addition, as shown in Table 10 previous table, all of the system components were installed and most were successfully commissioned, the exception being the PSA. It could not be commissioned because its operation is dependent on syngas from the gasifier.

It should be noted that the researchers were are going into the project that the gasifier was the most uncertain component in the system. Most all of the other equipment is well-proven and essentially off-the-shelf technology. It was expected that obtaining a gasifier that could produce the syngas quality required, and then integrating that gasifier into the overall system would be the greatest challenge. The research team also knew it provided the area where the greatest learning could be achieved and, if successful, the greatest benefits could be realized.

In addition to the design, procurement, installation and testing work accomplished, the researchers also developed mass and energy balance models that allowed them to develop estimates of system performance based on the data and information assembled. The results of the modeling exercise are presented in Section 3.1.7.8 of this report and shed considerable light on the potential viability of a BIGFC system. In addition, in Section 3.1.7.9, an alternate DG biomass gasification system was examined and compared to the BIGFC system.

The net result is that a BIGFC system does not appear to be economically viable. It is, in its current configuration, both too expensive and too inefficient. Because this project was a demonstration of leading edge technology, there was limited literature available for review during the application and design phase. One source that supported the pursuit of a fuel cell solution because of its potential for a high biomass-to-electricity energy conversion efficiency was a Ballard white paper titled “Biomass-to-Fuel-Cell Power… For Renewable Distributed Power Generation” (Ballard 2013). This paper predicted biomass-to-fuel-cell system electrical efficiencies of 29% to 32%, and total system efficiencies as high as 80% to 90% if all the waste heat was captured and utilized.

The white paper was of course based on estimated information. For example, Proton Power’s reported results were that their gasifier could produce syngas with a composition of 65% hydrogen, 30% CO2, and only 5% CO. However, in practice at the scale of the BLR unit the CO concentration is about 35% and the H2 concentration is about 55% (without a water-gas shift reactor and/or other gas clean up equipment). In addition, the white paper assumed far too much hydrogen could be generated per unit of biomass input. In fact, the required biomass is more than twice what was estimated in the white paper, even with a water-gas shift reactor included. Finally, there are substantial parasitic electrical loads associated with the system that were not accounted for in the white paper. For example, the heat for the gasifier reactor was assumed to come from the waste heat in the taigas, but this is not currently a feature of the Proton Power CHyP™ gasifier system.

These assumptions made for over-optimistic estimates of hydrogen output as a function of both biomass fuel and electrical energy inputs. Where the Ballard white paper estimated a biomass-to-electricity energy conversion efficiency of approximately 30%, it was found it is likely to be only about 11%, even with the heat needed for the gasifier and water-gas shift reactor coming from the flare. If that heat comes from electric resistance heaters, as is now the case, the overall system efficiency drops to about 3%. This type of understanding occurs only through the implementation and study of real-world projects, where equipment and balance of system details must be worked out during design, procurement, installation and commissioning phases. This type of learning is a key benefit of this project.

The analysis indicates that a biomass-integrated gasification fuel cell system using a PEM fuel cell is not likely to compete on a cost and efficiency basis with a biomass-integrated gasification gas generator system. However, these conclusions only apply to low-temperature, PEM fuel cells that are sensitive to CO concentrations. High temperature fuel cells that can handle higher CO concentrations, like molten carbonate and solid oxide fuel cells, might fare better, though they will likely pose their own challenges. This is discussed further in the next section where various DG biomass options are discussed and assessed on their technological and market status and how they compare with each other.

3.1.8.2 Biomass Distributed Generation Options and Status

In this section various technology options for converting woody biomass fuel into electricity for distributed generation applications (i.e., < 10 MW) are considered. Technology options considered include:

- Steam boiler with steam turbine
- Gasifier with internal combustion (IC) gas engine-generator
- Gasifier with simple cycle gas turbine or microturbine
- Gasifier with fuel cell generator
- Hot water boiler with organic rankine cycle (orc) turbine

Table 26 compares these technology options in terms of various criteria. The maturity and availability criterion refers to technologies that are proven, available, off-the-shelf, integrated solutions. As can be seen, there are currently no proven, off-the-shelf, integrated solutions for available for biomass distributed generation applications.

Table 26: Comparison of Various Woody Biomass DG Technologies

Technology	Maturity & Availability	Cost	Efficiency	Complexity
Steam boiler + steam turbine	mature, low availability for small scale DG applications	high	low	medium
Gasifier + IC engine-generator	low maturity for gasifiers, IC engine-generators are mature, low availability and maturity for integrated systems	medium	medium	medium
Gasifier + gas turbine	low maturity for gasifiers, gas turbines are mature, no availability and maturity for integrated systems	medium/ high	medium	medium/ high
Gasifier + fuel cell	low maturity for gasifiers, fuel cells are mature, immature and no availability for integrated systems	high	low for PEMFC, potentially medium to high for SOFC/MCFC	high
Hot water boiler + ORC turbine	mature components, immature and no availability for integrated systems	low/ medium	low	low

Source: Schatz Energy Research Center

During the proposal phase of this project all of the technology options listed in Table 26 were considered. Systems explored in some detail included close-coupled gasifier steam boilers and stoker steam boilers coupled with small Rankine cycle steam turbines for electricity generation. While these types of systems do exist in the size range needed by BLR (≤ 500 kWe), their availability is sparse. In addition, their electrical generation efficiencies are typically low, i.e., less than 10%, and their costs per kWe of capacity are relatively high. At this low efficiency level, the cost of the biomass fuel (~ $30/wet ton) can be greater than the retail value of the generated electricity. A list of the DG biomass technology options considered during the proposal phase are included in Appendix F.

Other systems considered included two-stage gasifier systems that produce a syngas that can be used to fuel an internal combustion engine-generator or a gas turbine. A few commercial systems using internal combustion engine-generators were also identified, but they were deemed not to be a good fit based on cost and level of maturity. Organic Rankine cycle systems were also considered, but biomass-to-electricity efficiencies are again low (e.g., ~ 10%), making this technology also a poor fit. The possibility of integrating a gasifier with a high temperature molten carbonate fuel cell (MCFC) was also explored, but the project team was unsuccessful in engaging the MCFC manufacturer in a potential project. Eventually the team chose an integrated biomass gasification PEM fuel cell system as discussed in this report. However, given the difficulties experienced trying to implement this technology solution, as well as the low predicted efficiencies and high cost of this option, other options ar being explored.

The BIGFC system solution that was chosen used a low-temperature PEM fuel cell technology. This required very pure hydrogen gas and was particularly intolerant to high CO concentrations in the syngas. Others have explored the possibility of coupling a biomass gasifier with high-temperature fuel cell technology, such as a molten carbonate fuel cell (MCFC) or solid oxide fuel cell (SOFC). For example, a biomass-integrated gasification fuel cell system using a solid oxide fuel cell was examined via both experimental and modeling research (F.P. Nagel et. al. 2009a, 2009b, and 2011). The system tested ran non-stop for 28 hours. Results from this study predict potential biomass-to-electricity efficiencies in the range of 20% to 30%. Ph. Hoffmann et.al. (2007) also experimented in the laboratory with a SOFC coupled with a two-stage fixed-bed downdraft gasifier. The system was tested for approximately 150 hours and an average system electrical efficiency of 24%. Some modeling studies predict integrated-biomass gasification SOFC system efficiencies of 25% to 40% (Paengjuntuek, W. et.al. 2015, Athanasiou, C. et.al. 2006). However, it should be noted that these modeling and bench-top experimental studies are likely to underestimate parasitic loads that are likely to occur in actual field applications, and therefore overestimate actual system efficiencies.

A recent report by the California Biomass Collaborative (B. Williams & S. Kaffka 2015) does a good job of reviewing the current status and availability of biomass gasifiers for distributed generation applications. The authors note that there are numerous small to large scale biomass CHP systems in Europe. A number of systems and/or projects in California are also identified, none of which are mature or commercially readily available. This report also includes an appendix that provides a fairly extensive list of biomass gasification manufacturers.

Based on experience and literature review, the researchers do not think there are any technologically mature and commercially ready woody biomass distributed generation systems available in the United States at this time. Many people are trying, but the industry is not there yet. However, they believe the technology configuration that has the greatest chance of success at this time is a gasifier coupled with an internal combustion gas engine-generator. In fact, Proton Power, Inc. has designed and implemented such a system at a commercial site in Tennessee, though the team is uncertain of its success since they have not seen any performance data for the system. Another project that is currently under development and will also use this technology configuration is Phoenix Energy's North Fork Project in North Fork, CA. This project will feature an integrated biomass gasification solution from General Electric that includes a GE biomass gasifier, gas conditioning system and GE Jenbacher gas engine-generator. The GE Jenbacher generator is a well-established unit that has been successfully deployed in numerous biogas applications. The gasifier technology is evidently a down-draft design developed by the Indian Institute of Science and licensed by GE from a company in India (Krishnan R. 2015). This will likely be the first DG biomass system that has a fully integrated process train that has been designed and integrated and will be supported by a single manufacturer. If this system is successful it could be a significant breakthrough.

Additional information about various gasifier technologies and products is included in Appendix E. The following literature sources also provide fairly recent reviews of biomass gasification technology: Ahrenfeldt, J. et.al. (2013), Ilkka Hannula (2009) and Kumar, A. et.al. (2009).

3.2 Task 3: Develop, Implement and Evaluate Mad River Valley Community Energy Upgrade Program

3.2.1 MRVC Program Design and Setup

3.2.1.1 Timeline

The project was completed over the following timeline:

September – December 2013

- Program Administration
  - Identify staff and resources and assign tasks for program development.
  - Begin establishing program policies and procedures.
  - Engage with contractors to determine guidelines and participation protocols.
  - Identify and reach-out to community partners, including key stakeholders.
  - Identify resources and timelines for program implementation.
- Contractor Recruitment and Training
  - Identify and coordinate training opportunities.
  - Conduct outreach to contractors.
  - Conduct training and guidance through participation channels.

January – March 2014

- Continue contractor recruitment and training.
- Connect with community stakeholders and make presentations.
- Design marketing and outreach collateral and plan coordinated outreach effort.
- Design and set-up program tools, including databases and forms; order project materials and resources.
- Coordinate with existing programs to integrate tools and resources; develop implementation strategy.

March – September 2014

- Conduct targeted outreach, including canvassing and distribution of marketing materials.
- Plan outreach events.
- Design workshop materials. Plan and conduct workshops.
- Conduct bulk of implementation activities.
- Engage with stakeholders and coordinate efforts.

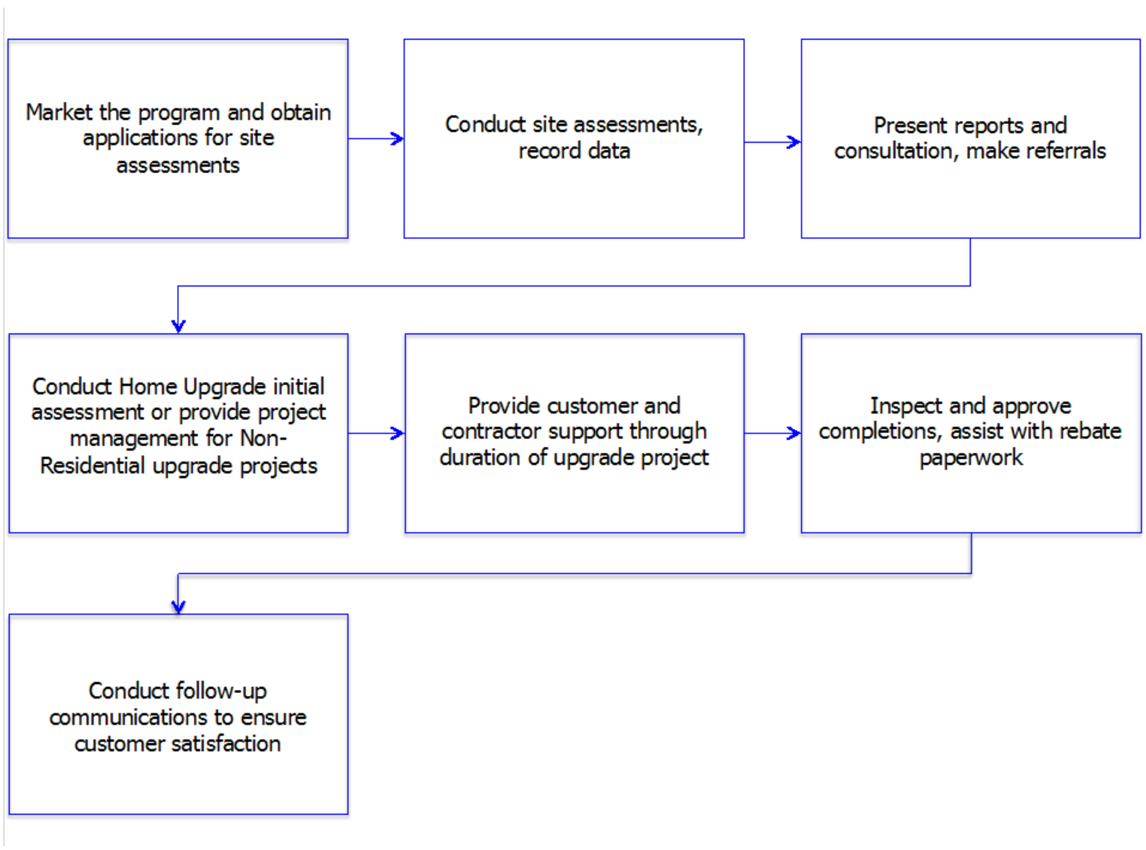
October – March 2015

- Wrap-up implementation activities.
- Evaluate program.
- Report results.

3.2.1.2 Overview of Program Design

The basic steps for a customer to participate in the program are outlined in Figure 43.

Figure 43: Process Flowchart for Completing Site Assessments and Upgrade Projects



Source: Redwood Coast Energy Authority

- **Market the program and obtain applications for site assessments**: conduct outreach to recruit participants who then submit an application for a site assessment, are prioritized based on site specifications and interests, and are scheduled.
- **Conduct assessments and record data**: program technicians conduct on-site analysis, enter information into software and databases, and generate reports.
- **Present reports, schedule consultations, and make referrals**: technicians and program staff deliver reports, conduct consultations to discuss the results, and make referrals to other programs or program contractors to pursue upgrade projects.
- **Move forward with projects**: program staff works in concert with participating contractors to conduct Home Upgrade initial assessments or provide project management services for solar and non-residential upgrade projects.
- **Provide customer and contractor support**: program staff continues providing project support by assisting with any necessary coordination and paperwork.
- **Inspect and approve completed projects**: staff inspects sites or provides a test-out to ensure that work is within program criteria and finalize any rebate or incentive applications.
- **Conduct follow-up communication**: staff performs courtesy calls to ensure customers are satisfied with their project and to resolve any issues when needed. Staff also contacts previous participants about new offerings or to identify new opportunities that were missed in the initial site assessment.

3.2.1.3 Tools and Resources

The program design included utilizing existing tools as well as creating new project management and assessment tools to aide in program implementation. To track customers and project progress, a simple Microsoft Excel database was set-up. To determine whether a customer participating in an existing program was qualified to received services under the MRVC Upgrade Program, a project boundary map was created with Google maps to map customer site locations. This enabled a customer to be tagged as qualified for the program if they had not signed up through program-specific outreach. This also enabled cross-referencing to be sure all qualified customers were entered into the tracking database. The existing Energy Watch program utilizes its own scheduling process and customer database. Additional program reference functions were added to the existing database so that program customer assessment information could be safely stored and easily queried for reporting purposes.

Energy assessments culminated in a report of findings that included recommendations for behavioral and no-cost changes; an overview of any no-cost energy efficient technology measures that were installed through the Energy Watch program (e.g. lighting or low-flow showerheads); and recommendations for energy upgrade investments that could be pursued through the Home Upgrade® program or with a solar site survey.

Solar site surveys involved the development of incorporation of several new tools, including:

- A solar site analytical tool based in Microsoft Excel
- Solar Pathfinder™ tool and Solar Pathfinder Assistant software[4] (Figure 44)
- Site survey field forms
- NREL's PVWatts® online calculator[5]
- Solmetric's Roof Azimuth Tool[6]
- Customer report template.

Figure 44: Solar Pathfinder™ Tool

The Solar Pathfinder™ tool was used to determine shading of potential solar module array locations.
Photo Credit: Redwood Coast Energy Authority

Contractors and experts were consulted in the development of program tools, including the solar assessment components and promoting heat pump technology.

3.2.1.4 Data Collection and Management

Several types of data were collected for the program, including:

[4] http://www.solarpathfinder.com/

[5] http://pvwatts.nrel.gov/

[6] http://tools.solmetric.com/Tools/roofazimuthtool

- Paper based field data: sign-up sheets, customer intake forms, audit records, participation agreements, usage data releases, completion forms, inspection forms, customer reports, work orders, and contracts.
- Electronic field data: photographs, test equipment logs.

Wherever possible data was directly entered into digital tools, including software programs and customer databases. All data was organized by customer or project and retained in archives for issue resolution. Customer contact and project progress tracking tools were developed for project assistance and for querying program results.

3.2.2 MRVC Financing Program Development

The original program scope of work included implementation of a pilot financing initiative during the course of the project with the goal of financing several of the upgrade projects completed during the grant period. It became clear in the planning phase that a better approach was to focus on developing a longer-term strategy focused on rolling out financing resources as part of the scaled-up expansion and replication efforts targeting the broader County-wide community. Conversations with lenders and evaluations of other financing options revealed that it would be an inefficient use of resources to develop a pilot-scale program for a community of under 2,000 people and the accelerated timeline of the grant was too short to establish new County-wide offerings in time to be available to finance the upgrade projects completed during the grant period.

The following financing options were identified and evaluated for inclusion in the financing program guide and associated outreach materials:

Bank Loan Financing

Three local/regional banks were identified and engaged to support traditional loan financing options for energy upgrades: Umpqua Bank, Redwood Capital Bank, and Coast Central Credit Union. All three lenders were enthusiastic about partnering to promote energy upgrade project financing. Umpqua Bank offers an existing program for energy upgrade and electric vehicle financing, Greenstreets Lending, which offers some terms superior to those of their standard loan products (www.umpquabank.com/personal-banking/greenstreet/). To facilitate collaboration between lenders and future upgrade program implementation efforts, a memorandum of understanding (MOU) was developed. The objective of the MOU is to insure that there are knowledgeable local lenders available who understand the importance and potential payback of investments in energy-efficiency and renewable energy. The MOU defines a working relationship with the lenders that includes coordinate customer outreach and designating specific lending officers as program ambassadors who will become familiar with the details of local energy-program offering and serve primary points of contact for cooperative efforts.

Property Assessed Clean Energy (PACE) Financing

PACE programs facilitate local-government financing for residential and commercial energy projects through a voluntary tax-assessment that customers repay through their property tax bill. 2014 saw the rapid expansion of state-wide PACE programs available through multi-government joint powers agencies; these include:

- CaliforniaFIRST and AllianceNRG PACE, available through the California Statewide Community Development Authority
- HERO, available through the Western Riverside Council of Governments
- Ygrene Works available through the Golden State Finance Authority (formerly known as the California Rural Home Mortgage Finance Authority or CHF)
- FigTree OnDemand PACE, available through the California Enterprise Development Authority

The initial project plan was to consider development of a local PACE program modeled off of Sonoma County's successful program launched in 2009. However as stated-wide programs became available this strategy was reevaluated and it was determined that the benefits of a locally-implemented program are not significant enough to warrant the additional complexity and costs of development and operations in comparison to the streamlined process of simply opting into one or more of the existing state-wide programs listed above. The project team is working with the County Treasurer and local government staff on County-wide roll-out of PACE financing in spring of 2015 that will be available to support MRVC replication and expansion efforts going forward.

PG&E On-bill Financing Program

RCEA partners with PG&E on local implementation of the PG&E On-bill financing program. The program offers 0% interest loans of up to $100,000 for eligible commercial energy efficiency projects. Eligible projects include lighting, HVAC, electric motors, LED street lights, refrigeration, food service equipment and water pumps. While clearly 0% interest makes the program an excellent option, there are numerous restrictions that limit its applications: renewable energy projects are not eligible, residential customers cannot participate, projects must have a 5-year payback from energy savings, upgrade measures must qualify for a rebate or incentive through a PG&E efficiency program, single end-use lighting can comprise no more than 20% of the total loan amount (with the exception of LED retrofits and advanced controls that exceed Title 24 requirements). Despite these restrictions the program is almost certainly the best option for commercial customers with qualifying projects due the very favorable loan terms.

California Energy Commission Financing

The Energy Commission's energy financing program currently offers 1% loans for local governments and 0% loans for public school institutions for qualifying energy efficiency and distributed generation systems. These loans can fund 100% of project costs within 17 or 20 year (maximum) terms, and must have a simple payback allowing for the loan to be repaid from energy savings within the loan term. The loan term cannot exceed the useful life of loan-funded equipment, though partial funding can be provided for projects that exceed the simple payback.

While this program is a strong option for public entities funding is limited and applications are accepted on a first-come, first-served basis.

The above suite of financing resources offer a range of options for customers to choose from and are incorporated into the Financing Program Guide and the Plan for Countywide Implementation of the Energy Upgrade Program.

3.2.3 MRVC Contractor Recruitment and Training

Contractors were recruited to participate in the program by reaching out via mass email solicitations, print advertisements for training opportunities, and by contacting contractors directly through email or by phone. Individual meetings to recruit receptive contractors to participate in the program were set-up to accommodate contractor's schedules. Meetings were tailored to provide applicable program information, gather trade-specific input and guidance on program development, and offer guidance for obtaining the necessary training to participate in the program. Contractors were presented with packets of information and were able to discuss training obligations, how the program would assist in developing a market for their services, and other opportunities for collaboration.

In addition to the resulting list of participating contractors, several other contractors were met with in one-on-meetings or discussed their interest over the phone, including Pacific Builders, DANCO Construction, Barry Smith Construction, Ray Construction, Sunlight Heating, and the Blue Lake Rancheria Construction Manager. The Blue Lake Rancheria Construction Manager is interested in enrolling as a Home Upgrade® Participating Contractor to be able to perform upgrade projects at Rancheria-owned housing. RCEA is continuing to provide enrollment support and planning future training opportunities beyond the program end date because of this continuing interest.

3.2.3.2 Training

For energy efficiency upgrade projects the protocols for the Home Upgrade® program were used. As described in further detail in section*, the Home Upgrade® program is a state rebate program focusing on whole-house energy efficiency upgrades. The qualifications for contractors to participate in this program include contractor's licensing requirements, Building Performance Institute, Inc. certification, and specialized home performance classes hosted by the Pacific Energy Center. After meeting the qualification requirements, contractors then had to enroll directly with the Home Upgrade® program and as a result are then listed in the program's directory and could be included in MRVC promotional materials. Trainings that focused on energy efficiency that were offered through RCEA included:

- **Building Performance Institute Building Analyst Certification Course**: required to become certified or to renew certification and a requirement for participation in the Home Upgrade® program and to perform the MRVC energy-efficiency upgrades. RCEA incentivized participation by offering to waive or refund the course fee for contractors who went on to become enrolled in the Home Upgrade® program and complete a qualified project.

RCEA targeted home performance professionals, including general building contractors and specialty contractors, for training to be qualified to participate in the Mad River Valley program. Program requirements included Building Performance Institute Building Analyst certification. RCEA coordinated a course to take place in early January 2014 for professionals to become certified or to renew certification. Only one local business was qualified to offer Building Performance Institute courses and testing, making scheduling the training challenging, but ultimately successful. The team used their email distribution list, print advertising in local papers, and coordinating with the Humboldt Builder's Exchange to recruit a sufficient number of attendees for the course.

- **Home Performance, Putting it All Together**: a one-day workshop class by the Pacific Energy Center and hosted by RCEA that focused on a whole-house approach to home performance.
- **Home Upgrade® Classes**: classes required for participation in the Home Upgrade® program included either a three-day course if not BPI Building Analyst certified, and includes fundamentals of building science and practical experience with core measures in the program (e.g. testing systems, insulation standards), or a one-day course for BPI certified professionals who wish to conduct combustion safety testing for their projects. These classes were offered free through the Pacific Energy Center in Stockton, CA.

3.2.3.3 Participating Contractors

1. Archangel Builders
    - General Building contractor
    - Provides energy assessment services
    - Building Performance Institute (BPI) Certified Building Analyst
    - Energy Upgrade California Home Upgrade and Advanced Home Upgrade qualified
2. Alchemy Construction
    - General Building and Solar Electric contractor
    - Energy Upgrade California Home Upgrade qualified
3. Simple Visions
    - General Building contractor
    - Provides energy assessment services
    - BPI Certified Building Analyst
    - Energy Upgrade California Home Upgrade and Advanced Home Upgrade qualified
4. Comfortable Efficiency
    - General Building contractor

- Specializes in home performance
- Provides energy assessment services
- BPI Certified Building Analyst
- Energy Upgrade California Home Upgrade and Advanced Home Upgrade qualified

5. Scurfield Solar
    - Solar and Warm Air Heating, Ventilating & Air-Conditioning Contractor
    - BPI Building Analyst & Envelope Certified Professional on Staff
6. Brant Electric
    - Electrician
    - Solar Contractor
7. McKeever Energy & Electric
    - Solar Contractor
    - Home Energy Efficiency Rater (HERS) on Staff
    - BPI Building Analyst Certified Staff

3.2.4 MRVC Outreach, Marketing and Workshops

The goal of the program was to engage people in activities to increase energy efficiency and renewable energy in their community, but to specifically target high-priority sites. This was accomplished through a variety of marketing and outreach tasks to leverage existing energy programs and services in the region, and to develop a new, targeted campaign for the Mad River Valley community where program marketing and outreach materials were specifically developed to target contractors, high priority installations, and relevant community stakeholders. A campaign to distribute the outreach materials and marketing messaging to the community followed.

3.2.4.1 Leveraging Existing Programs

The Mad River Valley was already familiar with the local Energy Watch program[7], which promoted energy efficiency programs to residential and business customers since 2006. This previous effort provided a knowledgeable staff with established relationships and an extensive database. The Energy Watch program was engaged to identify work already performed along with additional opportunities at a variety of sites. Energy Watch staff also adjusted their outreach schedule to focus intensively on the Mad River Valley during the RePower project.

During the program period, the RePower team also engaged with GRID Alternatives[8] to bring their income-qualified solar program to the Mad River Valley. The RePower team conducted

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[7] http://www.redwoodenergy.org/programs/energy-watch

[8] http://www.gridalternatives.org/

outreach, provided background information, and established contacts. The GRID Alternatives team provided funding, qualified candidate sites, trained volunteers, and coordinated project installations. The collaborative effort worked well to extend the reach and capabilities of both teams and achieve mutually beneficial goals.

3.2.4.2 Developing a Targeted Campaign/ Key Messages

The targeted marketing campaign was guided by key program messages, the method of delivery, and the ability to co-brand with community partners. Based on other program activities in the region, the target audience had prior exposure to energy efficiency and renewable energy topics, and was understood to be aware of and receptive to underlying concepts. This allowed the program to provide focus less on education and awareness activities, and instead concentrated on establishing customer engagement with the targeted campaign. Based on prior customer experience and awareness, the marketing emphasis was to capitalize on a high-touch, high-engagement model. This approach has proven effective in small rural communities where relationship building over time has proven essential to establish trust and program credibility. Messaging consisted of simple statements to encourage customer action toward efficiency and renewable energy in their community. The messaging identified key topics of potential interest to the target audience, highlighted the services being offered through the pilot program, and provided contact information.

3.2.4.3 Method of Delivery

The campaign emphasized a combination of print and online media to deliver programmatic information to the community. To establish and reinforce program awareness, all delivery mechanisms followed a branding approach and used a shared set of messages, typography, color, graphics, and related elements.

Additionally, collateral for existing programs was utilized for rebate programs, such as the Home Upgrade and California Solar Initiative programs, and local utility rebate and rate information. Combining messages across programs helped to promote the organization as a local and reliable "one-stop-shop" for all energy questions.

While most distribution was through targeted community-based channels, coordination with other RCEA program outreach, including radio, community events, workshops, press releases, and social media, helped provide broader awareness and reinforce localized messaging. A summary of outreach is included as Table 27.

Table 27: Summary of Outreach Efforts for Mad River Valley Community Upgrade Program

Date	Event	Format
9/12/13	Blue Lake School Back to School Night	Informational table/booth
October – December 2013	Contractor recruitment for Energy Upgrade California Home Upgrade and Building Performance Institute Training	Mass email; print advertisement; targeted phone calls and meetings
3/12/14	Blue Lake Chamber Mixer	Presentation
3/13/14	Blue Lake Rancheria canvassing	Door hangers
4/5/14	Climate Action Plan Meeting at the City of Blue Lake	Table and Presentation
4/12/14	Dell Arte Pancake Breakfast	Presentation
5/5/14	Humboldt State University Renewable Energy Student Union	Presentation
5/7/14	Outreach canvassing	Door hangers
5/12/14	Heat Pump Workshop	Presentation
5/14/14	Meeting to Coordinate Outreach with the Energy Watch program	Meeting and Presentation
5/19/14	Non-Residential outreach / canvassing	Door-to-door outreach to business owners
6/5/14	BMW Ride and Drive Event with KHUM	Table and radio interview
6/6/14	Postcard Mailer sent to Blue Lake Residents	Postcard Mailer
6/8/14	Mad River Grange Breakfast	Table
6/14/14	You Light Up My Life Benefit	Table
6/17/14	Canvassing	Door Hangers
6/27/14	Solar Site Survey Community Volunteer Day	Workshop Presentation
7/13/14	Annie and Mary Days	Table
7/19/14	Folk Life Festival	Table
8/1/14	Non-Residential Canvassing	Door-to-door outreach to business and facility owners
9/26/14	Second You Light Up My Life Benefit	Table
10/2/14	Arcata Chamber Mixer at Blue Lake Casino	Presentation

Date	Event	Format
12/4/14	Annual Elder's Luncheon at Blue Lake Rancheria	Presentation and Table
12/6/14	Blue Lake Climate Action Plan Workshop	Presentation and Table

Source: Redwood Coast Energy Authority

3.2.4.4 Print Collateral

A number of types of print collateral were produced to reach a broad sector of the community. These included the following:

- Mailer: A direct mailing is one of the most effective ways to reach home and facility owners in the community. In coordination with the City of Blue Lake, a targeted postcard-sized mailer was created and mailed to each City of Blue Lake water customer (Figure 45).
- Door Hangers: Prior to the postcard mailer being sent out, the City of Blue Lake and surrounding areas were canvassed and a door-hanger was placed on the front door, or other accessible area of homes and businesses. Subsequent canvassing campaigns followed to flood the community with an introduction to the project.
- Flyers: Program flyers were posted at local businesses and the offices of community stakeholders, such as the City Hall, Blue Lake School, and the Mad River Grange. Flyers served to advertise events as well.
- Targeted Brochures: A targeted program brochure was created to distribute to interested customers.
- Workshop Materials: An informational brochure was created for Electric Air Source Heat Pumps to be distributed to interested homeowners. A summary of energy financing options was also updated to include local lenders.
- Event Banner: A large (6 foot) vinyl banner was created to display at events.

Figure 45: Example of Print Collateral Used in Outreach Efforts (Front of Postcard Mailer)

Source: Redwood Coast Energy Authority

3.2.4.5 Online

The primary mechanism to reach the target audience was through print media, but an online presence was important to supplement the printed collateral, create digitally searchable content, and provide a space to expand on messages constrained by space limitations in printed material. A webpage[9] through the Redwood Coast Energy Authority, as well as a Facebook page were created for the project (Figure 46). The webpage and a Facebook "QR" code were included on materials, and were used to provide project updates, advertise events, and recruit participants. The themes were designed to complement the printed materials.

[9] http://www.redwoodenergy.org/programs/madrivervalleycommunityproject

Figure 46: Snapshot of Program Webpage

Source: Redwood Coast Energy Authority

3.2.4.6 Co-Branding with Community Partners

The program utilized community-based social marketing to increase participation and market demand for energy efficiency programs and building performance. Using community-facing organizations, message placement occurred in settings such as community meetings and groups, school meetings and events, and staff collaboration with local agencies and governments.

Several presentations were made to local stakeholder groups. These groups included:

- City of Blue Lake
- Blue Lake Climate Action Planning Committee
- Mad River Grange Members
- Chamber of Commerce
- Blue Lake School Staff
- Blue Lake Rancheria Staff

Stakeholders and project partners in particular had a far-reaching effect. RCEA recently completed a Climate Action Plan for the City of Blue Lake making this program an easy and natural progression for the City to embrace. Additionally, the formation of the Blue Lake Climate Action Planning Committee provided a channel for programmatic messaging, and the group's efforts were supported by the program activities as well.

RCEA also worked with the Blue Lake Rancheria quite closely to provide services through the program to non-residential facilities, as well as their residential rentals and other member housing. The Rancheria was instrumental in coordinating the dissemination of information and serving to direct community interest to the program. Using their existing social capital increased participation by establishing credibility and spreading awareness.

3.2.4.7 Workshops

One of the main channels for targeted presentations was through workshops. The program utilized several types of community-facing workshops and professional-facing workshops, including:

- Home Upgrade® Workshops[10]
- Building Performance Institute Training[11]
- Heat Pump Workshop in partnership with the PG&E Pacific Energy Center[12]
- Solar Site Survey Workshop

Community-facing workshops mostly consisted of Home Upgrade® workshops, which presented information on building performance and the local utility's whole-house rebate program to homeowners. These were conducted once per month starting in March 2014. Another community-facing workshop focused on information about solar energy and how to determine the solar potential of a proposed solar project site.

Other workshops that were geared towards professionals included a Building Performance Institute training course and an Electric Air Source Heat Pump workshop. Both workshops were designed to engage contractors and energy professionals with building performance and described in section 2.2.3.1 Training.

3.2.4.8 Tabling

Tabling at community events was an effective way to engage community members one-on-one to identify and target high-priority opportunities, such as homeowners looking to switch from high-cost fuels like propane, or who were interested in energy upgrades and solar. It also promoted general awareness of the program, energy efficiency and distributed and community-scale renewable energy. Most tabling occurred at long-established community events and served to provide information; one exception was the "You Light up My Life" fundraiser that a

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[10] http://www.redwoodenergy.org/programs/energy-upgrade

[11] http://www.bpi.org/schedules.aspx

[12] http://www.redwoodenergy.org/component/content/article/10-events/31-solar-water-heating-systems-workshop

local business hosted to assist neighboring non-profit organizations, including the Mad River Grange and the Blue Lake Museum, with the proceeds going towards lighting efficiency upgrades. This event came about as a result of other marketing and outreach activities for this program.

3.2.5 MRVC Site Assessments

Despite completing the bulk of the program implementation activities in less than a year, the program goal of conducting 20 to 60 site assessments was achieved. Targeted outreach and canvassing resulted in participation of many residential customers, whose site assessments were prioritized by coordinating closely with the Energy Watch team. Additionally, face-to-face canvassing of non-residential facilities resulted in a good number of site assessments, leaving very few buildings in the Mad River Valley area untouched. Individual upgrade projects each took many weeks to complete. This was because of the need for multiple customer interactions in generating upgrade projects, as well as the necessary steps to go through the Home Upgrade® program and non-residential direct install program, and the design and installation of renewable energy systems. Completing as many site assessments as possible early on in the implementation stage, encouraging homeowners to attend workshops, and providing follow-up reports and consultation was important in hitting participation goals.

3.2.5.1 Residential Site Assessments

Site assessments for the residential sector included Energy Watch home assessments and solar site surveys (Table 28). This enabled technicians to directly install energy savings devices at no-cost or reduced-cost utilizing Energy Watch incentives. Devices included compact florescent light bulbs (CFLs), Light-emitting Diode technology light bulbs (LEDs), a variety of low-flow showerhead options (hand held, thermostatic), and low-flow faucet aerators. Technicians also relayed energy saving behavioral tips, inspected existing conditions of buildings and appliances, and provided a report and consultation. For Energy Watch site assessments elsewhere in the county, the consultation is a $20 fee. This service was offered free of charge to MRVC participants. The report recommended improvements to increase efficiency or address problems, promote renewable energy, and document existing conditions of energy related features. The site assessment was also used as an opportunity to promote Homeowner workshops and provide referrals to other energy-related resources.

Solar site surveys were conducted in concert with the residential Energy Watch assessments. These were estimated to be a $75 value for field time. Most MRVC program participants received a solar site survey, unless they were renters and had not engaged the homeowner in the process, or simply knew they were not interested in a renewable energy project at this time. It should also be noted that the solar assessment tools had not been finalized by the time energy efficiency site assessments were due to begin. The sites that were served prior to when the solar components of the program were fully implemented were contacted at a later date and re-visited to complete the solar site survey. The resulting report provided a shading analysis of the proposed solar location or locations, estimated solar electric system efficiency based on shading and roof orientation, recommended system size based on one year's worth of electricity usage and site capacity (roof or ground), and estimated price, payback, return on investment, energy savings, and green house gas savings.

The program ended up working very closely with one of the partners and key community stakeholders, the Blue Lake Rancheria, on site assessments. The tribe owns several homes on the Rancheria and their staff was happy to provide assistance in coordinating with their renters to schedule site assessments and collect the necessary applications and forms. Once the assessments were complete, the detailed reports were delivered to the Tribal Construction and Maintenance staff. From there, the program worked with the Rancheria to identify eligibility for upgrades through the Home Upgrade® program, and priority locations for other energy efficiency improvements. Renters who qualified were also referred to GRID Alternatives, which had its own assessment process.

Table 28: Residential Site Assessments Performed and Delivered

Site Address	Assessment Date(s)	Energy Assessment Report Delivered	Solar Site Survey / Report Delivered
322 Chartin Road	1/24/14	X	X
230 F Street	3/4/14	X	
29 Glendale Road	3/7/14	X	
300 Warren Creek Road	3/28/14	X	
211 B Street	4/29/14	X	X
640 3rd Ave	4/29/14	X	
134 Esther Ln	4/30/14	X	
1985 Ivye Lane	5/6/14	X	
725 Rancheria Rd, #6	5/8/14	X	
523 Chartin Road	5/13/14	X	
225 Russell lane	5/20/14	X	X
310 Blue Lake Blvd	5/20/14	X	
390 Ivye Lane	5/24/14	X	X
725 Rancheria Rd, #18	6/5/14	X	
310 Wahl Street	7/1/14	X	X
141 G Street	7/15/14	X	X
531 First Avenue	7/19/14	X	X
725 Rancheria Rd, #2	7/22/14	X	X
504 Chartin Road	7/24/14	X	X
135 Sunkist Lane	8/5/14	X	X

Site Address	Assessment Date(s)	Energy Assessment Report Delivered	Solar Site Survey / Report Delivered
725 Rancheria Rd, #1	8/5/14	X	X
558 Chartin Road	8/12/14	X	X
586 Rancheria Road	8/16/14	X	X
579 Rancheria Road	8/17/14	X	X
502 Chartin Road	8/21/14	X	X
560 Chartin Road	8/21/14	X	X
410 Greenwood	8/26/14	X	
521 Chartin Road	8/26/14	X	X
725 Rancheria Rd, #3	8/27/14	X	X
562 Chartin Road	9/2/14	X	X
490 Chartin Road	9/6/14	X	X
521 First Avenue	9/6/14	X	X
504 Chartin Road #1	9/11/14	X	X
529 Rancheria Rd, #3	9/11/14	X	X
320 B Street	9/13/14	X	X
312 Chartin Road	9/16/14	X	X
391 S. Railroad	9/16/14	X	X
117 Rouss Court	9/27/14	X	X
731 5th Street	10/7/14	X	X
410 I Street	10/10/14	X	X
126 Park Avenue	11/25/14	X	X
711 2nd Avenue	12/6/14	X	X
355 Chartin Road	1/24/15	X	X
555 Rancheria Road	2/5/15	X	
331 Wahl Street	2/19/15	X	X
720 4th Avenue	3/19/15	X	
331 I Street	3/27/15	X	
Total	**47**	**47**	**33**

Source: Redwood Coast Energy Authority

3.2.5.2 Energy Watch Non-Residential Direct Install Program

Unlike the residential site assessments, non-residential site assessments often involved multiple site visits to complete an energy audit (Table 29). For that reason, it was found to not be as important to complete the solar assessment at the same time. It seemed customers viewed the site assessments as a normal part of business or facility management, which allowed then more time to invest prior to and during upgrade projects.

Table 29: Non-Residential Site Assessments Performed and Delivered

Business	Status	Incentive	Net Cost	Dollar Savings	kWh Savings	Notes
Blue Lake Union School	Assessment completed, report delivered	550	2714	723.93	4156	
Blue Lake Laundromat	Assessment completed, report delivered	830	1216.61	382.33	2110	
Dell Arte	Project completed	1235.01	4.56	698.56	4179	
Blue Lake Rancheria Tribal Offices	Project completed	2526.85	6635.88	1897.53	10472	
Blue Lake Casino C-Store (Phase 1)	Project completed	1944	1333.80	1693.61	10558	
Blue Lake Casino C-Store (Phase 2)	Project completed	8735.03	22512.44	9071.67	56553	
Mad River Woodworks	Project completed	1875	148.64	401.36	2215	
Mad River Grange	Project completed	142.61	428.39	16.13	89	
Blue Lake Casino and Hotel	Project completed	6828.39	0	22484.15	122710	
Blue Lake Rancheria Tribal Offices	Project in progress	350	630	205.16	1279	
Blue Lake Museum Society	Report in progress	0	1360.16	141.15	779	
Blue Lake Museum Society	Project complete	231.25	0	38.60	213	
Dell Arte (Phase 2)	Report ready to submit to PG&E for approval	735.17	637.70	239.04	1430	
Royal Gold LLC	Assessment complete; no opportunities	190.36	101.74	136.08	751	

Business	Status	Incentive	Net Cost	Dollar Savings	kWh Savings	Notes
	identified					
Kernen Construction	Assessment completed					Fuel switching
Almquist Lumber	Project Completed					Solar
Dell Arte	Project Management proposal delivered					Solar
Mad River Grange	Contractor referral					Solar
Mad River Brewery	Assessment completed and report delivered					Solar
City of Blue Lake Facilities	Assessment completed and report delivered					Solar
Total	**20**					

Source: Redwood Coast Energy Authority

3.2.6 MRVC Energy Upgrade Project Assistance

The program provided hands-on implementation assistance and start-to-finish project management support to participants who proceeded with an energy upgrade project. This included homeowners who were interested in the Home Upgrade® program, business owners or facility managers who were interested in participating in the Energy Watch Non-Residential Direct Install program, as well as home and facility owners interested in installing solar electric generating systems. Upgrade projects initiated and completed during the program period included residential energy efficiency upgrades, non-residential energy efficiency upgrades, and residential and non-residential solar electric generating systems.

3.2.6.1 Residential Project Assistance Activities

The main residential energy efficiency upgrade pathway was through the Energy Upgrade California Home Upgrade® program, a statewide program that offers rebates of up to $6,500 for home energy efficiency improvements. The rebates are meant to incentivize a whole-house approach to energy efficiency rather than focusing on just individual improvements. The building envelope and all the systems of the home all work together to create a comfortable and energy-efficient space. The program was identified as fitting well with the RePower Humboldt vision and goals which includes maximizing the energy savings opportunities in all market sectors of the county. Home Upgrade® fits well with the MRVC Energy Upgrade Program by being a cost-effective way to maximize the energy savings opportunities achieved from each site assessment. Although homeowners are presented with a comprehensive list of energy saving measures they can address, like replacing individual appliances, providing an established pathway to whole-home efficiency has been an effective strategy in quickly engaging customers with deeper energy savings opportunities.

For renewable energy upgrade projects, a pathway was designed specifically for the MRVC program, but incorporated existing resources including the California Solar Initiative and GRID Alternatives, a non-profit organization offering solar incentives to low-income households.

Qualified Participating Contractors

Using the guidelines and protocols set forth for contractor participation in the Home Upgrade® program provided quality assurance without having to develop extra program requirements. Contractors were recruited for participation in the MRVC program, but fulfilled the requirements for Home Upgrade®, making it easier and less time intensive for both homeowners and contractors to begin and complete upgrade projects that were focused on maximizing energy savings and qualifying to rebates to help offset project costs.

A complete list of local licensed solar contractors and installers can be found on the California Solar Initiative website that was made available to customers, however solar contractors were also recruited to participate in the MRVC program specifically. Some solar contractors were engaged in the program design phase, and some were already participating in the Energy Watch Non-Residential Direct Install (DI) program. Guidelines for participating included going through Home Upgrade® enrollment procedures, or being part of the Energy Watch DI program which also has rigorous qualification and quality assurance standards. Contractor recruitment, training, and enrollment support is detailed in Task 3.3 List of Contractor Training Activities.

Homeowner Workshops

After the initial site assessment, homeowners were invited to monthly Homeowner Workshops. These were held at the Redwood Coast Energy Authority (RCEA) office and were free of charge. Typically they lasted about one to one and a half hours, depending upon the questions that came up, and included food and all the documentation needed to get started on a Home Upgrade® project. The workshops promoted the whole house approach to home efficiency upgrades, explained the rebate program in detail, and outlined next steps for participation. The workshops also solicited sign-ups for Initial Assessments through RCEA's HERS II Rater Pathway program, which worked in concert with participating contractors.

Initial Assessment Services

Home Upgrade® initial assessment services were performed by RCEA staff who had become a Participating Home Upgrade® Rater. A fee of $300 was set for these services after reviewing what other contractors and Raters in the area were charging. RCEA offered an incentive of 50% off the regular fee through the Fall 2014 for homeowners wanting initial assessment services to spur involvement in the new program. The initial assessment involved:

- Inspecting existing conditions of the building and appliances.
- Performing diagnostic testing to determine problem areas, including:
  - Combustion Safety Testing
  - Blower Door Test
  - Furnace Duct Pressure Test
  - Energy Modeling

The initial assessment service culminated in delivering a detailed report and consultation regarding:

- Existing building and appliance conditions.
- Identified problems and recommend solutions.
- Recommended upgrade packages.
- Rebates and savings estimates for recommended upgrades.
- Referrals to Participating Contractors.

Final Rating Services

After a Home Upgrade® project was completed RCEA also offered final rating services by the Participating Home Upgrade® Rater on staff. These services were offered free of charge as they were required for homeowners to submit their completed rebate applications. Final rating services involved inspecting the installed upgrades after installation to meet the program specifications, and perform the same diagnostic testing (Combustion Safety Testing, Blower Door Test and Furnace Duct Pressure Test) to verify the upgrade project results (Table 30).

Project Management Services

In addition to initial assessments and final rating services, homeowners and contractors were provided with project management support throughout the upgrade project. This helped maintain program specifications, ensure project submissions were completed, and help resolve any problems that would arise.

Referrals to Other Programs

Homeowners were referred to other programs when appropriate; those programs are listed below. Although the team did not follow-up on whether most of those referrals resulted in any further endeavors that resulted in energy savings, RCEA was involved in projects that resulted from referrals to two organizations, GRID Alternatives and the All Points North Foundation.

GRID Alternatives: RCEW focuses foremost on energy efficiency in response to priorities established in the California Energy Action Plan[13]. For RePower, this required additional services to include renewable energy education and services. Although the team developed specific renewable energy services, an opportunity was identified to engage with GRID Alternatives[14]. GRID Alternatives' vision "is a successful transition to clean, renewable energy that includes everyone. The mission is to make renewable energy technology and job training accessible to underserved communities." The RePower team saw an opportunity to partner with GRID Alternatives and encourage broader engagement in Humboldt County.

The relationship with GRID Alternatives:

- Coordinated engagement with local solar installers
- Facilitated workforce training through volunteer teams;
- Provided SASH funding for low- and no-cost solar installations to income qualified homes.
- Developed targeted outreach using local knowledge and contacts to increase the percentage of qualified customers that met stringent participation criteria;
- Helped to establish a North Coast Coordinator, along with a network of volunteers to support future projects.

All Points North Foundation: All Points North is a private foundation that provides grants for projects and initiatives that support improving public middle school education and teacher training, and implementing effective solar energy programs in the United States. Proposals are by invitation only[15]. They also welcome the opportunity to work with government agencies to pool resources and intertwine efforts.

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[13] Energy Efficiency Potential and Goals Studies"; California Public Utilities Commission, 2015; http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/Energy+Efficiency+Goals+and+Potential+Studies.htm

[14] http://www.gridalternatives.org/

[15] http://www.allpointsnorthfoundation.org/grant-making/what-we-fund/

Table 30: Residential Energy Upgrade Projects

Address	Status	Rebate	Kwh Savings	Therm Savings	Notes
300 Warren Creek Road	Project Completed	Pending $1500	985	382	Propane savings (not natural gas)
322 Chartin Road	Project Completed	$4813	955	549	
310 Wahl Street	Soliciting Contractor Bids	Projected $1500	Not modeled	Not modeled	Home Upgrade pathway (savings not modeled)
410 I Street	In Progress	Pending $3459	441	310	
312 Chartin Road	Soliciting Contractor Bids	Projected $2569	259	186	
29 Glendale Road	Soliciting Contractor Bids	Projected $4275	659	390	
523 Chartin Road	Completed				Solar PV through GRID
504 Chartin Road	Completed				Solar PV through GRID
Total	6 projects completed or in progress	$18,116 in rebates back to homeowners	3299	1817	

Source: Redwood Coast Energy Authority

3.2.6.2 Non-Residential Upgrade Projects

The program pathway for any non-residential energy efficiency project, which included businesses, municipalities, school buildings, community facilities, industrial warehouses, and any building that was not a residence, was through the Energy Watch DI Program (Table 31). The DI program maintains a referral program consisting of qualified and vetted contractors. It then provides project management services to assist customers completing a project with a contractor, but also provides a pathway for customers to “self-install” approved measures. If a project consists of lighting only, program staff is qualified to perform a “sweep” install of incentivized measures at any point once a customer has agreed to begin a project.

Table 31: Non-Residential Energy Upgrade Projects

Business	Status	Incentive	Net Cost	Dollar Savings	kWh Savings	Notes
Dell Arte	Project completed	1235.01	4.56	698.56	4179	
Blue Lake Rancheria Tribal Offices	Project completed	2526.85	6635.88	1897.53	10472	
Blue Lake Casino C-Store (Phase 1)	Project completed	1944	1333.80	1693.61	10558	
Blue Lake Casino C-Store (Phase 2)	Project completed	8735.03	22512.44	9071.67	56553	
Mad River Woodworks	Project completed	1875	148.64	401.36	2215	
Mad River Grange	Project completed	142.61	428.39	16.13	89	
Blue Lake Casino and Hotel	Project completed	6828.39	0	22484.15	122710	
Blue Lake Rancheria Tribal Offices	Project in progress	350	630	205.16	1279	
Blue Lake Museum Society	Project completed	231.25	0	38.60	213	
Dell Arte (Phase 2)	Report ready to submit to PG&E for approval (in progress)	735.17	637.70	239.04	1430	
Almquist Lumber	Project Completed					Solar
Dell Arte	Project management proposal delivered (in progress)					Solar
Mad River Grange	Contractor referral (in progress)					Solar
Total	**13 Projects completed or in progress**					

Source: Redwood Coast Energy Authority

Dell Arte International School: a DI "sweep" was conducted that resulted in the installation of 28 new LED lights at no cost to the customer. Dell Arte was put in contact with All Points North, a foundation that funds solar projects. Their detailed site assessment report and a project management proposal outlining the services that RCEA would offer through the MRVC program was delivered to the foundation. Dell Arte is awaiting a grant award to begin the project.

Blue Lake Rancheria Tribal Offices: a self-installed, co-pay project that focused on the replacement of T12 florescent lighting fixtures to T8 fixtures throughout the tribal offices. Occupancy sensors were also installed. Additional opportunities for exterior lighting and refrigeration upgrades were identified and not capture in this initial phase of the project.

Blue Lake Casino C-Store (The Play Station): the first phase of this project involved replaced case lighting with LEDs at the gas station convenience store. The second phase included refrigeration upgrades and linear florescent upgrades, as well as replacing the gas station canopy lighting with LEDs. The project was over $30,000 before incentives, but resulted in significant cost and energy savings.

Mad River Woodworks: a self-installed, do-it-yourself project that replaced high/low bay lighting fixtures and industrial T12 florescent strip fixtures with T8 strip fixtures.

Mad River Grange: a self-install conversion from T12 to T8 linear florescent lighting fixtures for their main hall. Additional opportunities for lighting upgrades were identified, and installation of already acquired solar electric modules is planned. They were referred to a solar installer and are working on a design plan to get final costs and funding approved by the Grange members.

Blue Lake Casino: Self-install of 198 LED lights in the gaming facility, restaurant, and bar.

Blue Lake Museum Society: a small DI "sweep" that replaced lighting with LEDs.

Almquist Lumber: Almquist Lumber operates a small mill in the Mad River Valley. In 2006 they built a new 50,000+ square foot retail operation with buildings designed to take advantage of the south. The site already had a 15 kW PV array on the main sawmill building, and based on this initial experience, Almquist Lumber added a 10 kW PV system on the new building in late 2014. The owner, Eric Almquist, is eager to install significantly more solar as finances permit.

3.2.6.3 Potential for Community Wide Replication

Because the MRVC program leveraged existing, long-established programs to complete energy efficiency assessments and guides upgrade projects, community-wide replication is within reach. With continued funding to support the Redwood Coast Energy Watch program, these services will stay intact. The more comprehensive program that was piloted in the Mad River Valley community is also easily scalable to the entire area that RCEA serves. Adding services to the Energy Watch model and providing project management guidance for renewable energy projects is achievable with additional staff support and using the tools and resources developed and implemented for this pilot. By taking advantage of existing programs that embodied the RePower vision and goals, replication would be fairly straightforward.

3.2.7 MRVC Heat Pump Installation and Assessment

Data collection for the heat pumps and natural gas furnaces began in October 2014 and culminated in February 2015. A description of the heat pump assessment data collection activities and a summary of the data collected are included in Appendix G.

The measured performance parameters for the two heat pumps and two natural gas furnaces are shown in Table 32. One of the furnaces performed at a substantially lower overall efficiency than the other. Gas Furnace 2 was on for substantially more hours, and therefore consumed substantially more energy, but it delivered less heat than Gas Furnace 1. The most obvious operating differences between them were the airflow rate and the air differential temperature. The higher performing furnace had both a higher average differential temperature, as well as a higher airflow rate. Examination of the ducting for the underperforming furnace did not reveal any obvious leaks, and the recorded temperatures were similar to those produced by a different thermocouple probe that was inserted into the ducting.

Near the end of the testing period the airflow measurements for all four systems were redone and there was some difficulty getting consistent results with the Minneapolis Duct Blaster and plastic bag plenum. Small changes in the setup would produce substantial differences in the measurements. Some fine-tuning of the procedure produced flow rates in line with the original measurements. However, it is clear that this is a very important measurement as a change in the airflow results in a proportional change to the calculated heat delivered and therefore the efficiency and overall performance. The measured efficiency for Gas Furnace 1 is consistent with what would be expected for a natural draft furnace that is 20 plus years old. The measured efficiency for Gas Furnace 2 is a bit low, but not unbelievable.

Summary data for the heat pumps are also given in Table 32. The seasonal efficiency, referred to as the Heating Seasonal Performance Factor, or HSPF, is given. The HSPF is calculated as the total heat delivered in Btu’s divided by the total electrical energy consumed in Watt-hours. The measured HSPFs for the two heat pumps were quite similar, and in both cases exceeded the manufacturer HSPF rating of 8.3. This could be due in large part to the mild climatic conditions on the North Coast of California.

Table 32: Natural Gas Furnace and Heat Pump Measured Performance

Heating System	Efficiency
Gas Furnace 1	68%
Gas Furnace 2	50%
Weighted Average	58%
Heat Pump 1	9.5 HSPF
Heat pump 2	10.1 HSPF
Weighted Average	9.8 HSPF

Source: Schatz Energy Research Center

The average measured furnace efficiency and heat pump HSPF were used to assess the greenhouse gas benefits associated with heat pumps and to compare the operating costs for heat pumps versus natural gas furnaces. For this comparison it was assumed a representative month (based on the month of January from the data collected). The average heat delivered for the four classrooms in the month of January was 567 kWh. When comparing the heat pump with a natural gas furnace the team assumed the amount of heat delivered would be the same. This will generally be true, though it depends on where the delivered heat is being measured. If the heat delivered is measured at the output of the furnace and then it is ducted to the heated space, there could be substantial losses in the ducting.

For the heat pumps there are no duct losses because there are no ducts. The data collected show that in general there was more heat delivered to the natural gas furnace classrooms. This could be due in part or in whole to duct losses. On the other hand, it is possible that the occupants of those rooms desired more heat, or that those rooms suffered greater heat losses to the environment. While the team tried to avoid large discrepancies due to these types of factors, they are not sure what affect they might have had.

In any event, for comparison purposes the researchers assumed the amount of heat delivered to each space will be the same, 567 kWh for the month. Table 33 shows a greenhouse gas emissions comparison for a classroom using a heat pump compared to an old gas furnace, and for a classroom using a heat pump compared to a new, high efficiency gas furnace. The heat pump generates only about 33% as much greenhouse gas emissions as a 95% efficient furnace (a 67% drop), and only about 20% as much greenhouse gas emissions as the existing 58% efficient furnace (an 80% drop). Clearly the *RePower Humboldt Strategic Plan* was correct in identifying that significant gains can be made toward reducing greenhouse gas emissions by switching from heating with natural gas furnaces to heating with heat pumps. Note that the greenhouse gas emission factors being utilized were obtained from PG&E (PG&E 2013). The electricity emission factor is for PG&E’s 2011 grid mix, and the natural gas emission factor is from the U.S. Energy Information Administration as recommended by PG&E.

However, the cost effectiveness of the heat pumps does not look as good. Assuming an electricity cost of $0.18/kWh and a natural gas cost of $0.94/therm, the results show that the heat pumps are more expensive to operate in both cases. Table 34 shows heat pump costs of about $35 per month. This compares to about $31 per month to operate the existing inefficient furnace, and only $19 per month to operate the 95% efficient furnace.

The installed cost of a heat pump appears to be comparable to the installed cost of a high efficiency furnace. The installed cost for each of the Daiken heat pump units was $7951. This included: roof mounting of the compressor unit, installation of a new electrical circuit, mounting the indoor unit, and installing, evacuating and charging the two refrigerant lines. The two systems were then tested to ensure they were performing to the manufacturer's standards.

If the existing gas furnaces were replaced with new high efficiency units, the estimated cost would be approximately $7,000 to $8,000. This would entail a simple swap of similar sized units while retaining the existing ducting, gas line, and electrical line. The cost would be higher if this supporting infrastructure was not already present.

The overall result is the installation costs for these systems is essentially the same, and the operating cost is somewhat higher for the heat pump system. This increase in operating cost would likely pose a barrier to adoption, though it might be overcome with monetary incentives or by selling people on the value of reducing their greenhouse gas emissions. However, the price per metric ton of CO2e reduction is greater than $200 assuming PG&E's greenhouse gas emissions factor. If 100% renewable electricity is being utilized, then the CO2e emissions associated with the heat pump system go to zero, and in this case the price per metric ton of CO2e reduction drops to about $145/ton (assuming no change in the cost of electricity). With carbon prices hovering around $10 to $15 per metric ton of CO2e, a heat pump is not a very cost effective greenhouse gas reduction measure. However, for a customer who purchases or generates 100% renewable electricity, a heat pump can allow them to zero out their space heating related CO2e emissions, and this can be a motivating factor.

Table 33: Greenhouse Gas Emissions Comparison – Heat Pump vs. Natural Gas Furnace

Heating System	Heat Delivered	Efficiency	Energy Used	MT CO_2e/ unit	MT CO_2e	% Change
95% Eff. Furnace	19 therms	0.95	20 therms	0.00531/ therm	0.107	-(67%)
Heat Pump	567 kWh	2.9	196 kWh	0.000178/ kWh	0.035	
Existing Furnace	19 therms	0.58	33 therms	0.00531/ therm	0.176	-(80%)
Heat Pump	567 kWh	2.9	196 kWh	0.000178/ kWh	0.035	

Source: Schatz Energy Research Center

Table 34: Operating Cost Comparison – Heat Pump vs. Natural Gas Furnace

Heating System	Heat Delivered	Efficiency	Energy Used	Cost/ unit	Cost	% Change
95% Eff. Furnace	19 therms	0.95	20 therms	$0.94/ therm	$19.43	+81%
Heat Pump	567 kWh	2.9	196 kWh	$0.18/ kWh	$35.19	
Existing Furnace	19 therms	0.58	33 therms	$0.94/ therm	$32.13	+10%
Heat Pump	567 kWh	2.9	196 kWh	$0.18/ kWh	$35.19	

Source: Schatz Energy Research Center

It should be noted that these results are based on a single rate comparison. The team used the A-6 Small Commercial Time-of-Use electric rate from PG&E ($0.18 per kWh), and the Small Commercial G-NR1 Core Commercial Gas Rates from PG&E ($0.94 per therm). If natural gas rates increase this cost comparison could change, though rising natural gas prices will likely also be reflected in rising electricity prices. At current electricity prices, the price of natural gas would need to increase to $1.76 per therm to reach an equivalent cost of heat delivered.

Since much of the land area in Humboldt County is without natural gas service, it is worth examining the cost effectiveness of a heat pump compared to a propane-fired furnace. Assuming a propane price of $2.50/gal and an energy content of 0.9 therms/gal, the cost to operate a 95% efficient propane furnace is 44% higher than the cost to use a heat pump assuming an electricity cost of $0.18/kWh.

3.2.8 MRVC Electric Vehicle Charging Infrastructure

The effort to find two suitable locations stretched over the duration of the project. One of the most suitable locations was determined early on to be the Blue Lake Rancheria Tribal office. The Tribe's fleet of vehicles includes a Nissan Leaf battery electric vehicle used almost daily by staff, and at least one Tribal Office employee was found to be commuting to work by electric vehicle. The office is also in close proximity to the Blue Lake Hotel and Casino, a popular Mad River Valley attraction and tourist destination. However the team continued evaluating whether or not to install both stations at the same locale and offer a bank of four electric vehicle-only parking spaces, or to find a separate location to provide more options in the Mad River Valley for electric vehicle drivers. Working with the Blue Lake Rancheria, it was decided that the Tribe would be able to accommodate two, dual-head bollard-style charging stations for a bank of multiple charging stalls, and would provide the installation labor and materials costs so that grant funds only had to cover the cost of the charging equipment.

Leveraging this additional match funding from the Tribe enabled the purchase of two chargers for the Rancheria site with adequate funds remaining to install at a second site as well. Multiple sites within the City of Blue Lake were considered, and the Blue Lake City Hall was determined to be the best option. However, it was determined that the City Hall's electrical service could not accommodate the addition of a level 2 charging station as it was extremely outdated, undersized, and already at-capacity. Consequently it was necessary to design and install upgrades to building electrical supply, including trenching and installation of new wire and conduit from the PG&E distribution system and a new electrical panel for the building.

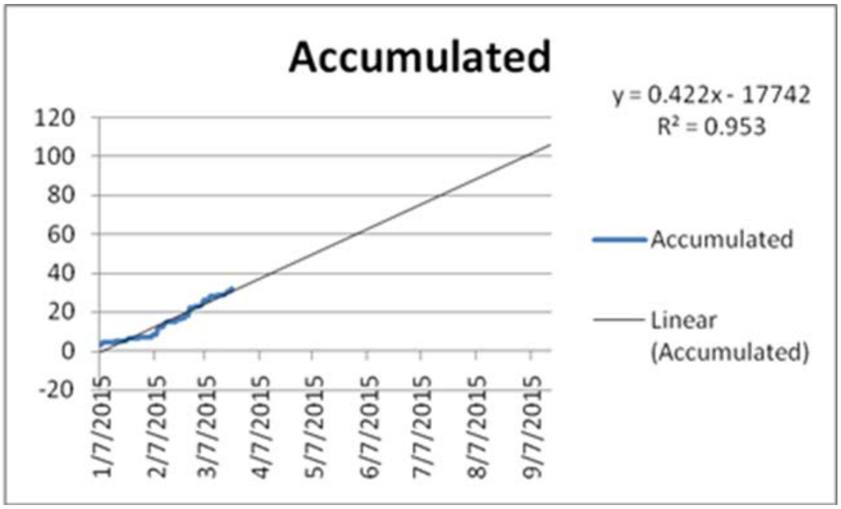
The project installed ChargePoint CT4000, level-2, units – two dual-port units at the Rancheria (BLR) and a single-port unit at the City Hall (Figure 47). ChargePoint units were selected to utilize the existing network management systems already in place for other local ChargePoint units previously installed in Eureka and Arcata, and because the units offer robust integrated capabilities for remote data collection and monitoring, including details on the timing and duration of charging sessions, number of unique customers served per day, quantity of energy dispensed per charging session, and other usage details.

Figure 47: Electric Vehicle Charging Station

Electric vehicle charging stations installed at the Blue Lake Rancheria.
Photo Credit: Redwood Coast Energy Authority

The design and approval process for the additional work at the City Hall resulted in considerable delays to the charging station installation schedule, which in turn significantly limited the amount of data collection time during the grant term. That said, with installation now complete the ongoing data provided by the charging stations is being used to monitor and project usage, the quantity of electricity dispensed, station duty-factors, demand-load profiles, and greenhouse gas savings. Projecting into the future from the data collected to-date suggested that targeted utilization of 100 or more charging events over the first twelve months of operations should be achievable sooner than anticipated, as show in the Figure 48.

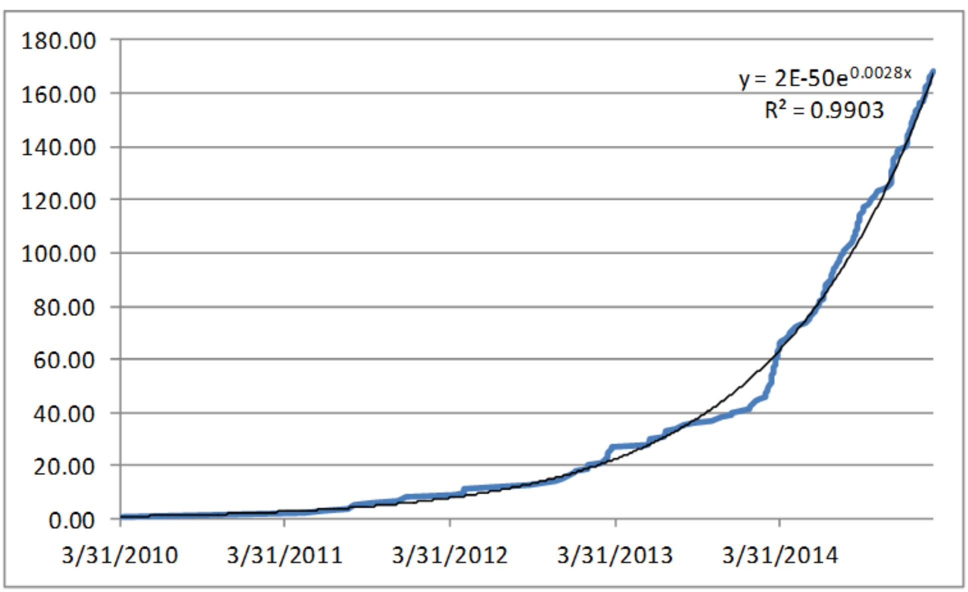
Figure 48: Projected Total Accumulated Charging Events



Source: Redwood Coast Energy Authority

Currently the stations are dispensing approximately 25kWh of electricity per month per charger. At that rate the stations will dispense an estimated total of approximately 900 kWh over the first year of operation, which is the functional equivalent of about 90 gallons of gas and greenhouse gas reduction of about 1,700 pounds of CO2. However, the rate of charger use is expected to grow as the number of electric vehicles in the County increases; currently electric vehicle sales, as measured by CA Clean Vehicle Rebates Program statistics for Humboldt County, is increasing at an exponential rate as shown in Figure 49.

Figure 49: Cumulative Plug-In Electric Vehicle Rebates Issued in Humboldt County



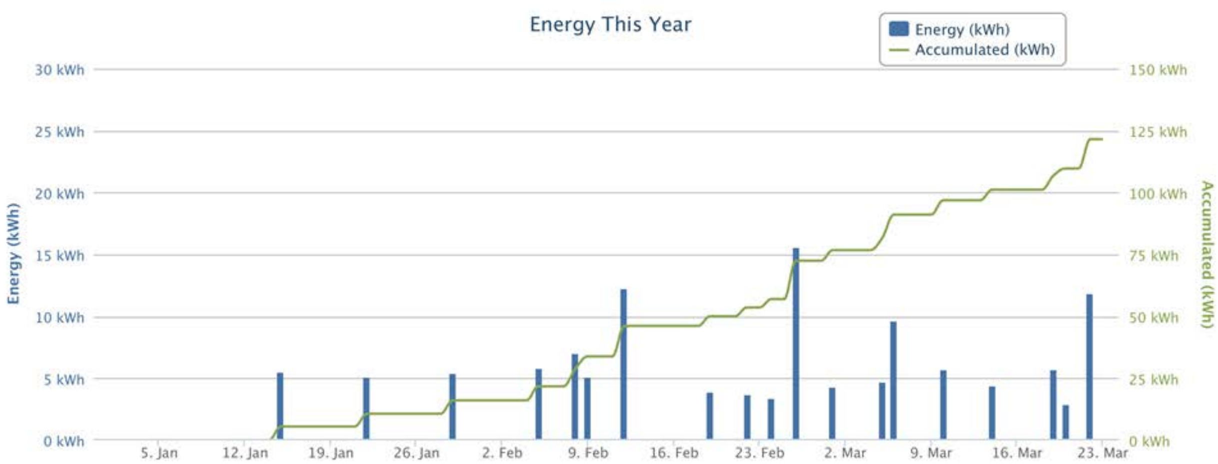
Source: Redwood Coast Energy Authority

The data provided by the Mad River Valley charging stations will provide detailed information as local electric vehicle adoption is tracked and resulting charging station usage can be analyzed and compared to modeled projections. This information will be valuable in evaluating the needs and benefits associated with public charging infrastructure and will help guide the efficient and effective future deployment of additional charging stations across the region in support of the RePower Humboldt vision (Figures 50 and 51).

Figure 50: Greenhouse Gas Emissions Savings Resulting From BLR Charging

Source: Redwood Coast Energy Authority

Figure 51: Energy Use for Charging BLR Charging Station



Source: Redwood Coast Energy Authority

3.2.9 MRVC Program Evaluation and Scale-up

The MRVC Energy Upgrade Program utilized new and existing energy efficiency and renewable energy delivery mechanisms, combined with a targeted outreach campaign, to promote and incentivize energy savings actions and adoption of solar electric systems. RCEA engaged stakeholders to promote the program, recruit participants, and advocate the benefits of energy efficiency and renewable energy in their community. The program provided for educational opportunities, including presentations, workshops, one-on-one consultations, and detailed reports of findings, to fill in knowledge gaps regarding energy technologies, and the benefits of potential energy and cost savings associated with adoption of these technologies. Several site assessments were completed, resulting in immediate energy savings through the existing Energy Watch program. Referrals to participating contractors resulted in several upgrade projects as well. Goals related to customer engagement, site assessments, and upgrade projects were met and the program also demonstrated the viability of a targeted campaign with community-focused outreach and social marketing efforts.

3.2.9.1 Program Cost-Effectiveness

Determining the cost-effectiveness of the program is an ongoing endeavor and will be essential to evaluate program success and to plan for future expansion and scale up.

3.2.9.2 Customer Engagement

Support was garnered from the City of Blue Lake through an official endorsement of the program and collaboration through their climate action planning efforts, and the installation of an electric vehicle charging station at their City Hall building. This program was promoted in their climate action plan as a way for businesses and residents to reduce their green house gas emissions. Program staff coordinated with the City planner, presented to the City Council and City Manager, and participated in climate action planning community workshops and citizen action groups. The program was an easy way for residents and businesses to take immediate action to reduce their greenhouse gas emissions, as well as to consider long-term greenhouse gas reduction goals through planning for deeper energy retrofits an the additional of renewable energy systems. Because transportation is often a big contributor of greenhouse gases in communities, the City was a great advocate and supporter of promoting electric vehicles in the community as well. Council members who were also residents and in some cases business owners in the Mad River Valley community acted as program champions in the community, connecting and fostering relationships with other community groups and business owners. Of note, the Mad River Grange hosted informational tables at their Sunday pancake breakfasts and pursued an energy upgrade project. The Mad River Brewery served as a meeting place for the Climate Action Planning Citizens Committee, and used the program as an opportunity to pursue information about adding a solar electric system to their facility. The Logger Bar, although empty of any significant energy-savings opportunities, hosted a fundraiser for neighboring Mad River Grange lighting upgrades. Although not necessarily produced quantifiable metrics, the level of community engagement in the program points to successful social visibility, outreach, and dissemination of the value of program goals and vision.

3.2.9.3 Coordination and Integration with Other Programs

The success of this program was dependent upon leveraging and expanding upon existing energy efficiency programs and climate action planning in Humboldt County. The Redwood Coast Energy Watch (RCEW) program offers comprehensive locally-based energy efficiency services to traditionally hard-to-reach market sectors in Humboldt County and was instrumental in providing comprehensive services. This collaboration with the Pacific Gas and Electric Company (PG&E) initiated in 2004 under the auspices of the California Public Utilities Commission. RCEW provides a cost-effective, comprehensive approach to accomplishing real energy savings through education, technical assistance, and direct installation services for the public agency, small and medium business, and residential market sectors. Other services include guidance and assistance on emerging technologies, renewable energy, regional standards, and new policy initiatives such as climate change and green building.

RCEW also works with public agencies on a range of strategic initiatives to develop local plans and programs that encourage energy efficiency and promote energy security and reliability. Examples include municipal benchmarking, greenhouse gas inventory analysis, and climate action plans. RCEW operates the Redwood Coast Energy Resource Center (and associated web site and toll-free Energy Answerline), offering information, workshops, and technical assistance to the general public in Humboldt County.

RCEW provided the RePower team with:

- An established, trusted local partner with a mission that focuses on energy efficiency and renewable energy;
- Connections in the municipal, business, and residential communities;
- Access to technical experts such as contractors, planning departments, and local utility staff;
- Staff with relevant training, experience, and local knowledge;
- Match funds through energy efficiency direct implementation programs;
- A regional resource center to support the general public and RePower team with general and technical assistance, workshop support, and information sources.

The main benefits were an opportunity to leverage existing customer engagement activities, dramatically reduce transaction costs, deliver program messages and services through a mature, trusted channel, expand on existing community and professional relationships, and expand the comprehensiveness of both programs through complementary services. Although the direct benefits have not been quantified yet, leveraging this program was without a doubt instrumental in providing cost-effective program offerings.

3.9.2.4 GRID Alternatives

RCEW focuses foremost on energy efficiency in response to priorities established in the California Energy Action Plan[16]. For the MRVC program, this required additional services to include renewable energy education and services. Although the team developed specific

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[16] "Energy Efficiency Potential and Goals Studies"; California Public Utilities Commission, 2015; http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/Energy+Efficiency+Goals+and+Potential+Studies.htm

renewable energy services, an opportunity was identified to engage with GRID Alternative[17] . GRID Alternatives' vision "is a successful transition to clean, renewable energy that includes everyone. The mission is to make renewable energy technology and job training accessible to underserved communities." The RePower team saw an opportunity to partner with GRID Alternatives and encourage broader engagement in Humboldt County.

The relationship with GRID Alternatives:

- Coordinated engagement with local solar installers
- Facilitated workforce training through volunteer teams;
- Provided SASH funding for low- and no-cost solar installations to income qualified homes.
- Developed targeted outreach using local knowledge and contacts to increase the percentage of qualified customers that met stringent participation criteria;
- Helped to establish a North Coast Coordinator, along with a network of volunteers to support future projects.

3.2.9.5 Lessons Learned

The program was slow start to performing the solar site assessments. This was due to the need to create new tools and resources from scratch that took longer than anticipated. There were many site assessments in the early stages that did not include the solar component. Technicians had to return to these homes a second time to perform this service. This could have saved on labor and miles if it as avoided by being prepared to perform the comprehensive site assessment at the launch of the program.

The initial discounted price for Home Upgrade Initial Assessments (50% off) lead to many signups that could not afford to move forward with an upgrade project. At the low price of $150 the team encountered do-it-yourself homeowners and bargain hunters that wanted a professional assessment at a reduced cost. Since adjusting the initial assessment price to $300, the ratio of projects completed to assessments performed has increased.

The team was unable to follow up with each resident who received a site assessment. There were likely many efficiency upgrades performed as the result of some assessments that the team cannot take credit for. If more time had been budgeted for customer follow up activities, more completed projects would have been reported.

Priority scheduling of Energy Watch Home Assessments was provided for residents in the program territory, as planned. However this resulted in some unexpected scheduling challenges when the waiting list for residents outside the program's territory grew longer. Because the MRVC program was community-based, but only focusing on a small geographic location, the database could not discern if applicants were inside the qualified area. Each

[17] http://www.gridalternatives.org/

application for services received by RCEA during the program's implementation phase had to be checked against a map to discern whether they were part of the program. Although this was an easy tool to set-up, it resulted in extra labor for scheduling staff.

Workshop attendance for MRVC residents was low, and it was anticipated that conducting a workshop in the Mad River Valley area would not have attracted enough attendees to make it worthwhile. Offering workshops open to everyone likely cut down on costs by sharing them with other program initiatives. Recruiting participants through other means kept staff busy, considering they also served the remainder of the county. Getting more customers to attend workshops and consider upgrade projects is a good goal with increased capacity to serve them, as well as increased contractor participation to transfer more of the service load to the private sector.

Areas of the program design and offerings that needed more attention included recruiting contractors to meet increasing market demand, and offering unique financing options to overcome cost barriers. Although contractors report that heat pumps are being installed in homes around the county, including the Mad River Valley, more assessment of their energy and cost savings potential would assist customers in choosing this technology. Additionally incentivizing heat pumps at either the utility or local level would likely aid in increased adoption rates. County-wide bulk purchasing events and more developed local installation capacity and equipment stock would be avenues to explore in the future.

Some unanticipated successes included working with the Blue Lake Rancheria Housing allowed us to provide efficiency services to tribal residents who have been difficult to reach in the past. The interests of these residents were mixed with some being very interested and some not. The team helped one resident identify a significant gas leak in their home that was repaired, as well as connect residents with GRID Alternatives who recently launched a tribal initiative. The Maintenance / Construction Manager of the Blue Lake Rancheria is interested in becoming a Participating Contractor for the Home Upgrade® rebate program. He is hoping to combine grant funding that the tribe has access to with rebates. He plans to perform the efficiency upgrades himself on tribal homes.

3.2.9.6 Opportunities for Program Expansion

The Mad River Valley Community Upgrade program could be replicated in other areas by using the same design foundation of a comprehensive set of services for customers, adaptable approach to the unique make-up of a community and their energy-use context (residential, commercial, industrial, renters, etc.), and targeted campaign. A certain amount of analysis prior to designing a program to target high-priority sites in a community would be necessary. Identifying applicable community metrics beforehand would help in the development of community-specific goals and streamlined efforts towards greater energy savings. However using the same one-stop-shop approach by offering comprehensive services, demonstrating the value of those services, and building social capacity in the community, effectively overcomes some market barriers.

Sustaining the momentum of this program may be achieved through the focus on social visibility and engagement of local government and community groups. Because this program was implemented alongside other community climate action planning efforts, a lot of "cross-pollinizing" took place. Local governments and citizen groups could see the value of energy-saving efforts in the context of greater goals and implementation of State policies. The timeliness of targeted campaigns, or coordination with other related efforts, may help relay the value of the services and help sustain momentum of the efforts of the program. One of the lessons learned from the Energy Upgrade Project Assistance task is that is takes multiple contacts with a homeowner before committing to an upgrade project. This means that efforts need to accommodate the longer time period it takes to engage customers with deeper retrofits, or implement a plan for sustained momentum long after a targeted campaign.

Additional funding has been secured to integrate the Home Upgrade® efforts into the existing utility funding, including continuing contractor recruitment and training. The other way that efforts are being sustained is by charging customers a fee for services. This fee covers initial consultation and testing to help produce a plan for the customer, and is refunded by the project contractor after completing a project. This fee-for-service approach seems feasible for others aspects of the MRVC program, such as the solar site surveys, which would necessitate their own funding mechanism. Charging an initial fee for completing a survey and a report might be a way to sustain this service.

As the program has demonstrated, there are many concurrent energy-related efforts that communities are taking on in California. Climate Action Planning, energy efficiency programs, local government committees, are just a few. Successful programmatic elements can be incorporated or added to ongoing efforts.

3.2.9.7 Plan for Countywide Implementation

Redwood Coast Energy Authority, through the Redwood Coast Energy Watch (RCEW) program, is uniquely positioned to implement energy efficiency programs throughout Humboldt County. The RCEW Direct Installation program, which offers the installation of incentivized energy-saving measures in multiple sectors, provides an effective way to engage with energy users about multiple levels of service, as offered in the Community Energy Upgrade Program. The foot-in-the-door approach is a popular marketing technique; combined with the further tailoring of services to help each customer achieve the highest energy savings possible within realistic means, will offer a successful way to scale-up the pilot program with minimal cost. The EW program has acknowledged this trend towards deeper energy retrofits and multi-levels of education that will result in bigger long-term savings. With this in mind, the EW program is planning on incorporating the Community Energy Upgrade Program-approach by offering three levels of service for each of two main sectors beginning with the 2016 program cycle:

Residential

Energy Saver Assessment: aimed at tenants who do not have landlord buy-in, and homeowners only interested in no-cost to low-cost investments. This service will include referrals, as appropriate, to other programs such as Pacific Gas and Electric Company's Energy

Savings Assistance Program, Redwood Community Action Agency's Energy Services division, and GRID Alternatives; financing resources; and online educational tools (like Energy Upgrade California).

- Assessment findings will be provided on an initial site visit.
- Incentivized measures will be installed on an initial site visit.
- Generalized educational collateral will be distributed with relevant information/actions noted.

Homeowner Assessments: aimed at tenants with landlord buy-in and homeowners interested in deeper retrofit upgrades. The Homeowners Assessment will include tailored recommendations after an initial site visit and follow-up with the customer regarding next steps. Recommendations may include everything from no or low-cost behavioral changes and incentivized measures, to whole-house upgrades, fuel-switching, and renewable energy systems based on a customer's interest.

- Technician will prepare a tailored report after the initial site visit, and consult with the customer to plan any follow-up services.
- A required first step to qualify for the next level of service.

Whole House Assessment: aimed at homeowners who are interested in completing deep energy retrofits, would like to take advantage of California's whole-house rebate program, or want to obtain an energy rating. This level of service has an associated fee that is fully refundable upon completing a qualified Home Upgrade program.

- Qualifies as a Home Upgrade (California's whole-house rebate program) Initial Assessment and Final Rating.
- Is a Building Performance Institute (BPI) certified assessment which includes a Home Energy Score rating.
- Qualifies as an Energy Efficient Mortgage/HERS Whole House Rating assessment.
- Includes project management (as described below) if proceeding with a project.

Non-residential

Walk-Through Assessment: aimed at business owners who are tenants and do not have landlord buy-in, or who are only interested in no-cost to low-cost investments.

- Assessment findings will be provided on an initial site visit.
- Incentivized measures installed on an initial site visit.
- Educational collateral distributed with relevant information/actions circled.

Energy Audit: aimed at business owners who are tenants with landlord buy-in and property owners interested in deeper retrofit upgrades. An Energy Audit will include a detailed report after an initial site visit and follow-up with the customer regarding next steps.

- Technician will prepare a tailored report after the initial site visit, and consult with the customer to plan any follow-up services.
- A required first step to qualify for the next level of service.

Project Management: aimed at incentivizing customers to proceed with an energy upgrade project, this service will provide assistance with contractor selection/access to an pre-qualified internal vendors list, financing options, project quality assurance, post-project testing, and rebate submission.

Prior determination of a customer's level of interest will be a key factor in delivering the above services county-wide in a cost-effective way. Utilizing service applications, pre-screening forms, pre-qualification steps, and fees will effectively sort customers into appropriate service categories. Whereas the pilot program provided a full energy and solar site assessment to each customer to maximize the benefits to the community, as well as determine any affect on uptake based solely on education and availability of the free service, this did not prove to be the best way to determine high-priority sites. Sorting customers to achieve the highest realistic savings, and leveraging existing incentive programs, will provide a way to quickly and cost-effectively scale-up the campaign.

Outreach will continue to occur through print and online media and will have generalized messaging that is customer and solution based. Additional program information will be available online and through Redwood Coast Energy Authority's Resource Center. Marketing materials were specifically developed for the Mad River Community, but the graphics and templates will be repurposed to maintain consistent branding. It will be cost-effective to also utilize collateral offered by other programs that are being leveraged, such as Home Upgrade and the California Solar Initiative.

Outreach through community involvement (Chamber of Commerce, committees, event outreach, presentations) will also continue. Additional specific focuses will include qualified contractor/vendor recruitment through direct marketing and attendance at industry conferences and expos, and monthly homeowner workshops at the Resource Center.

3.3 Task 4: Data Collection and Analysis

3.3.1 DG Biomass System

Data collection and analysis for the DG biomass system was discussed in Section 3.1.7. DG biomass system project evaluation was discussed in Section 3.1.8.

3.3.2 Community Energy Upgrade Program

Data collection and analysis activities for the Energy Upgrade Program, the heat pump demonstration project and electric vehicle charging stations were discussed in Section 3.2.

3.4 Task 5: Technology Transfer Activities

3.4.1 DG Biomass System

The goal of this task was to develop a plan to make the knowledge gained, experimental results and lessons learned from this project available to key decision-makers, and to disseminate the project results to facilitate replication in other communities. Given the outcome of this project, it is not appropriate to attempt to facilitate replication in other communities. That said, there have been many important lessons learned and those lessons have and will continue to be shared with other communities to help inform their choices with regard to DG biomass energy system options.

During the course of the project numerous presentations were delivered to inform various audiences about the DG biomass project. Table 35 lists some of the key presentations that were delivered.

Also, as further progress is made to make the system operational and/or as further lessons are learned, it is expected that additional presentations will be delivered and other technology transfer activities will be performed, such as the preparation and publication of journal articles.

Table 35: DG Biomass Project Presentations

Date	Location	Event	Presenter
5/29/13	Chandler, AZ	U.S. Department of Energy, Office of Indian Energy, Indian Energy and Infrastructure Working Group Quarterly Meeting	Jana Ganion (BLR)
9/19/13	National Renewable Energy Laboratory, Golden, Co	U.S. Department of Energy, Community-Scale Renewable Energy Workshop	Jana Ganion (BLR)
9/24/13	Sacramento, CA	Statewide Biomass Working Group	Matthew Marshall (RCEA)
11/6/13	Eureka, CA and Blue Lake Rancheria	North Coast Community-Scale Wood Bioenergy Workshop & Field Tour, University of California Woody Biomass Utilization Group at UC Berkeley	Matthew Marshall (RCEA), Jim Zoellick (SERC), and Jana Ganion (BLR)
2/26/14	National Webinar	U.S. Department of Energy (DOE) Office of Indian Energy, the DOE Office of Energy Efficiency and Renewable Energy's Tribal Energy Program, and the Western Area Power Administration (Western) Tribal Renewable Energy Series webinar: Strategic Energy Planning	Jana Ganion (BLR)
5/13/14	Humboldt State University, Arcata, CA	Biomass Research & Development Initiative (BRDI) Kick-off Meeting	Jim Zoellick (SERC)
8/12/14	CA Energy Commission, Sacramento, CA	Critical Project Review Meeting	Matthew Marshall (RCEA), Jana Ganion (BLR), Jim Zoellick (SERC)
10/16/14	CalEPA, Sacramento, CA	CA Hydrogen Business Council Hydrogen and Fuel Cell Summit	Jim Zoellick (SERC)
3/4/15	Sacramento, CA	U.S. Department of Energy, Office of Indian Energy Policy & Programs Tribal Leader Forum "Tribal Energy Systems: Climate Preparedness and Resiliency."	Jana Ganion (BLR)
3/5/15	Sacramento, CA	U.S. Department of Energy, Office of Indian Energy, Indian Energy and Infrastructure Working Group Quarterly Meeting	Jana Ganion (BLR)
3/24/15	UC Irvine, Irvine, CA	ICEPAG 2015 Clean Energy Conference	Jim Zoellick (SERC)

Date	Location	Event	Presenter
3/25/15	CA Energy Commission, Sacramento, CA	Final Project Meeting	Matthew Marshall (RCEA), Jana Ganion (BLR), Jim Zoellick (SERC)
7/29/15	CA Energy Commission, Sacramento, CA	CEC Workshop, Energizing California's Communities with Renewables: Past Successes and Future Opportunities	Matthew Marshall (RCEA)
9/2/15	National Renewable Energy Laboratory, Golden, CO	U.S. Department of Energy; Commercial-scale Tribal Energy Development Forum	Jana Ganion (BLR)
9/21/15	Redding City Hall, Redding, CA	CEC Workshop, Energizing California's Communities with Renewables: A North State and Rural Perspective	Jim Zoellick (SERC)
9/22/15	Washington, D.C.	Plenary, U.S. Department of Energy, National Tribal Energy Summit	Jana Ganion (BLR)
10/8/15	Smith River, CA	North Coast Tribal Chairmen's Association Monthly Meeting	Jana Ganion (BLR)
10/21/15	U.S. EPA Las Vegas Campus, Las Vegas, NV	Clean Power Plan and Tribes	Jana Ganion (BLR)
11/6/15	National Webinar	"EPA's Clean Power Plan, What Tribes Need to Know" U.S. Department of Energy National Webinar	Jana Ganion (BLR)
11/12/15	Hitachi Data Systems, San Jose, CA	"Grid of the Future," Silicon Valley Leadership Group Energy Summit	Jana Ganion (BLR)
11/18/15	CA Energy Commission, Sacramento, CA (remote participation)	Advanced Distributed Generation Research Workshop	Jim Zoellick (SERC)

Source: Schatz Energy Research Center

3.4.2 Community Energy Upgrade Program

The MRVC Energy Upgrade Program replication package was developed to serve as a program toolkit to support the dissemination of best practices and lessons learned from the pilot program and to share the materials, tools, and other program resources that can assist other communities to replicate or expand on the program. The replication package includes:

- An overview of the program design and implementation plan
- Copies of tools and resources such as customer intake forms, field forms, and report templates

- The marketing and outreach plan and copies of promotional materials used
- An overview of other programs that were coordinated with and their tools and resources that were utilized, such as customer databases, software programs, and equipment
- Best practices
- Lessons learned

Plans for replication and expansion in Humboldt County are discussed in Chapter 3, Section 3.2.9. The package will be available on RCEA's website and promoted through collaboration with other organizations and local government partners on ongoing and new projects.

3.5 Task 6: Production Readiness Plan

The goal of the production readiness plan is to determine the steps that will lead to the manufacturing of the technologies developed in this project or to the commercialization of the project's results. The individual components of the BLR DG biomass system are mostly fully developed commercial products that are readily available. That includes the fuel cell generator and the pressure swing adsorption unit.

The Ballard ClearGen™ Fuel Cell Generator is a fully commercial product. According to Ballard they have reached their 4th generation design with this system. These units are available in sizes ranging from 100 kW to 1 MW.

Xebec Adsorption offers a range of PSA technology solutions for various applications. Their H2X Solutions product line is suited to hydrogen purification and comes in a range of sizes. The also offer PSAs for biogas purification applications and complete integrated biogas upgrading plants.

Proton Power continues to offer the CHyP™ gasifier for electricity generation and synthetic fuels applications. Their featured configuration for electricity generation is their gasifier integrated with a gas genset, such as the GE Jenbacher unit. The team found in this study, that is likely the most cost-effective, efficient and technically viable configuration. Proton Power's gasification technology is still in the early stages of commercialization.

With regard to the fully integrated system designed and installed at the Blue Lake Rancheria, there are currently no plans to pursue further commercialization of this system. However, if further progress is made and/or other system configurations are developed that prove successful, commercialization plans could be considered at future time.

Refer to Section 3.1.8.2 for the general production readiness of DG biomass systems in the U.S.

CHAPTER 4: Conclusions and Recommendations

4.1 Conclusions

4.1.1 MRVC Energy Upgrade Program

The MRVC Energy Upgrade Program utilized new and existing energy efficiency and renewable energy delivery mechanisms, combined with a targeted outreach campaign, to promote and incentivize energy savings actions and adoption of solar electric systems. RCEA engaged stakeholders to promote the program, recruit participants, and advocate the benefits of energy efficiency and renewable energy in their community. The program provided for educational opportunities, including presentations, workshops, one-on-one consultations, and detailed reports of findings, to fill in knowledge gaps regarding energy technologies, and the benefits of potential energy and cost savings associated with adoption of these technologies. Several site assessments were completed, resulting in immediate energy savings through the existing Energy Watch program. Referrals to participating contractors resulted in several upgrade projects as well. Goals related to customer engagement, site assessments, and upgrade projects were met and the program also demonstrated the viability of a targeted campaign with community-focused outreach and social marketing efforts.

The heat pump performance assessment found that while heat pumps can offer substantial greenhouse gas reduction benefits, they are 80% more expensive to operate than a new, high efficiency natural gas fueled furnace. Natural gas prices would need to nearly double to attain cost parity. This will likely make it difficult for heat pumps to achieve broad market appeal. However, in areas where natural gas is not available and more expensive heating fuels, like propane, are utilized, heat pumps are cheaper to operate. While the greenhouse gas emission reductions attributable to heat pumps are significant, the cost per ton of CO2e reduced is excessive ($150-$200/MT). That said if a customer is purchasing or generating 100% renewable electricity a heat pump can allow them to zero out their space heating related CO2e emissions, and this can be a motivating factor for some customers.

4.1.2 DG Biomass Project

The investment in demonstrating a biomass integrated gasification fuel cell (BIGFC) system achieved significant benefits, primarily in direction for further research and development of biomass fueled distributed generation systems. While many of the stated goals of the DG biomass project were not met, much was accomplished. An innovative DG biomass energy system was conceived, designed, procured and installed, and many lessons were learned in the process. In addition, mass and energy balance models were developed that provided estimates of system performance. The results of the modeling exercise shed considerable light on the potential viability of a BIGFC system. In addition, an alternate DG biomass gasification system was examined and compared to the BIGFC system. What follows are the key conclusions from the DG biomass project.

- The key setback for the project was that despite a concerted investment of time, money and effort both during and beyond the end of the project timeline, as of this writing the gasifier is not yet operational. The technology is still being refined and is in the early stages of commercial development. Proton Power is working to develop a tar reformer and water-gas shift reactor that they expect will enable their system to meet the required performance specifications for this application.
- Without a working gasifier the overall system could not be operated and tested. Nonetheless, the rest of the equipment was installed and commissioned to enable immediate final system commissioning when gasifier is made operational. If Proton obtains or develops the gas conditioning equipment required to meet the performance specifications, it is expected the overall system should function as planned.
- All other components are fairly standard off-the-shelf components and are expected to meet their performance specifications. The Ballard Power Systems ClearGen™ fuel cell generator was tested at Ballard's facility and exceeded its performance specifications.
- Although the team was not able to operate and test the overall system, they collected a substantial amount of information about the system components. This allowed us to develop a mass and energy balance model that could be used to estimate system performance. The results of that analysis tell us that even if Proton Power is able to provide a gasifier system with gas conditioning equipment that meets the required specification and the entire system functions, the overall efficiency and economic viability of the system will be poor. In addition, even if the syngas composition meets specifications for major gas constituents, there is a risk that trace impurities could still cause problems. In this case an additional guard bed cleanup system would need to be added to remove select trace impurities.
- Modeling results indicate the parasitic loads and other system losses are excessive, causing very low system efficiencies. Key losses are associated with the PSA, gasifier and fuel cell. One of the best options to reduce these losses is to utilize the high quality waste heat in the PSA tail gas to heat the tar reformer, WGS reactor and gasifier reactor, assuming the resultant heating system would allow for enough control over the temperatures needed in the reactors.
- An alternate system configuration that replaces the fuel cell with an internal combustion engine-generator appears to be a cheaper, less complex and more efficient option than the integrated gasifier PEM fuel cell system. This alternative would eliminate the water-gas shift reactor, PSA and reciprocating compressor, thereby substantially reducing the parasitic loads and improving the overall system efficiency. A GE Jenbacher gas genset was identified as a viable candidate. Its advertised efficiency running on biogas is 36%. While this is somewhat less than the 50% efficiency displayed by the fuel cell generator, reducing other parasitic loads and losses more than makes up for the lower efficiency.
- DG biomass energy systems are not mature, readily available, cost-effective or practical at this time. More work clearly needs to be done to overcome obstacles and challenges.

The BIGFC system does not appear to be economically viable, and although the biomass gasification engine-generator system looks substantially more attractive, its economic viability still looks marginal at best. At this time the research team believes the biomass gasification engine-generator system configuration shows the most promise.

4.2 Lessons Learned

- Cutting-edge technology demonstration projects are not for the faint of heart. Project hosts must be prepared for cost and schedule over-runs, and must be flexible with regard to project outcomes. Project hosts who simply want and need a cost-effective distributed generation system that meets their energy needs should not undertake a technology demonstration project.
- Technology Maturity - In situations where technology maturity is uncertain and project hosts are not interested in a technology demonstration project, project hosts should follow conservative guidelines for ensuring that the technologies being specified are fully commercialized and proven, are backed by firm warranties, and are supported by companies that will be there to uphold the warranties. Technology screening criteria should include guidelines such: minimum number of commercial installations, minimum cumulative operating hours, multiple references who have operated the equipment for more than a year and who provide favorable reviews, and proper certifications (UL listed, etc.).
- Distributed Generation Biomass Energy Systems – DG biomass energy systems are not mature, readily available, cost-effective or practical at this time. The BIGFC system does not appear to be economically viable. The biomass gasification engine-generator system configuration shows the most promise.
- Biomass Gasification Technology – Biomass gasification technology for distributed-scale applications is not mature. Gasifiers tend to be temperamental with regard to feedstock characteristics. Gas cleanup is challenging and expensive. Generators that have a low tolerance for impurities in the syngas create challenges. The adverse effects of tar production and deposition cannot be over-emphasized.
- Syngas clean up is complicated. Impurities must be dealt with, and if the refined gas has a narrow final specification, both the cost of testing the syngas composition and gas clean up will be significant.
- Syngas Characteristics – Syngas is a toxic and combustible gas that many entities seeking distributed generation-scale systems may not be accustomed to dealing with. In a non-industrial setting this can be challenging and can pose concerns from the site host/customer.
- Utility Interconnection - Insurance requirements for the interconnection agreement were substantial and should be reviewed in the project planning phase. The interconnection process and the appropriate interconnection agreement can be confusing. This merits a thorough discussion with the utility prior to selecting the type of agreement, application

form and supporting documents. Further, utilities may have standby costs and other costs related to interconnection that should be fully investigated in the project planning phase.

- Codes and Regulations - Although codes and regulations for hydrogen systems are fairly well developed, the same is not true for syngas systems that involve a toxic and combustible gas. Local Authority's Having Jurisdiction (AHJs) are not familiar with these types of systems and are looking for guidance from experienced knowledgeable people. A great deal of work was spent developing a conservative code path for this system. Certifications (e.g. UL, ANSI/CSA America FC1) that are required or advisable for project equipment should be researched prior to purchase.

- Hazardous Area Electrical Equipment - There is a lack of availability in the U.S. (versus Europe) of non-incendive and/or intrinsically safe electrical equipment. This can require the use of much more expensive explosion-proof equipment in order to meet code and safety requirements in Class I Division 1 and Division 2 hazardous electrical areas. This can substantially increase costs. Systems must be designed to be safe and code compliant, but it is important not to be too conservative and not to significantly over design systems as this will drive costs up significantly.

- Electrical Contracting - With demonstration energy projects, it is difficult to define a scope of work for electrical contracting. This project required a significant amount of low voltage work, testing and troubleshooting. Project leaders were fortunate to have an excellent contractor who was willing to prioritize this project, and encourage entities pursuing these types of projects to ensure they have experienced, reliable, and cost-conscious electrical contracting partners.

- Electrical Engineering - Understanding utility interconnection requirements is complicated. Meeting with the generator vendor, utility representatives and electrical engineer and/or contractor to ensure the generator equipment is compliant with local utility requirements prior to purchasing the generator is recommended. Arc flash studies must be budgeted for when installing electrical generators.

- Fuel Handling / Conveyance - The expense of biomass fuel handling and conveyance is significant and the systems can be complicated. Systems must be designed to meet the needs of specific fuel characteristics (size, moisture content, density, impurities/contaminants, etc.). Designing in some flexibility is desirable in case fuel characteristics change.

- Biomass Fuel Storage and Processing - Biomass storage and processing can require large covered areas. Biomass processing equipment for screening, grinding, etc. can be expensive. If dry biomass is handled and processed it can generate substantial amounts of dust. This can create a dust explosion hazard that must be evaluated and mitigated. The safety evaluation and the mitigation measures must be budgeted for. Carbon monoxide off-gassing from biomass piles can also be a concern and must be evaluated and mitigated, and stored biomass can result in fire hazards from within the fuel piles themselves.

- Fuel Supply - Biomass sawdust was the fuel used for this project. A considerable amount of time, effort and expense was spent working through composition / moisture content / pre-treatment. A readily available local resource was selected, and there were still problems with fuel workability in the gasification system. Although not a part of this project, it is clear that pretreatment of forest residues for a system such as this would entail a substantial cost to remove contaminants and achieve consistent size and moisture content.

- Biomass Drying – DG biomass systems tend to require biomass with low moisture contents. Even where higher moisture contents are allowed drying may be necessary. Biomass drying adds expense and parasitic energy demands. Using waste heat from a DG biomass energy system to dry biomass fuel is recommended. Flash dryers hold promise for utilizing waste heat for this purpose. Covered areas are needed to store dry fuel.

- Ventilation - Syngas contains hydrogen, a lighter than air combustible gas, and carbon monoxide, which is about the same density as air and is both toxic and combustible. Designing a ventilation system to mitigate the hazards associated with a potential syngas leak is complicated. Local HVAC vendors in the rural community did not have familiarity with designing such a system. Designing such a ventilation system requires substantial effort and should be budgeted accordingly.

- Site and Equipment Layout - Due to the toxic nature of syngas, consideration should be taken in locating as much of the gasification system and syngas components in a covered outdoor location where natural ventilation can reduce associated hazards.

- Fire, Life, Safety, Emergency Alarm Systems - In a toxic/combustible gas environment, life and safety systems and alarms require a focused design effort, and related low-voltage electrical contracting. Project design engineers partnered with a local fire alarm company to meet the specific needs of the project while also complying with standard fire and life safety code requirements.

- Budgetary contingencies for demonstration projects are significantly higher than standard construction project contingencies. The Blue Lake Rancheria Department of Energy and Technologies and Serraga Energy contributed the additional contingency on this project.

- Procurement Details - California Seismic Zone 4 requires specific engineering specifications for securing equipment. Equipment providers should be made aware of this requirement early in the sales process. Obtaining documented seismic designs compliant with the latest codes and related assurances from vendors in their sales agreements can prevent unanticipated costs later on.

- Shipping and Logistics - In a rural, truck-length-constrained transportation corridor area it is difficult to get large pieces of equipment delivered by standard carriers. Many of the skid shipments were broken up - happening several times after they were in transit due to shipping companies not being familiar with specific restrictions. This added expense and frustration. There is a need to factor shipping costs into the budget, and sharing shipping costs with vendors is advisable.

4.3 Recommendations

Entities interested in pursuing a DG biomass energy system should consider the following:

- Project design should be grounded in overall energy goals, appetite for risk and potential desire to further knowledge on cutting edge systems. Pay close attention to technology maturity and make sure you know what you are getting.
- Put together a strong team with the following areas of expertise: biomass fuel handling and processing, biomass energy systems, electrical engineering, mechanical engineering, controls engineering, safety engineering, codes and standards and electrical contracting. Vet your team well.
- Identify a long-term fuel source that is readily available at an acceptable price and that meets the fuel specifications for your equipment. Start building relationships with potential fuel providers early on.
- Start a relationship with your local utility as early as possible and provide them with periodic updates.
- Engage your local fire and building code staff early on in the project. Keep them informed each step of the way. They may not be familiar with the technologies you are installing and will look to you and your experts for guidance. If possible, find a helpful code official from another jurisdiction that has already approved a similar biomass energy system and connect them with your local code officials.

Communities considering Upgrade Programs to target high-priority opportunities for energy savings and renewable energy systems might consider the following:

- Leveraging existing programs and tools is important to cost-effective design and implementation.
- Identify partners and community advocates early on.
- Continue to focus on developing energy services capacity as demand increases.
- Allow several months from initial customer contact to project completion.
- Focus on how to provide additional incentives along with the comprehensive package of services, especially if promoting one technology over another.

4.4 Suggestions for Further Research

- Identify and demonstrate viable biomass distributed generation systems, especially gasification systems integrated with internal combustion engine-generators.
- Develop standardized, cost-effective syngas cleanup and conditioning systems for DG biomass gasification applications.
- Work to standardize codes and standards applicable to syngas systems.
- Develop syngas systems with a greater flexibility around types, sizes, impurities, and moisture contents of biomass fuels.
- Develop syngas-fueled generators with a wider specification for syngas composition and impurities.
- Standardize and improve biomass fuel handling and pre-treatment systems to improve safety (e.g. reduce dust), lower costs (standard conveyance designs), and allow for a typical array of pre-treatment activities (e.g. drying, screening, grinding, etc.).
- Develop higher efficiency biomass-to-electricity systems.
- Develop unique financing products and/or incentives to overcome cost barriers of adopting energy technologies.

4.5 Benefits to California

- Lower GHG emissions through implemented energy efficiency upgrades, electric vehicle charging infrastructure, and a new renewable energy system.
- Valuable lessons learned regarding DG biomass energy opportunities. Better understanding of which system types offer the best opportunities and which do not. Key recommendations for others looking to pursue DG biomass energy projects.
- A significantly improved sense of the costs, components, and complexities associated with the installation of DG biomass gasification systems.
- Recommendations for future research and development.

GLOSSARY

Term	Definition
BDT	bone dry tonnes (metric)
BIGFC	biomass integrated gasification fuel cell
BLR	Blue Lake Rancheria
BPI	Building Performance Institute
CA	California
CAISO	California Independent System Operator
CHP	combined heat and power
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
CPUC	California Public Utilities Commission
DG	distributed generation
DI	deionized water
EVSE	electric vehicle supply equipment
GHG	greenhouse gas
GWh	gigawatt-hour
JPA	Joint Powers Authority
HHV	higher heating value
HRC	Humboldt Redwood Company
HVAC	heating, ventilation and air conditioning
H_2	hydrogen gas
IC	internal combustion
kg	kilogram
kV	kilovolt
kW	kilowatt
kWh	kilowatt-hour
LCOE	levelized cost of energy

Term	Definition
LHV	lower heating value
LLC	Limited Liability Corporation
MC	moisture content
MCF	1,000 cubic feet
MCFC	molten carbonate fuel cell
MOU	memorandum of understanding
MRVC	Mad River Valley Community
MT	metric tonnes
MVA	megavolt-amps
MW	megawatt
MWh	megawatt-hour
NCMH	normal cubic meters per hour
NREL	National Renewable Energy Laboratory
O&M	operations and maintenance
ORC	organic rankine cycle
PEM	proton exchange membrane
PG&E	Pacific Gas and Electric
PPI	Proton Power, Inc.
ppm	parts per million
PSA	pressure swing adsorption unit
RCEA	Redwood Coast Energy Authority
RCEW	Redwood Coast Energy Watch
RE	renewable energy
RESCO	Renewable Energy Secure Community
RCEW	Redwood Coast Energy Watch
SERC	Schatz Energy Research Center
SOFC	solid oxide fuel cell
WGS	water-gas shift

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