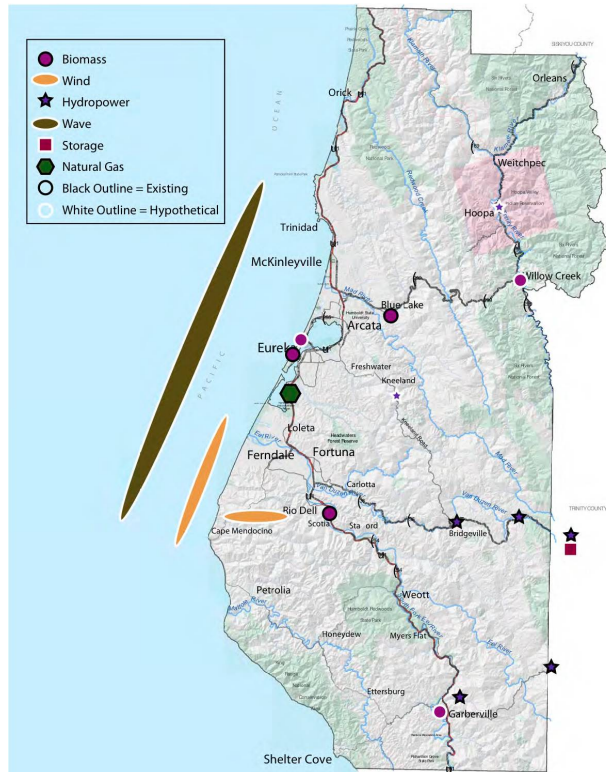


Renewable Energy in combination with Hydrogen Technology in Humboldt County

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Existing and Potential Resources for Electricity Production in Humboldt County
Source: SERC 2011

Abstract

The purpose of this paper is to consider the potential renewable energy resources that Humboldt County possesses in order to be developed in combination with hydrogen technology. First, I will describe what hydrogen technology is and how it generally works. Then I will answer the question of why implementing hydrogen technology is beneficial. I will next survey possible renewable energy resources that can be taken advantage of by Humboldt County. These renewable energy sources are biomass, hydroelectric, solar, wind and wave energies. Once when the case is made for hydrogen technology, I will discuss the socioeconomic implications brought about by new supply in the energy sector, along with the affects of implementing hydrogen technology. This new form of energy technology used in conjunction with newfound renewable energy can reduce Humboldt's reliance on imported fossil fuels thus help mitigate the output of greenhouse gasses.

Energy is ingrained in every part of our lives. It is interwoven into the fabric of our lives like a thread that keeps our clothes together. In the market behind all goods and services is energy with its uses in both production and consumption. Energy comes from many sources on earth. The most prevalent sources of energy come from non-renewable fossil fuels which are becoming ever more scarce due to society either exhausting our limited resources or it is significantly harder to find. Other means of attaining energy is by harnessing natural resources, which are abundantly renewable. Clean and efficient energy derives from natural sources such as the sun, biomass, wind, wave, and geothermal heat which all are restocked by nature. The urge to turn to renewable energy comes at a time where the degradation of the earth has increasingly become noticeable with the anthropogenic occurrence of global warming. A transition to clean and efficient energy can considerably reduce the energy and carbon potency of society. What technology is clean and efficient that can help Humboldt County support its energy needs? Humboldt County is fortunate to have potential renewable energy resources in which it can become sustainable in energy production in combination with hydrogen technology. This study will explore the potential local renewable energy, cost effectiveness, and local interest in hydrogen technology.

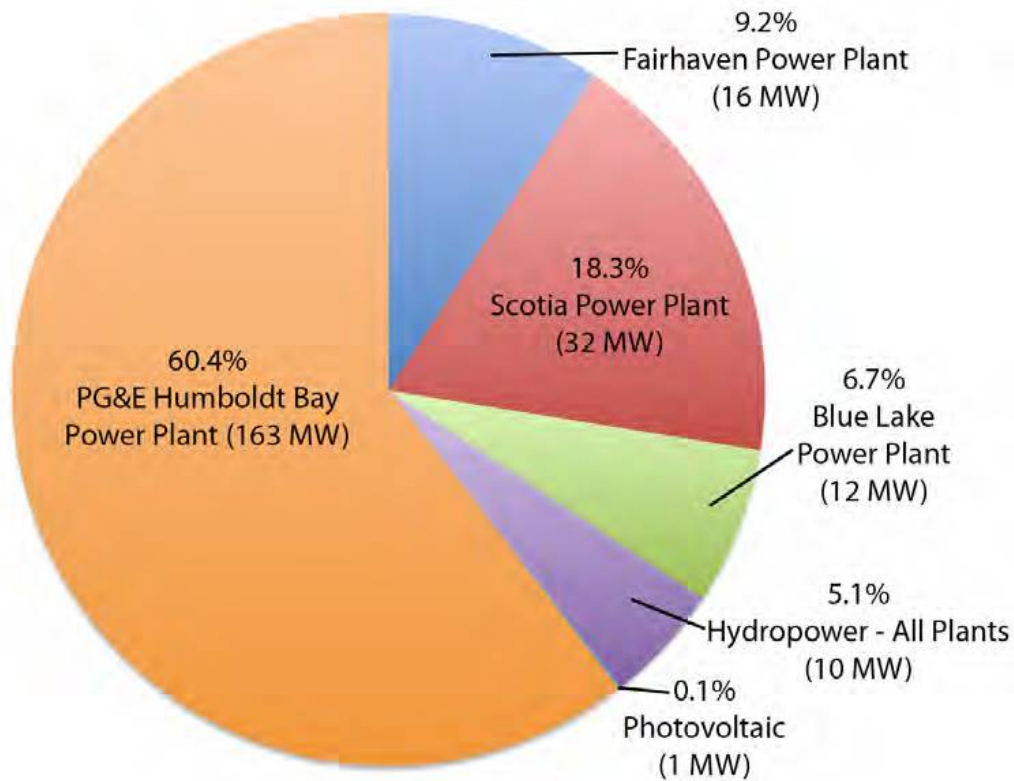
With an abundance of renewable energy there will be a need to store and process all the energy that is generated displacing the fossil fuels. Most renewable energy is intermittent due to supply and demand mismatch, which is when electricity is generated and stored but not utilized fully until peak demand, this has required some sort of battery backup system. An ideal battery backup system would be to use the energy that is generated from renewables to convert water into hydrogen. To describe how hydrogen technology will work, an understanding of the prevailing method must be understood. Batteries store electricity, however all their potential chemicals are stored in the battery itself until they are used up and run out of energy then they are either recharged or

discarded. Besides being discarded, batteries contain hazardous materials. Furthermore, they are cumbersome being heavy and bulky and have a high self-discharge rate which makes it unsuitable for long-term energy storage (Engel, Crea, & Woofenden, 2004).

On the other hand, fuel cells can continue to run essentially forever as long as it is supplied with hydrogen and oxygen, preferably replenished with renewable resources. The hydrogen that is produced can be compressed into a storage container for later use. The stored hydrogen has potential to create energy and therefore it acts a battery. “In a process called electrolysis, hydrogen is produced by passing electricity through two electrodes in water. The water molecule is split and produces oxygen gas at the anode and hydrogen gas at the cathode via the following reaction: $2\text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2$ ” (Levene, Mann, Margolis, & Milbrandt, 2006). The Schatz Energy Research Center SERC at Humboldt State University made a great improvement when producing hydrogen. SERC created a High Pressure Proton Exchange Membrane (PEM) electrolyzer “capable of generating hydrogen at high pressure in useful quantities for small-scale power systems” (Engel, Chapman, Chamberlin, & Lehman). This break through allows for safe and compact storage of hydrogen, also considered as potential energy, in other words a battery. Then this new formed hydrogen can be stored long term. The hydrogen can be converted to electricity on demand through the use of fuel cells when hydrogen is chemically bonded to oxygen to form water during the process of producing electricity. The byproduct of water is just one reason why hydrogen should be used because there are no carbon emissions as long as hydrogen is harvested through renewable energy sources. Out of so many different technologies, including batteries, superconducting magnets, and etc., using hydrogen is the best method of energy storage when testing under “balanced overall analyses considering technical feasibility, cost, wire-to-wire efficiency, lifespan, weight, and volume” (Engel, Crea, & Woofenden, 2004). Additionally, there would not be hazardous waste involved in the process of hydrogen production and from producing electricity through fuel cells.

Even with all the technology that this civilization has afforded us, there still remains a logistic problem of importing energy from outside the county lines. With considerable distances from neighboring cities, Humboldt remains an isolated community. A community that imports over half (54.36%) its energy needs in the form of natural gas and 100% of its transportation fuel. Conversely Humboldt meets its energy loads with all its energy produced in house from a 60.4 MW PG&E Humboldt Bay natural gas power plant, three local biomass power plants accounting for 34.2 MW, and remainder of energy is supplied by small scale hydroelectric and PV systems (Schatz Energy Research Center, 2011).

Humboldt County 2010 Estimated Electricity Supply by Generator



Source: SERC 2011

Humboldt could take some cues from an isolated island country such as Iceland, a country who is securing its energy independence by “over 70% of all primary energy used in Iceland comes from sustainable energy sources” (Mytelka & Boyle, 2008). Iceland’s sustainable energy sources are derived from geothermal and hydropower sources. In the book, “Making choices about hydrogen: Transport issues for developing countries”; the author advocates that small societies should invest in research and development and suggests that, “hydrogen effort should be included in a more broad-ranging effort to reach the goals that hydrogen technology is meant to strive for” (Mytelka & Boyle, 2008). The Schatz Energy Research Center SERC established 1989 at Humboldt State University HSU is an academic research lab that is making advances in energy and hydrogen technology. Some of SERC’s hydrogen technology projects include their Schatz Solar Hydrogen Project, proton exchange membrane (PEM) electrolyzers to separate hydrogen from oxygen, fuel cell equipment and services, hydrogen fueling station, and many others. With all the intellectual might, HSU is a prime school invest in research and development to innovate new technology that is surrounded by supporting community that is planning for a sustainable energy future. In order for Humboldt to have independence in energy supply, a broader look in its potential renewables must be considered to fulfill its energy needs. What’s holding us back? The primary reason is the lack of funding due to tough economic climate in the recent years since the onset of the 2007 recession. Recovery in the economy has been happening but not at a pace where there is sufficient government revenue from taxes to help the advancement of new and emerging technology. If the voters are up to it, they can implement a Feed-In Tariff policy (FIT) to help with the up-front cost of introducing a renewable energy technology to the energy market. The tariff is an energy supply policy that would tax society to help alleviate the introduction of new renewable power generation (Cory, Couture, & Kreycik, 2009). The chances of a new tax policy to pass in

this economic climate are slim, however in November 2010 voters defeated proposition 23 which would of have dismantled California's AB 32 global warming bill, albeit it not being a tax but a green policy. When it comes down to it, society will decide if they want to bring in new renewable energy to the mix towards energy independence.

So how is all this hydrogen fuel going to be made? It would only be appropriate and sustainable if energy were produced through renewable resources to store energy in the form of Hydrogen, which is the intention to abate green house gasses (GHG). There is an abundance of renewable energy potential to produce more than enough for the demands of Humboldt. The county has resources for wave, wind, biomass, solar, and hydro among other GHG emitting sources that will not be analyzed. In 2006, California created an aggressive policy instrument to take charge on global warming with its law AB32, the Global Warming Solutions Act. The state of California devised a research and development (R&D) program called the Public Interest Energy Research (PEIR), in which it makes strides in science and technology towards the development of energy efficiency, renewable energy, and many other advanced technology geared towards the environment and energy. The program commissioned an extensive report named "Humboldt County as a Renewable Energy Secure Community", also known as Humboldt County RESCO in short. "The Humboldt County RESCO project is a planning study intended to evaluate renewable energy opportunities in Humboldt County, California and develop a strategic plan for their efficient and successful development" (Schatz Energy Research Center, 2011). Out of the many energy resources that were surveyed in Humboldt, this study will only focus on wind, wave, biomass, hydro and solar because these sources of energy are renewable.

One of the most established renewable technologies is wind power generation. Harnessing the energy that is created by wind has been around for thousands of years with sailors casting their sails out to sea to propel their ships through the mighty sea. Just

like the wind blowing into the sails then came about windmills that were initially used to mill grains and pump water. Now windmills that produce energy are called wind turbines. The intermittency of how the way wind blows in nature leads to the usefulness of storing the energy generated in the form of hydrogen. When ample amounts of hydrogen is in storage, then energy can be used either in an internal combustion engine or through a fuel cell when wind is absent or when increased demand in electricity.

California's north coast stands a good chance to producing energy through wind farming due to its high wind potential. "Humboldt County's primary wind resource is located in the Cape Mendocino area" (Schatz Energy Research Center, 2011). "It has been estimated that there is greater than 400 MW of onshore wind resource potential in this area" (Schatz Energy Research Center, California Department of Water Resources, 1985). Implementing wind farming in the Cape Mendocino area should be trivial with its potential wind prognosis and maturity of wind technology. However, the residents of Ferndale object to Shell WindEnergy to build a proposed wind farm on Bear River Ridge. This is a common case of Not In My BackYard (NIMBY) with the residents objecting to harming the scenic views, disturbing the night sky with light pollution, construction disturbance for 6 to 8 months, development of supporting infrastructure, and the wind farms effect on property value (Beltz, 2011). Only time will tell if the residents will give into the opportunity cost of having a wind farm. Shell WindEnergy hopes to have this project completed in 2014.

Another potential and emerging renewable energy technology is wave power generation. The ocean is filled with currents and waves that are full of constant kinetic energy. A small percentage of this energy can be taken from the sheer power of waves along the coast of Humboldt, yet that small percentage can accumulate up to 7,600 MW of energy. From the north and south of Cape Mendocino are the main locations to collect energy from waves. Recently, PG&E's pilot 5 MW energy generation project had some promising results, yet the project was suspended due to the immaturity of the technology.

Wave technology is still in its infancy, so further investigation and analysis must be conducted to get a further conclusion on how this technology works. PG&E still looks to implement wave power generation when the technology and knowledge of wave generators are more understood (Schatz Energy Research Center, 2011).

Back on land, Humboldt is nicely situated in a densely forested area where 80% of the land is covered by the trees. Consequently, there are several logging companies that have biomass waste from their mills and leftover forest slash from timber harvest. There is also waste from remaining debris of forest thinning to prevent forest fires. The collection of all the biomass waste from the byproduct of logging and forest thinning are used in biomass power plants. Currently there are three biomass power plants, which are the Blue Lake Power, Fairhaven Power, and the Town of Scotia Company producing 11 MW, 17.25MW and 28.8 MW of electricity respectively. These power plants make a considerable amount of energy by providing Humboldt County with 34.2% of its energy needs (Schatz Energy Research Center, 2011). Furthermore, Humboldt sufficiently has enough room to grow in biomass energy production capable of producing up to 222 MW (Williams, 2008). All this extra energy can be used to produce hydrogen fuel through electrolysis then in turn be used for transportation fuel in internal combustion engines, fuel cell vehicles, or when increased demand in electricity. “Biomass is a potentially interesting source for hydrogen as it could provide most of the environmental benefits of wind or solar hydrogen, at costs closer to those of hydrogen from natural gas or coal” (Parker, Ogden, & Fan, 2008).

Besides the trees and biomass, Northern California has lots of rivers and tributaries that go through Humboldt County, which affords the possibility of expanding hydroelectric systems in the region. Currently there are six hydroelectric facilities that supply Humboldt with 11.5 MW; all except one are run-of-the-river systems. The one exception is the Matthews Dam Facility located at Ruth Lake. Without the use of a dam

or reservoir, a run-of-the-river system is when a portion of the river water is diverted to run a turbine along side of the river then the water is being returned to the river (Zoellick, 2005). A run-of-the-river system is usually considered a micro-hydro system because it produces up to 100 kW of electricity (Energy Savers, 2011). Additionally, there is an estimated 100 or more run-of-the-river systems supporting private residents that are in remote locations off the grid. Building more hydroelectric facilities in the county may sound like a good idea, however there are several costly barriers that could impede the development of hydroelectric systems. These barriers include strict environmental permitting, locations that are remote, and the inability to be economic feasible. Moreover, there are 2 reasons for not being economic feasible, which are the avoided cost rates not being sufficient and that most micro-hydro systems run intermittently during wet seasons. If the County of Humboldt including its residents could overcome the barriers of installing a micro-hydro system and keep it economically sustainable then there could be up to 35 MW of energy to be made (Zoellick, 2005). Even if the barriers were to be overcome, the energy produced would be negligible compared to the total electricity demanded of Humboldt County due to the disperse locations of micro-hydros would not be able to reach existing infrastructure, producing under 100 kW or less, and intermittent nature of the water supply due to seasons. Besides being tied to the grid and if a rural resident overcoming the barriers of hydro then they can provide for themselves with energy using a micro-hydro system during the wet months and in tandem use photovoltaic panels to supplement with energy during the dry months. This example of using two intermittent energy technologies would be a perfect candidate to implement a hydrogen battery back-up system with fuel cells to provide uninterrupted energy supply.

Finally, collecting energy from the sun using photovoltaic (PV) arrays and solar water heating systems has been a tried and trued technology. Such technology, that it has been quite popular by Humboldt residents having installations of one or both systems on

their rooftops. “In fact, on a per capita basis since 1998 the residents of Humboldt County have installed over twice as many grid-connected solar electric systems as the State of California as a whole” (Schatz Energy Research Center, 2011). As mentioned earlier, solar array systems can synergistically work in tandem with micro-hydro installations to supplement energy during dry months. While large scale solar array production would not be feasible, it would still be advantageous for residents to install solar systems for south facing roofs to collect up to 4.4kWh/m²/day (Schatz Energy Research Center, 2011). By allowing residents to harness their own energy from the sun, it allows for energy consumption to be used directly at the source of production, instead of having the power be lost through transmission over long distances. This method of energy production is called decentralized energy production, which will decrease energy usage from imported sources further decreasing the county dependence on outside fuel.

Discussed in this study were the old techniques of storing energy then the process of how and hydrogen can be useful and how it's processed. Surveying the various renewable energy sources brought about its pros and cons. Some proved to be more feasible than others, such as wind, biomass, and solar. Wave power generation the technology was too immature to develop thus needed further research and development. Hydropower had quite a few barriers to be a viable option in a Renewable Portfolio Standard for PG&E. The imposing barriers included strict costly permitting, location of hydro sites are too remote and away from existing infrastructure, it would not be good investment if the avoided cost rate from PG&E was too low and in flux, and most of the hydro sites would run only during wet months resulting in intermittent energy production, which would not be sufficient for a suitable payback period. Humboldt County can become sustainable in energy production in combination with hydrogen technology, with the potentially blessed and identified renewable resources in northern California.

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