UTILITY-SCALE SOLAR PHOTOVOLTAIC HOSTING POTENTIAL OF HISTORIC MILL SITES IN HUMBOLDT COUNTY, CALIFORNIA

By

Michael Avcollie

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Committee Membership

Dr. Arne Jacobson, Committee Chair

Dr. Kevin Fingerman, Committee Member

Dr. Peter Alstone, Committee Member

Dr. Margaret Lang, Program Graduate Coordinator

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ABSTRACT

UTILITY-SCALE SOLAR PHOTOVOLTAIC HOSTING POTENTIAL OF HISTORIC MILL SITES IN HUMBOLDT COUNTY, CALIFORNIA

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The adoption of Redwood Coast Energy Authority's (RCEA's) Community Choice Energy program in May of 2017 across Humboldt County has sparked interest in locally produced energy from solar photovoltaics (PV). RCEA has a goal of bringing 5 Megawatts (MW) of local, utility-scale, solar PV under contract by 2018 and 15 MW by 2023. Humboldt County's former mill sites offer features that make them suitable for hosting PV development. This study performed an inventory and analysis of these sites to answer two questions: Can Humboldt County's former mill sites provide the hosting capacity for 15 MW of local, utility-scale solar PV? Which of these sites have the most suitable conditions for hosting a utility-scale solar PV installation? A total of 37 sites were identified, and data were collected regarding six key criteria: available area, solar resource, grid hosting capacity, distance to nearest transformer, land acquisition cost, and land use compatibility. These criteria were used to score and rank sites based on their potential to act as utility-scale PV hosting sites. Overall there were 37 sites with enough available area to host 148 MW of PV capacity, limited to 18 MW given the current constraints on utility grid hosting capacity. Using these sites could satisfy the local demand for 15 MW of utility-scale solar PV without significant grid upgrades. The sites with the greatest potential were the Pilot Lumber, Hoopa Timber, Cal Pac, Pacific

Lumber Fortuna, Blue Lake Biomass, Pacific Lumber Yager Camp, Crown Simpson Mill, Georgia Pacific, DG Fairhaven and Cascade Forest sites.

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INTRODUCTION

Renewable energy sources like PV have many beneficial impacts, including reduced greenhouse gas emissions and reduced particulate air pollution when compared to fossil fuels (Wiser, et al., 2016). However, there are still serious land use implications for developing utility-scale solar generation sites. The development of a typical utility-scale PV array often includes site preparation techniques such as grading, vegetation removal, and herbicide applications that can lead to loss of wildlife habitat, habitat fragmentation and soil erosion (Macknick, Beatty, & Hill, 2013).

One way of avoiding some of the potential impacts of PV site development would be to re-use land that has already been degraded by previous land-use activities ("brownfield development"). For this reason, there is increasing interest in the idea of reusing and repurposing former industrial sites for hosting renewable energy generation projects like utility-scale solar PV (Waite, 2017). Humboldt County's former mill sites offer several features that could make them ideal sites for hosting renewable energy generation development. Mill sites have been cleared, graded, and in many cases, graveled or paved which facilitates future development without needing to encroach on productive agricultural lands or virgin ecosystems. And the same infrastructure that brought power to these sites could be useful for feeding renewable energy back onto the electrical grid.

The county's economy has long been associated with logging, an industry that began in the mid-to-late 19th century and spanned the entire 20th century (O'Hara &

Service, 2016). As recently as 1999 the USDA identified 12 softwood lumber mills operating in Humboldt County (US Department of Agriculture, 1999). In 2009, the number of operational lumber mills in the county had dropped to four (US Department of Agriculture, 2009). Many other former mills have long been vacant or have been listed as brownfields; the United States Environmental Protection Agency (EPA) defines a brownfield as "a property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant" (US Environmental Protection Agency, 2001). Because of this, these lands may be available for purchase or long-term lease at favorable prices. In addition, lumber mills were large consumers of electricity and represented considerable loads on the electrical distribution system. A recent study found that a softwood mills operating in Montana in 2009 consumed approximately 7,000,000 kWh of electricity per year (Loeffler, Anderson, Morgan, & Sorenson, 2014). The utility grid infrastructure that supplied power to former mill sites could be useful in delivery power from PV back onto the grid.

For this study, an inventory and analysis of Humboldt County's former mill sites was performed to estimate the potential of these lands to host utility-scale solar photovoltaic development. This study seeks to answer two questions: 1) To what extent can Humboldt County's former mill sites provide the hosting capacity for the regional demand of up to 15 MW of local, utility-scale solar PV production? And 2) Which of the former mills sites have the greatest potential and most suitable conditions for hosting a utility-scale solar PV installation?

To answer the questions of interest, former mill sites were identified and selected; data were collected and several key criteria were assessed for each of the sites. Among those key criteria were:

- Available area
- Available solar resource
- Hosting capacity of the utility distribution grid
- Distance to the nearest utility sub-station
- Estimated cost of land acquisition
- Site compatibility index score

The final criterion is a composite criterion developed for this study called the "site compatibility index" which is based on property ownership, zoning status and site contamination, if known.

Available area is among the key criteria because utility-scale solar installations have considerable land-use requirements. The National Renewable Energy Lab (NREL) estimates that small utility-scale, fixed-axis PV arrays require 5.5 acres/MW AC of direct area while the total area required is 7.6 acres/MW AC. Sites with greater available area will score higher than smaller sites.

The solar resource for a given location is often assessed in terms of insolation, an amount of solar energy on a surface over a period of time (Solar Energy International, 2013). This criterion will allow a valuable comparison of sites based on their varying insolation levels that occur across sites. Sites with greater available solar resource scored higher than those with less available solar resource.

This study will make use of an on-line tool called the photovoltaic renewable auction mechanism (PV RAM) map, made available by the local investor owned utility, Pacific Gas & Electric Company (PG&E), that shows the locations of distribution lines, transmission lines, sub-stations as well as a limited set of circuit characteristics for feeder lines that includes estimates of the available hosting capacity for new loads, generation and storage (Pacific Gas and Electric, 2015). Sites with greater utility grid generation hosting capacity scored higher than those with less capacity.

The site's distance to the nearest utility sub-station was also assessed because longer distances between site and utility sub-station can lead to costlier upgrades in utility feeder lines as these upgrades are often based on length of conductors needed to be upgraded (Pacific Gas and Electric , 2016). Sites that are closer to the nearest utility sub-station scored higher than sites that are farther.

The value of the lease rate and or assessed property values for each site will be used to estimate the cost of land acquisition as this plays an important role in PV project economics. Ideally, projects will be developed on low value properties and/or property already owned by the developer (International Finance Corportation, 2015). This study gave a higher score to sites that have lower lease rates or lower assessed property values than those that lease at, or are assessed at, greater rates.

A site compatibility index was developed for each site based on zoning status, ownership and status as a brownfield or EPA re-development site. Sites that are publicly owned scored higher than those that are privately owned; privately owned sites with multiple owners scored even lower. Sites that are known to be contaminated scored lower

than those that are not; sites with compatible zoning scored higher. Together these factors made up the composite criterion of site compatibility.

The six criteria outlined above were used to rank each of the site's potential to host a utility-scale PV project. However, not all the criteria carry equal importance or weight in the ranking process. For this reason, a weighted matrix was created to indicate the importance of each criterion. Each site received a raw score, between one and five, for each criterion and then these raw scores were weighted to create a final score. This process is highly subjective, and sensitivity analysis was performed to highlight how the weighting process affected the results of the ranking results. The intention of the ranking process was not to find a correct answer in ranking sites but merely to guide future investigation of the most promising sites.

The process outlined above yielded two valuable results: an inventory of the sites with their respective attributes, and a screening system that ranks each of the sites in terms of their potential to serve as utility-scale PV hosting sites. The data collected were used to estimate the total utility-scale PV hosting capacity of each site based on area as well as an estimate of each site's capacity based on the available grid hosting capacity. The ranking process and sensitivity analysis identified sites that show the greatest potential for hosting PV.

This thesis starts with review of developments in four fields: trends in the land reuse and redevelopment fields toward the idea of reusing former industrial sites and other degraded lands as renewable energy generation sites; utility-scale PV economics and site suitability analysis; Community Choice Aggregation (CCA) and the use of

weighted decision-making systems. This review provides context and background for the methods section of this thesis. The data to be collected and the methods used for data collection are described and shown to be grounded in standard solar industry practices and academic literature. The results in this study are reported based on the results from each of the six key criteria. The later part of the results section focuses on the total scores for the sites, both weighted and unweighted. The discussion section explores alternative weighting and scoring systems in an effort to discern the effects of the scoring system. There is also discussion of limitations of the available data and how these limitations affected the study. The document ends with a conclusions chapter, a list of references, and four appendices. Notably, Appendix D provides a detailed description of the 14 highest scoring sites, including a site map and added information about each site that was not included in the main body of this work.

LITERATURE REVIEW

A review of relevant literature provides useful background and context regarding the concept of re-use and re-development of industrial sites, utility-scale solar photovoltaic economics as it pertains to site suitability, Community Choice Energy in Humboldt County, and weighted criteria decision-making systems. The literature review provides context for the concepts and techniques that were used to conduct this study.

Land Reuse and Redevelopment

There is a growing movement toward the re-use and redevelopment of industrial sites as renewable energy generation sites. In 2013, the National Renewable Energy Lab (NREL) published a report titled *Solar Development on Contaminated and Disturbed Lands* that provides a broad analysis of the potential for solar development on already degraded lands to meet the US Department of Energy (DOE) SunShot Initiative's goal of 632 GW of solar PV and 83 GW of concentrating solar power (CSP) to be deployed by 2050 (Macknick, Lee, Mosey, & Melius, 2013). The potential sites in this study include United States EPA Superfund sites, Resource Conservation and Recovery Act sites, brownfields and abandoned mine lands. Also included in this study is the category of "disturbed lands," which are those "in an altered and often non-vegetated state due to disturbances" (U.S. Geological Survey, 2012). Sites were analyzed and screened based on technology, solar PV or solar CSP; solar PV screening also included project scale, either utility-scale or commercial-scale. Commercial-scale PV sites were screened for

those with less than five percent slope and between 10 and 100 acres. The NREL study found that contaminated lands alone would not provide enough potential capacity to meet the DOE SunShot goals, with a total PV installed capacity of 370 GW. However, if "disturbed, barren, invasive" lands were included, the total PV installed capacity of these lands would be 1,600 GW; more than enough to meet the SunShot goals of 632 GW of PV by 2050 (Macknick, Lee, Mosey, & Melius, 2013).

In 2015, the EPA created its Re-Powering America's Land Initiative "to demonstrate the enormous potential that contaminated lands, landfills, and mine sites provide for developing renewable energy in the United States" (U.S. Environmental Protection Agency, 2015). The project developed an inventory of qualified sites from various state and federal agencies and pre-screens the sites for potential renewable energy projects including solar PV, concentrating solar power (CSP), wind power, biomass energy and geothermal energy. Data from the National Renewable Energy Lab (NREL) were used for screening sites. The methodology for evaluating solar PV potential was based on available solar resource, area, distance to transmission lines, and distance to graded roads. For a site to be included in the mapped results, utility-scale sites were required to have greater than or equal to 5.0 $kWh/m^2/day$ direct normal irradiation (DNI), greater than or equal to 40 acres of area, and be located less than or equal to 10 miles from transmission lines and graded roads. For large solar PV projects greater than 300 kW but less than 6.5 MW, the minimum solar resource was 3.5 $kWh/m^2/day$ DNI, minimum area was two acres, and distance to transmission lines and graded roads should be less than or equal to one mile. This program also uses a unique category of solar

project called "policy driven" solar PV, which is defined at the same size the study sets for utility-scale PV, 6.5 MW, but uses a lower threshold for the solar resource, with a minimum of 3.5 kWh/m^2/day DNI, less than the average 4.1 kWh/m^2/day in Humboldt County. This difference acknowledges that certain public policy priorities or incentives can make sites more compatible with PV development in spite of a lower solar resource. This notion helps inform the creation of the "site compatibility index" for this study described in the Methods section of this paper.

A recent article in the journal Land Use Policy, *Land Reuse in Support of Renewable Energy Development*, explores the degree to which contaminated or otherwise degraded lands in the United States could act as host sites for renewable energy installations in order to meet the renewable energy demand created by various state-level Renewable Portfolio Standards in the United States (Waite, 2017). This study performs a broad pre-screening of sites for both solar PV and wind power installations on lands associated with federal clean-up programs such as Superfund sites, brownfield sites and the EPA's Landfill Methane Outreach Program. The report collects data on solar resource, wind speed, area, distance to transmission lines, and distance to roads. The data are sourced from the EPA's Re-Powering America's Land Initiative as well as studies by NREL. The report concludes that if only 10% of the available area at these sites were suitable to PV development, 399 gigawatts (GW) of solar PV capacity could be hosted at these sites based on an average 7.6 acres/MW. This far outstrips the demand created by the RPS standards of 36 GW by 2030 (Waite, 2017).

Utility-Scale PV Economics and Site Suitability

The definition of utility-scale PV system size varies; some studies define utility-scale as ≥ 1 MW (Ong, Campbell, Denholm, Margolis, & Heath, 2013).Other studies use a much larger system size of ≥ 5 MW (Barbose & Dargouth, 2016). Another way to define utility-scale PV is by how the power generated is delivered to the market. If power is sold directly to a load-serving entity, either to an investor-owned utility, municipally-owned utility or a CCA, through a power purchase agreement (PPA), then it qualifies as utility-scale (Donnelly-Shores, 2013). For the purposes of this report, a much more modest 0.5 MW size will be used to define utility-scale PV. One reason for this choice is that, as the Schatz Energy Research lab noted in its Re-Power Humboldt report "Humboldt County is not well suited to large, utility-scale photovoltaic…installations" because "most of the flat areas are in the foggy coastal parts of the county" (Schatz Energy Research Center, 2013). RCEA has indicated that it would be willing to enter into a PPA to directly purchase power to meet its goals from smaller systems down to 0.5 MW (Engel, 2017).

There are two common methods for estimating the land-use requirements for a utility-scale solar PV installation. One is in terms of required acres per installed megawatt of AC power (acres/MW AC), and the other is in terms of required acres per generated gigawatt-hour of AC power (acres/GWh/year) (Macknick, Beatty, & Hill, 2013). The National Renewable Energy Lab (NREL) estimates that small utility-scale, fixed-axis PV arrays require 5.5 acres/MW AC of direct area while the total area required is 7.6

acres/MW AC. Direct area was defined as the direct footprint of the installed PV panels, inverters, transformers, access roads and service buildings while the total area is defined as all the land that is enclosed by the site boundary (Ong, Campbell, Denholm, Margolis, & Heath, 2013). This study will use the metric based on installed capacity, acres/MW, and will default to the total direct area required of 7.6 acres/MW when referring to the land-use requirements of utility-scale PV installations. Based on this study's use of the cutoff for utility-scale PV at ≥ 0.5 MW, the minimum available area for a site to host a PV installation would be 3.8 acres.

There is ample evidence in the literature that the site assessment criteria selected for this study have significant impacts on utility-scale solar PV site suitability and economics. Available solar resource measured in kWh/m^2/ day plays an important role in utility-scale PV plant performance. Low solar resource will increase the levelized cost of energy (LCOE), defined as the lifetime costs of a project divided by the lifetime energy production calculated at the present value (Masters, 2013). LCOE is a useful metric when comparing disparate technologies or identical technologies operating under varying conditions. LCOE includes capital costs, fuel costs, and operations and maintenance costs; but since PV plants do not have fuel costs, the available solar resource has a significant impact of the LCOE of a PV plant (US Energy Information Administration, 2017). One NREL study modeled a commercial-scale PV plant in California with 6 kWh/m^2/ day and compared this to a site in Pennsylvania with 4 kWh/m^2/ day. The site with the greater solar resource had an LCOE of about $0.15/kWh while the low solar resource site had an LCOE of approximately $0.24/kWh (Macknick, Lee, Mosey, &

Melius, 2013). Due to the strong effect that available solar resource on the LCOE of a PV plant it is one of the key criteria being used to rank the suitability of potential PV sites in this study.

A key question when assessing sites for their suitability for utility-scale PV installations is the utility grid hosting capacity. Utility grid hosting capacity can be defined as the amount of PV that can be interconnected to the utility grid without causing negative impacts to the existing distribution infrastructure (Palmintier, et al., 2016). The hosting capacity of the utility grid plays an important role as any required utility upgrades can pose significant costs to a utility-scale PV installation (Fu, Feldman, Margolis, Woodhouse, & Ardani, 2017). Accurately determining grid hosting capacity is a complex task requiring large amounts of data and computing power (Pacific Gas and Electric, 2015).

A general rule of thumb for California's investor owned utilities (IOUs) is the assumption that PV penetration levels above 15% require detailed studies and can pose threats to the functionality of the IOUs distribution system (Palmintier, et al., 2016). PV penetration level is defined in Equation 1 as follows:

Equation 1 PV Penetration (%)

$$PV\ Penetration\ (\%) = \frac{Installed\ PV\ Capacity\ (peak)}{Circuit\ Peak\ Projected\ Load}\ x\ 100$$

This definition of PV Penetration is widely used when assessing the effects of PV installation on grid functionality (Nguyen, et al., 2016). High PV penetration levels can cause a variety of grid functionality issues such as need for voltage regulation due to PV

system output variability, reverse power flow when PV generation outstrips on-site electrical loads, increased tap operations for transformers due to voltage variability, and a need to increase reactive power to compensate for traditional inverters (Palmintier, et al., 2016). Installing PV in an area with constrained grid-hosting capacity can result in costly utility distribution system upgrades. Based on a review of 100 Small Generation Interconnection Procedures (SGIP) for PV installations between 2 MW and 20 MW, one study found that 50% the SGIP studies identified the total cost for utility upgrades for interconnection were less than $133,000 per MW (Sena, Quiroz, & Broderick, 2014).

The distance to the utility sub-station is important as it can affect costs of utility upgrades at the utility feeder level. It is common to include distance to transmission lines or distance to utility substation in PV site assessments (Waite, 2017) (U.S. Environmental Protection Agency, 2015) (Khan & Rathi, 2014). Conductor upgrades on distribution feeder lines can be one solution to over voltages and thermal overloads caused by utility-scale PV systems; these conductor upgrades are most often given in terms of cost per foot of conductor (Sena, Quiroz, & Broderick, 2014). Pacific Gas & Electric's Unit Cost Guide provides a non-binding estimate of upgrades to its facilities that are commonly required for interconnection of generating facilities to their grid; the price for conductor upgrades is $120/ft (Pacific Gas and Electric , 2016).

To develop a utility-scale PV project, a developer must secure sufficient property rights to build, operate, and maintain the PV power plant (Humes & McLean, 2012). Land availability and land acquisition costs are important factors in utility-scale PV site selection because land must be purchased or leased for a period longer than the projects

debt coverage period, usually 15-20 years (International Finance Corportation, 2015). Developers often seek property that is vacant, degraded or otherwise has little alternative use to bring down the cost of land acquisition (American Planning Association, 2013).

Community Choice Energy

In September of 2002 the state of California adopted State Assembly Bill No. 117, allowing a new method of retail electrical delivery in the state known as Community Choice Aggregation (CCA). This system allows end-use electrical customers who live in the same community or jurisdiction to aggregate, or pool, their electrical demand and allows an “aggregator” to buy and sell power on behalf of the end-use customers (California Assembly Bill 117, 2002). In May of 2017, the majority of the residents of Humboldt County adopted a CCA program through the Redwood Coast Energy Authority’s (RCEA) Community Choice Energy (CCE) program (Redwood Coast Energy Authority, 2018). RCEA is a Joint Powers Authority whose members include Humboldt County, the cities of Arcata, Blue Lake, Eureka, Ferndale, Fortuna, Rio Dell, and Trinidad as well as the Humboldt Bay Municipal Water District. When RCEA launched its version of a CCA, it was the eighth county in the state to do so and the first rural county to do so; today, there are currently 14 operational CCA programs in California (CalCCA, 2017).

In a September 2016 meeting, the RCEA Board of Directors adopted ambitious goals for renewable power procurement in support of the CCE program. This has increased regional demand for locally produced renewable energy from sources like solar

photovoltaics (PV). RCEA has a goal of bringing 5 Megawatts (MW) of local, utility-scale, solar PV production under contract by 2018 and 15 MW by 2023 (Redwood Coast Energy Authority, 2016).

Weighted Criteria Matrix

A weighted criteria matrix is a decision-making tool that is used to assess project alternatives using criteria that are weighted by importance (Ouye, 2009). The use of a weighted criteria matrix can be valuable when considering many variables that do not all have the same importance. Weighted criteria systems facilitate decision making by allowing some variables to have more importance than others. This type of decision making process is referred to by a variety of names including weighted decision making, multi-criteria decision making or a prioritization matrix but all follow a similar basic process. (Dutweiler, 2008). The first step is to develop criteria that are important to the issue, decision or solution being considered. After criteria are chosen, a weight is assigned to each in relation to the importance of that criterion to the issue being considered. Finally, the weighted scores are totaled for the proposed options, and the final scores are compared and the options are ranked by their total weighted score (Kaplan, 2004).

Weighted criteria systems are used widely in business and government to rank priorities and to aid in the decision-making process. The University of Wisconsin System Board of Regents Office of Quality Improvement publishes a guide that advocates for the use of such a system across the many departments of the University of Wisconsin. The

approach is recommended when departments need to prioritize projects in situations where “the amount of work that needs to be done surpasses the resources available” (Rust & Thayer-Hart, 2012). This method assumes a list of standing projects to be completed; developing criteria for evaluating proposals is the first step in the process. Each criterion is then given a score from 1-9. The weighting process starts by placing all criteria in descending order of importance and assigning a weight to each criterion. Emphasis is put on a group approach that involves working in teams to score and weight projects. Final weighted scores are then compiled for each project considered and results are discussed.

The National Association of County & City Health Offices (NACCHO) is a public policy and advocacy group that focuses its efforts on promoting policies that benefit local health departments nationwide. One of the techniques they promote is the use of a prioritization matrix. A list of health care issues will be compiled and then given a score of one to three depending on how well the issue meets the selected criterion. The criteria scores are then weighted based on how important the criteria are to the rater. (National Association of County and City Health Officials, 2017).

A wide range of institutions use weighted criteria decision making to influence a wide variety of issues. The Department of Civil and Building Engineering at Loughborough University in the UK has developed such a system for analyzing alternative building systems. This study developed over 50 criteria for scoring building systems for housing construction. The criteria were then weighted by building professionals via an interview process. The authors of the study published their results as

a support system for builders faced with complex choices when considering alternative building techniques (Pan, Gibb, & and Dainty, 2008).

Another example of weighted decision making is the University of Iowa Health Care's prioritization matrix. This process emphasizes brainstorms for identifying problems and issues upon which to decide. This system suggests four criteria, frequency, importance, feasibility, and cost that are weighted between a value of one and zero and a scoring system of one to five. The decision-making method could be used to rank possible procedures or appropriate personnel (University of Iowa Hospitals and Clinics, 2006).

In addition to these examples of the use of weighted criteria matrices in academia and industry, there are also studies that use criteria-based analysis to inform utility-scale PV site selection. One study of optimal site selection for utility-scale PV power plants in India selected a list of criteria that included the available solar resource, availability of vacant land, accessibility to highways, distance from transmission lines, and site topography. The continuous values for each criterion were converted to a numeric value between one and nine. The numeric values were then added for the three regions of Rajasthan province that were studied. The total of the numeric values for all criteria were used to rank sites within the study area (Khan & Rathi, 2014).

In another study about optimal site selection methods for large scale PV power plants done in Nigeria, researchers studied ten local government areas (LGAs) in the state of Imo. Five criteria were used for ranking sites: global horizontal irradiation (GHI), available energy, local cost of energy, population, and population density. After data

were collected, each site's continuous data were ranked in ascending order and converted to a numeric value between one and ten. This score was then weighted according to the following scheme: cost of energy was given a weight of five, available energy was given a weight of four, GHI was given a weight of three, population density a weight of two, and population a weight of one. The numeric scores between one and ten were then multiplied by the weighting factor for each criterion. This allowed the study to report out which sites were optimal based on different criteria and to derive what the authors called a PV Site Suitability Ranking that ultimately ranks each site when all the criteria are considered (Jacob, Umoren, & Markson, 2016). These studies of PV site suitability, along with the EPA's Re-Powering America's Lands Initiative and Jacqueline Waite's *Land Reuse in Support of Renewable Energy Development*, have influenced and informed the methods that were developed for this current study of Humboldt County mill sites.

STUDY SITE

The study site for this research is Humboldt County, California, a rural county on the coast of northern California with a population of approximately 134,000 people and an area of over 9,240 square kilometers (U.S. Census Bureau, 2016). The county is rugged and remote; its southern border is 225 miles north of San Francisco. It is accessed from the south and north by one major highway, US 101. There are two state highways, CA 299 and CA 36, that connect the county to California's central valley and the I-5 corridor, but both close often in the winter due to snow and landslides and neither support large truck traffic (American Society of Civil Engineers, 2014). There are seven municipalities in the county that are home to almost half of the county's residents: Arcata, Blue Lake, Eureka, Ferndale, Fortuna, Rio Dell and Trinidad. While these cities account for almost half the population, they account for less 2 percent of the county's total area. The rest of the population lives in unincorporated areas that are administered by the county (Humboldt County, 2018).

The county's geographic features can pose many challenges to the development of utility-scale PV. The primary challenge is a modest solar resource due to its northern latitude ranging between 40° N and 41.5° N, and the high amount of rainfall, 40" to 100" per year, that the county receives annually. There is also a considerable amount of coastal fog around Humboldt Bay and along much of the coastal areas. Furthermore, as much as two-thirds of the county's land is covered in a variety of conifer and mixed hardwood forest (Humboldt County, 2018). The ubiquitous forest coverage county wide does not

yield many open large spaces suited to large scale PV. The county is also fairly mountainous, with flat lands found largely near the coast and in some river valleys, like Eel River Valley and the Hoopa Valley along the Klamath River. Flat, open lands along the coast can suffer from low solar resource due to coastal fog. River valley locations may contain open, flat lands that are also prime agricultural resource. Figure 1 shows Humboldt County's location as well as some of its major roads and cities.

Figure 1 Location and boundary of Humboldt County, California (map created by author with base map from Esri).

METHODS

The first step to perform an inventory and analysis of the utility-scale PV hosting potential of Humboldt County's former lumber mills is to identify and select research sites. After site identification and selection, data were gathered on each of the sites including information associated with, but not limited to, the six key assessment criteria (available area, available solar resource, grid hosting capacity, distance to the nearest transformer, land acquisition cost, and site compatibility). A more comprehensive list of data collected include: name, address, owner, zoning status, assessor's parcel number (APN), assessed value, lease rate (if known), and total acreage as well as utility feeder information like voltage, projected peak load, and existing and queued distributed generation. Finally, each of the six key criteria, were weighted based on relative importance to utility-scale PV development.

Site Selection

The site selection process began with research into industry publications and historic documents. The site locations listed were sometimes vague and reviewing aerial photography, satellite images or newspaper photos was often useful in making a determination of what sites were formerly mill sites. This was also complicated by the existence of many businesses listed as "mills" that were not lumber mills as we know them today. Most typically these were shingle mills that did not require large amounts of

area or power to conduct their activities. These smaller mills were not included in the research sites.

From 1999 to 2009 the United States Department of Agriculture's Forest Product's Lab published a semi-annual report on softwood sawmills in the United States and Canada. The report describes the production capacity of softwood mills in the US and Canada including information on timber availability, cost and product diversity. The bulk of this report lies in Appendix A, a detailed inventory of lumber mills, their location, and annual production volumes in cubic meters. The appendices contain a section titled *Northern California Softwood Roundwood Inventory and Softwood Sawmill Capacity*, and the map and inventory tables provide company names and the cities in which the mills are located and lumber production volumes over a five-year span. They also include a listing of mills that had closed in the prior five-year period. This series of reports was used to locate currently operating mills and recently closed mills. Over the ten years that the document was published, the number of active lumber mills in Humboldt County went from 12 mills in 1999 to four in 2009 (Spelter & McKeever, 1999) (Toth, Spelter, & McKeever, 2009).

The Humboldt Room at Humboldt State University (HSU) contains excellent historical resources that were useful in identifying older mill sites. Between 1958 and 1965, the Greater Eureka Chamber of Commerce published an annual publication titled *Directory of Lumber and Forest Products in Humboldt County, California*. In 1965, the directory listed over 40 lumber mills and 4 pulp mills operating in the county. This

resource is extensive; however, the details are minimal, mostly listing mill owners' names and mailing addresses along with the mills annual production in board feet.

A third source that proved invaluable in identifying Humboldt County mill sites was Andrew Whitney's 2010 master's thesis *An Inventory of Brownfields in Humboldt County, California.* This work contains a list of the mill sites, along with a list of the APNs associated with them, that the author had identified while cataloging the county's Brownfield sites.

Old photographs and newspaper articles available in HSU's Humboldt Room were helpful for putting names and places together. Aerial photographs and satellite imagery were also used to visually identify impacted lands that were once likely mill sites. Two additional sites were included in the study, the Blue Lake and DG Fairhaven biomass plants. The reason for this inclusion is that both sites have similar characteristics to mill sites and both plants were idle at the time this study began. The Fairhaven site has since restarted operations but its future is uncertain. Ultimately, sites that were identified were recorded and all parcels associated with the sites were cataloged by APN using the Humboldt County web GIS application. A shapefile of Humboldt County parcels was downloaded from the County's web site, and the parcels identified with mill sites were selected using the "Select by Attributes" tool in ArcMap (Esri, 2017) using County APNs. The selected parcels were then exported to a separate shapefile titled "research sites" that was used for identifying the former mill sites This shapefile of qualified research sites was also used for assessing each site's Utility-scale PV hosting potential.

Site Assessment

Once mill sites were identified, these research sites were assessed and data were gathered following a set of utility-scale PV project pre-screening criteria, including available area, available solar resource, utility grid hosting capacity, land acquisition costs, environmental contamination, and land-use compatibility/zoning (International Finance Corportation, 2015) (U.S. Environmental Protection Agency, 2015) (Waite, 2017).

Available Area

The available area for PV development was estimated using spatial analysis conducted in ArcMap 10.4 (Esri, 2017). The "research site" shapefiles, containing parcel numbers and parcel boundaries that were created and identified as mill sites in the site selection process, were used as a starting point. For this research, available area was designated as land that was not occupied by trees, buildings, or bodies of water. Trees and bodies of water pose obvious obstacles to the installation of a PV project; buildings were not included in the definition of available area because the assessments were done remotely and the structural quality of buildings was impossible to assess. In some cases, rooftop installations could be a viable option and are an area where future research would be needed. These available areas were identified by adding a base map based on aerial photography under the "research site" shapefile layers. The available areas, minus trees, buildings, and bodies of water, were then hand-digitized as polygons; these polygons were exported as new shapefiles titled "available area." A new field titled "available

area" was added to the properties table of the new shapefile and the "Calculate Geometry" tool was used to calculate the area of the new polygons. The range of values for available area per site was 1.4 acres to 189.6 acres, these continuous values were then translated into assessment criteria scores as shown the Table 1 below.

Table 1 Translation of continuous values to criterion scores for available area.

Available Area (acres)	Assessment Criteria Value
0 - 38	1
37 - 76	2
77 - 114	3
115 - 152	4
153 - 190	5

Solar Resource

The solar resource was analyzed in terms of global horizontal irradiance (GHI). GHI is a measure of the amount of total solar energy hitting a horizontal surface; it is a combination of direct beam radiation and diffuse radiation caused by clouds, atmospheric scattering and reflection (Masters, 2013). NREL's Geospatial Data Science's 10-km data for GHI, measured in kilowatt hours per meter per day (kWh/m^2/day), for the lower 48 United States and Hawaii was downloaded, un-zipped and loaded into ArcMap. The national shapefile was clipped to the Humboldt County boundary. The symbology was changed to display a graduated color ramp based on annual average GHI. This file was exported as a new shapefile titled "solar resource". The results of this process can be seen in Figure 2 below.

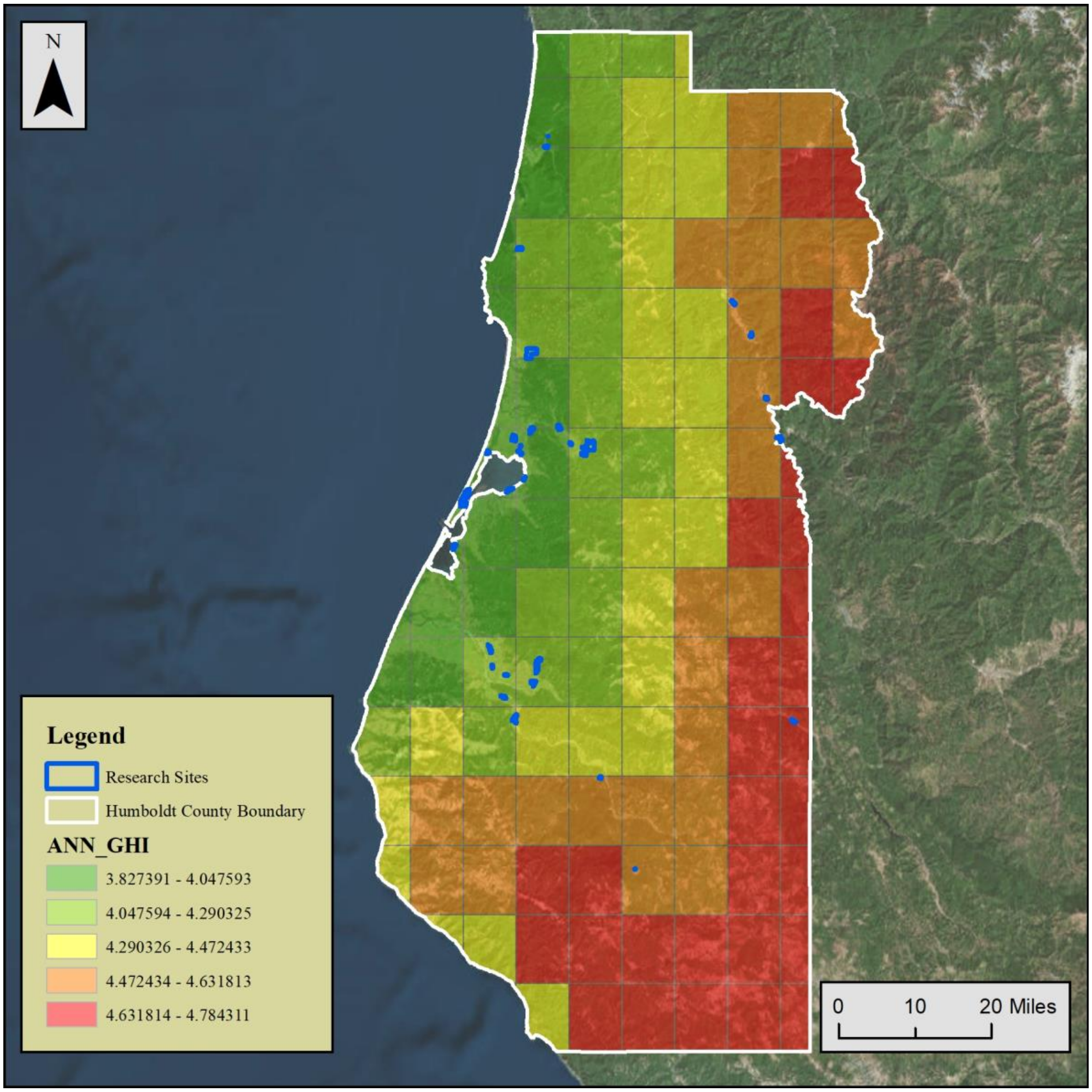

Figure 2 Humboldt County's solar resource in kWh/m^2/day (map created by author with base map from Esri).

The continuous values for global horizontal irradiance (GHI) were then translated to assessment criteria values as shown in Table 2 below.

Table 2 Translation of continuous to assessment criteria values for global horizontal irradiance.

Solar Resource (kWh/m^2/day)	Assessment Criteria Value
3.80 - 3.99	1
4.00 - 4.18	2
4.19 - 4.37	3
4.38 - 4.56	4
4.57 - 4.75	5

Utility Grid Hosting Capacity

Utility grid hosting capacity and the distance to the closest utility sub-station were estimated using Pacific Gas & Electric's (PG&E) Photovoltaic Renewable Auction Mechanism (PV RAM) map. This is an online tool that PG&E provides to the public to help PV developers plan projects with minimal impacts to the transmission and distribution system. The PV RAM map lists the capacities for several types of Distributed Energy Resources (DERs) at the zone, feeder, and substation level, in kW, that can be hosted with "minimal impacts" to their distribution system. Correspondence with PG&E via the Rule21Gen email indicate that minimal upgrades to the distribution system will be required at the given kW value. The value listed under "minimal impacts" for PV at the zone level from the PV RAM map will be used as an estimate of utility grid hosting capacity. This is not the final limit of the circuits capacity, with distribution upgrades greater amounts of photovoltaics could be installed.

The PV RAM map also provides utility distribution feeder identification name and number as well as values for nominal voltage, circuit capacity, circuit peak projected load, substation capacity, substation load, existing distributed generation and queued distributed generation. The PV RAM map, does not provide any method of exporting data in a tabular format like excel or .csv files. The data were "copy and pasted" from the PV RAM map into an excel file and were recorded for each site

The grid hosting capacity based on utility distribution system constraints is simply the sum of the hosting capacities across the sites. In this, case there were only 31 sites summed because some sites are located on a common utility feeder. Duplicates were removed because any installed capacity at one site will limit the availability on that distribution feeder. For example, the PG&E feeder named Blue Lake 1102 has a max capacity of 1,639 kW, but it hosts three sites, so the sum-total potential for those three sites is 1,639 kW; if utility-scale PV is installed at one site upgrades may be needed to utilize one of the others. The continuous values for grid hosting capacity in kW were translated to assessment criteria values as shown in Table 3 below.

Table 3 Translation of continuous to assessment criteria values for grid hosting capacity.

Hosting Capacity (kW)	Assessment Criteria Value
0 - 400	1
401 - 800	2
801 - 1200	3
1201 - 1600	4
1601 - 2000	5

<u>Distance to Utility Substation</u>

The PV RAM map shows the geographic location of all of PG&E's 12 kV substations. These locations were hand digitized as a point shapefile in ArcMap 10.4 titled "PG&E Substations" using an Esri satellite image as a base map for comparison to the PV RAM satellite image. The "Measure" tool in ArcMap was used to measure the distance from the center of each research site to the nearest PG&E transformer. The continuous values were translated to assessment criteria values as shown in Table 4 below.

Table 4 Translation of continuous to assessment criteria values for distance to substation.

Distance to Substation (meters)	Assessment Criteria Value
0 - 3,045	1
3,046 - 6,090	2
6,091 - 9,135	3
9,136 - 12,180	4
12,181 - 15,225	5

<u>Land Acquisition Costs</u>

The land acquisition costs were estimated by using a combination of assessed property value (used to estimate an expected lease rate) and advertised lease rates. Unfortunately, only two of the 35 research sites were listed for lease during the time this study was conducted. When published lease rates were available, these values were recorded. Assessed property value of each property and the date of the last assessment was obtained from the Humboldt County Tax Assessor's office. These assessed values

were then adjusted to 2017 dollars using the US Bureau of Labor Statistics Consumer Price Index (CPI) values with Equation 2 as follows:

Equation 2 Assessed value adjusted to 2017 dollars.

$$2017\ Value\ (\$) = Assessed\ Value * \frac{2017\ CPI}{Assessment\ Year\ CPI}$$

The known lease rates were converted to terms of dollars per acre per month ($/acre/month) and this value was compared to the 2017 adjusted assessed value of the same properties. The lease-to-total value ratio was calculated for both properties and the average of the two values as used to estimate a lease rate for each site with Equation 3 as follows:

Equation 3 Calculation used for estimated lease rate.

$$Estimated\ Lease\ Rate = 2017\ Assessed\ Value * \frac{Known\ Lease\ Rates}{Total\ Assessed\ Value}$$

Table 5 below shows the range of values for land acquisition costs and their assessment criteria values.

Table 5 Translation of continuous to assessment criteria values for cost of land acquisition.

Land Acquisition Cost (dollars/acre/month)	Assessment Criteria Value
0-400	1
401-800	2
801-1200	3
1201-1600	4
1601-2000	5

Site compatibility index

A site compatibility index was developed for each site based on zoning status, ownership, and status as a Brownfield or EPA re-development site. Ownership data were obtained from the Humboldt County Tax Assessor's office and were evaluated in two ways. Ownership "type" refers to whether the property is in private ownership or public/municipal ownership. Public/municipal ownership is assumed to be more compatible with utility-scale PV development because public entities can generate revenues through lease rates for properties that are often otherwise vacant. In addition, if the site is known to be contaminated or a designated EPA Brownfield, public entities would be eligible for any state or federal clean-up funds available. Ownership "quality" refers to whether the ownership of a site is unified, meaning one entity owns the entire site, or whether the ownership a site is divided among multiple entities. Sites with divided ownership are assumed to pose greater barriers to development than sites with unified ownership.

Zoning status was obtained from the Humboldt County parcel shapefile used in site selection. Sites zoned vacant industrial, heavy industrial, light industrial, or commercial were rated as more compatible with utility-scale PV development. Sites that are zoned for agriculture, timber production, rural, rural residential and sites in the coastal dependent zone were rated as less compatible.

The EPA's RE-Power America web site was used to identify ten of the former mill sites as Brownfield sites. Andrew Whitney's *An Inventory of Brownfields in Humboldt County, California* was also useful in identifying contaminated sites. Another

excellent source of information on contamination at former mill sites is Humboldt Baykeeper, a non-profit organization that focuses on environmental and water quality issues. Sites that have been designated as an EPA Brownfield, or otherwise have been identified as a contaminated site, are deemed less compatible if contamination levels are known to be dangerous.

The site compatibility index is simply a score from one to five. All sites start with one point. One additional point is added for public ownership, unified ownership, compatible zoning and if the site is not contaminated. Starting at one, with four possible points to allocate, maps these to a score from one to five, matching the other criteria. The process of scoring and weighting the scores are discussed below. The scoring process for the site compatibility index is can be seen in Table 6.

Table 6 Categories and scoring for the site compatibility index.

Unified Ownership	Zoning	Contamination	Public Ownership
1=Unified 0=Divided	1=Compatible 0=Incompatible	1=Uncontaminated 0=Contaminated	1=Public 0=Private

Weighted Criteria Matrix

A weighted criteria matrix was developed to analyze and rank the results of several key criteria that would affect the utility-scale PV hosting capacity of each site. Six criteria from the site assessment were chosen to be incorporated into the matrix. After the data were collected for each category, the ranges of continuous values were divided into five bins of assessment criteria values from one to five. Individual values for each

criterion were then scored between one and five depending on the binned results for the respective site. The exception to this process was the site compatibility index which was already on a scale of one to five by design as described above.

After the data were translated to a score of one to five, the scores were weighted based on the relative importance of each characteristic with respect to the utility-scale PV hosting capacity of each site as shown in Table 7.

Table 7 Criteria and weights used in the weighted criteria matrix.

Criterion	Available Area (acres)	Solar Resource ($kWh/m^2/day$)	Grid Hosting Capacity (kW)	Substation Distance (m)	Land Acquisition ($/acre/month)	Site Compatibility Index
Weight	3	4	3	2	2	1

The weight in this case will act as a multiplier to the original score derived from the raw data. There will be a range of weights from one to four. An example of this weighted criteria matrix can be seen in Table 8 below.

Table 8 Example of Weighted Criteria Matrix used for ranking sites.

Criterion	Available Area (acres)		Solar Resource ($kW/m^2/day$)		Grid Hosting Capacity (kW)		Substation Distance (meters)		Land Acquisition Cost ($/acre/mo.)		Site Compatibility Index	
Scoring Values	1-5		1-5		1-5		1-5		1-5		1-5	
Weight	3		4		3		2		2		1	
	Score		Score		Score		Score		Score		Score	
Site #	Raw	Wtd	Raw	Wtd	Raw	Wtd	Raw	Wtd	Raw	Wtd	Raw	Wtd
1												
2												
3												

For many locations, the available solar resource has the greatest effect on levelized cost of energy at a utility-scale PV plant over the project's lifetime (Macknick, Lee, Mosey, & Melius, 2013). Though this may be less true for Humboldt County due to modest differences in the solar resource from one location to another, this study gives this criterion a weight of four. Constraints due to lack of available area and limited utility grid hosting capacity can derail utility-scale PV projects (IFC, 2015); therefore, these criteria were given the weight of three. The estimated cost of land acquisition and the distance to the nearest utility distribution substation can both have significant effect on the project development costs and so these criteria were given a weight of two. The site compatibility index received a weight of one.

RESULTS

The site selection process yielded 37 final research sites across Humboldt County. Nineteen of the sites were within 10 miles of the coast. The largest concentrations of mills were in the Eel River valley, with nine sites (~24% of all sites), and around Humboldt Bay, with seven sites, (~19%). A map showing the locations of the research sites can be seen in Figure 2 below.

Figure 3 Location of 37 former mill sites in Humboldt County, CA (map created by author with base map from Esri).

Lesser concentrations were found in the Mad River valley with five sites, (~14%), and the Klamath-Trinity River Valley with four sites, (~11%). The former Hoopa Timber Company was divided into two separate sites, Hoopa Timber Co. 1 and Hoopa Timber Co. 2. This was done because the property was split evenly between two owners, one tribal and one private. This was the only case of divided ownership between only two parties that were clearly defined differently. The Korbel mill site was also divided for the purpose of this study. The mill was idled when this study started but was re-opened during the study period. There is a log deck that will likely not be utilized by the new operations and it is analyzed in this study as Simpson Timber Korbel Log Deck, separately from the Simpson Timber Korbel site.

Available Area

The total area encompassed by all sites was 3,000 acres based on the parcel boundaries; the total "available area" for PV as estimated in this study was 1,170 acres, meaning only about 38 percent of the total area was estimated to be useful for hosting a utility-scale PV installation. The mean available area was 32 acres with a minimum of 1.5 acres, a maximum of 190 acres. The 25th percentile as 11.5 acres and the 75th percentile was 39.5 acres. Using Equation 4 below, it is estimated that the 1,170 acres of available area could host approximately 148 MW of installed PV capacity.

Equation 4 Hosting capacity based on 7.6 acres/MW.

$$Hosting\ capacity = \frac{\sum_{i=1}^{n} Available\ Area\ (acres)}{7.6(\frac{acres}{MW})}$$

Based on the average area of 32 acres, a typical site in this study could host about 4 MW of utility-scale PV capacity. An example of a typical site boundary, below in Figure 4, with available area shaded in blue, shows why the estimated available area is often significantly less that the total area of a former mill site.

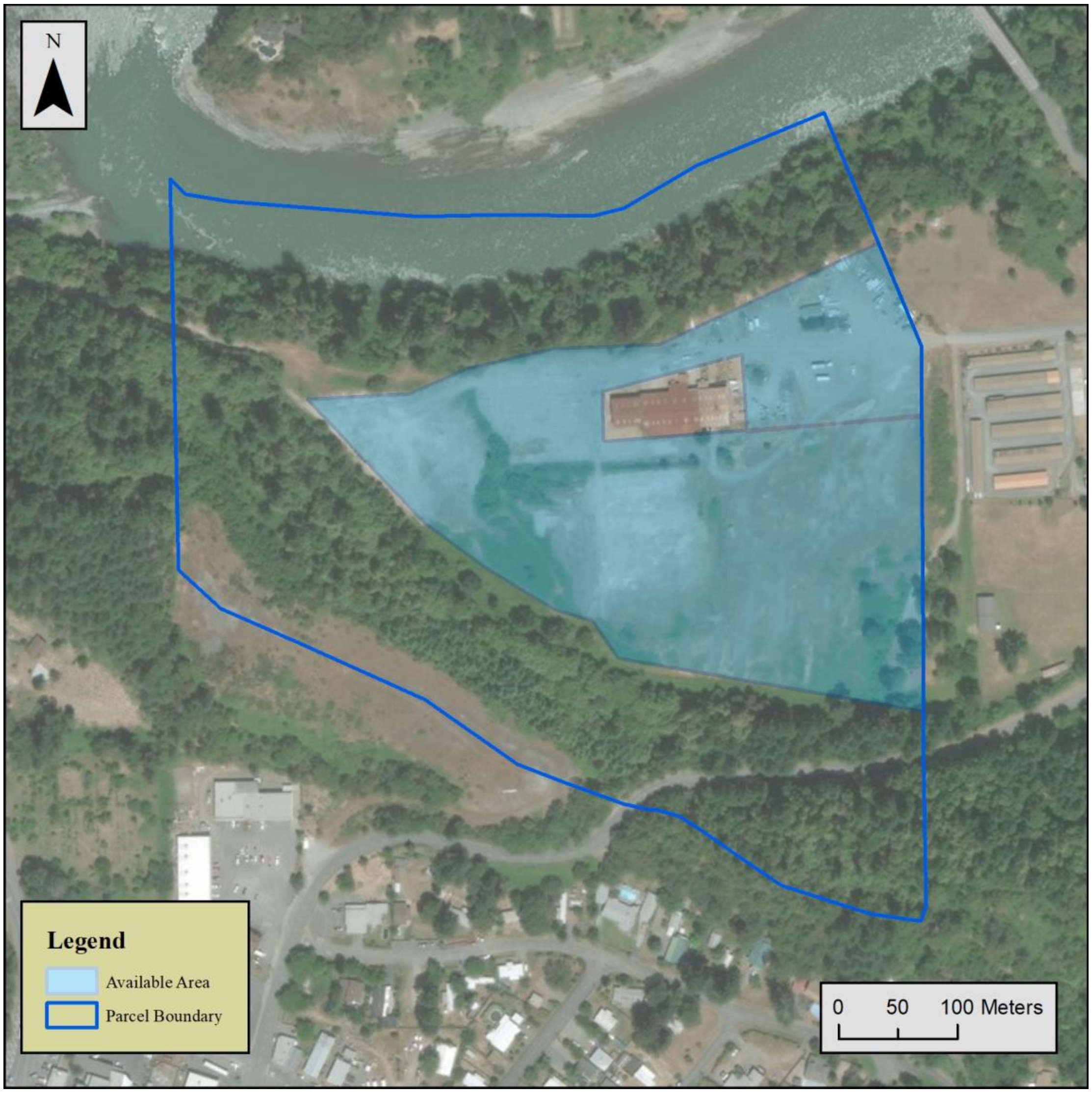

Figure 4 Former Pilot Mill site with parcel boundary and "available area" in blue (map created by author with base map from Esri).

Figure 5 below shows the results of the assessment of available area for all of the research sites.

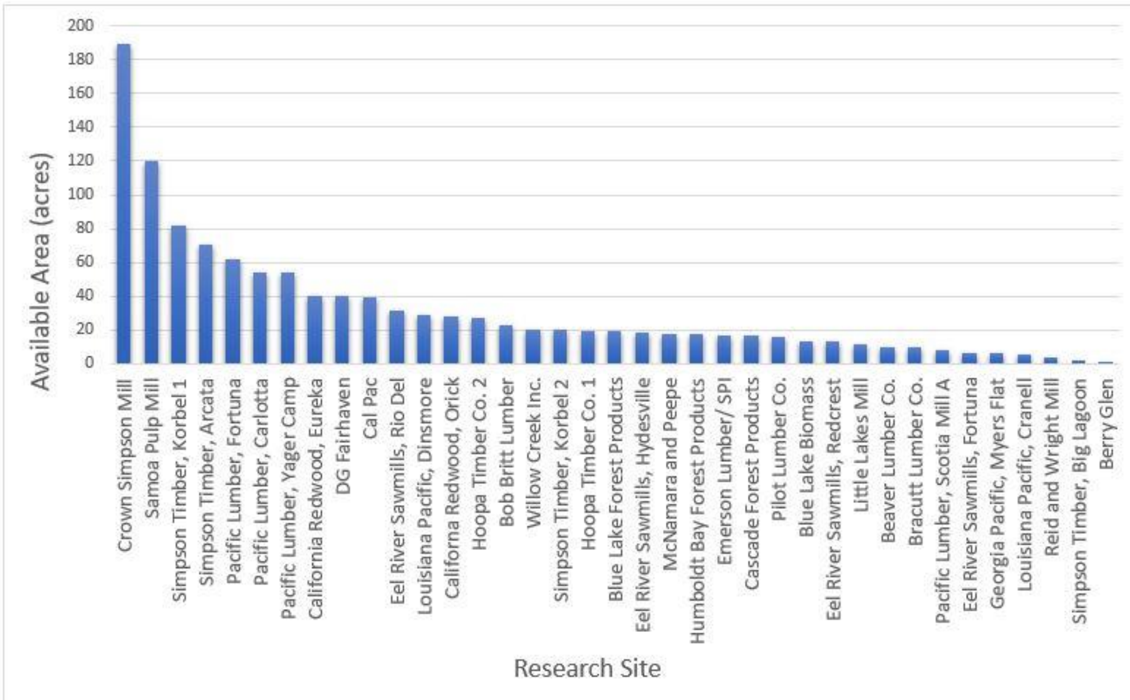

Figure 5 Research sites ranked left to right based on available area.

Multiplying each site's hosting capacity based on area times each site's specific irradiance and typical system losses of 14 percent and inverter efficiency of 96 percent, this could produce approximately 190 GWh/year, or about 23% of Humboldt County's annual electric consumption in 2016. Table 9 provides a summary of the total acres of available, the total PV capacity this area could host, the potential annual energy production and the rate of energy offset this could provide Humboldt County

Table 9 PV hosting capacity and production based on area constraints.

Total Area (acres)	Total Hosting Capacity (MW)	Potential Annual Energy Production (GWh)	Humboldt County Energy Offset (%)
1167	148	188	23

Solar Resource

The available solar resource across the research sites ranges from a low of 3.83 $kWh/m^2/day$ at several of the coastal sites to a high of 4.72 $kWh/m^2/day$ at the former Louisiana Pacific mill site in Dinsmore. The mean solar resource across the study area was 4.13 $kWh/m^2/day$, the 25th percentile was 3.93 $kWh/m^2/day$ and the 75th percentile was 4.15 $kWh/m^2/day$. Figure 6 shows the results of the solar resource assessment for all the research sites.

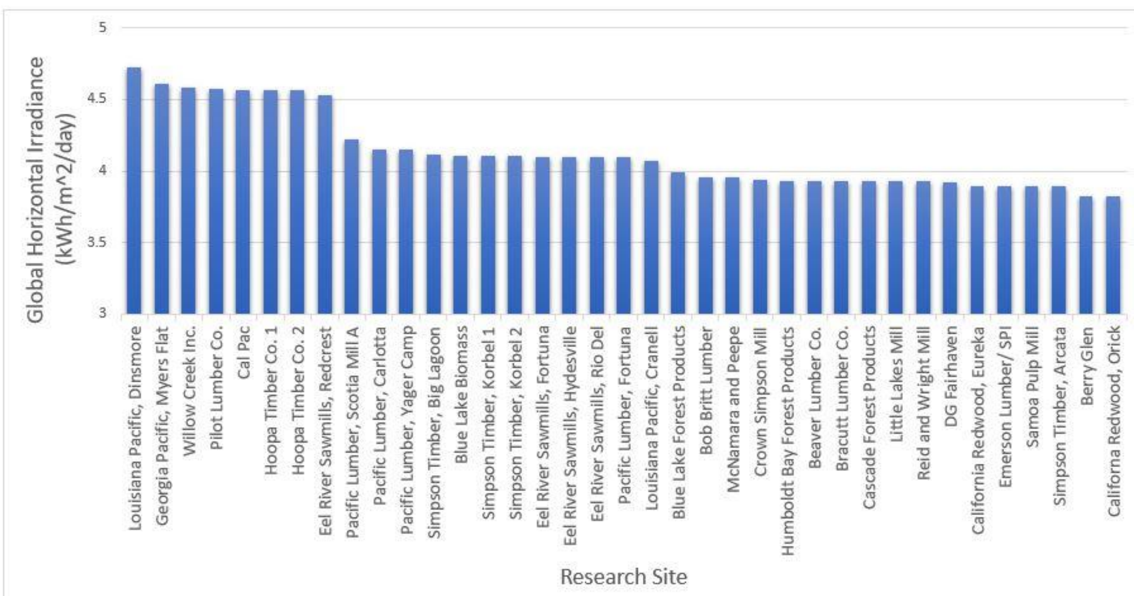

Figure 6 Research sites ranked left to right based on solar resource.

Grid Hosting Capacity

The values for "minimal impacts" for PV installations from the PV RAM map were a low of 46 kW at the former Simpson Timber mill in Big Lagoon to a high of 1693 kW for several sites on PG&E's Blue Lake 1102 feeder. The mean hosting capacity for the 37 sites is 650 kW, the 25th percentile was 256 kW and the 75th percentile was 867 kW. The total utility-scale PV hosting capacity based on the "minimal impacts" category for PV in PG&E's PV RAM map was calculated by summing the capacities of the individual sites. Six of PG&E's distribution feeders hosted more than one research site. Duplicates were removed because any installed capacity at one site will limit the availability on that distribution feeder. The 37 sites studied could host almost 18 MW of PV installed with "minimal impacts" to the utility distribution grid. Figure 7 shows the grid hosting capacity for all sites.

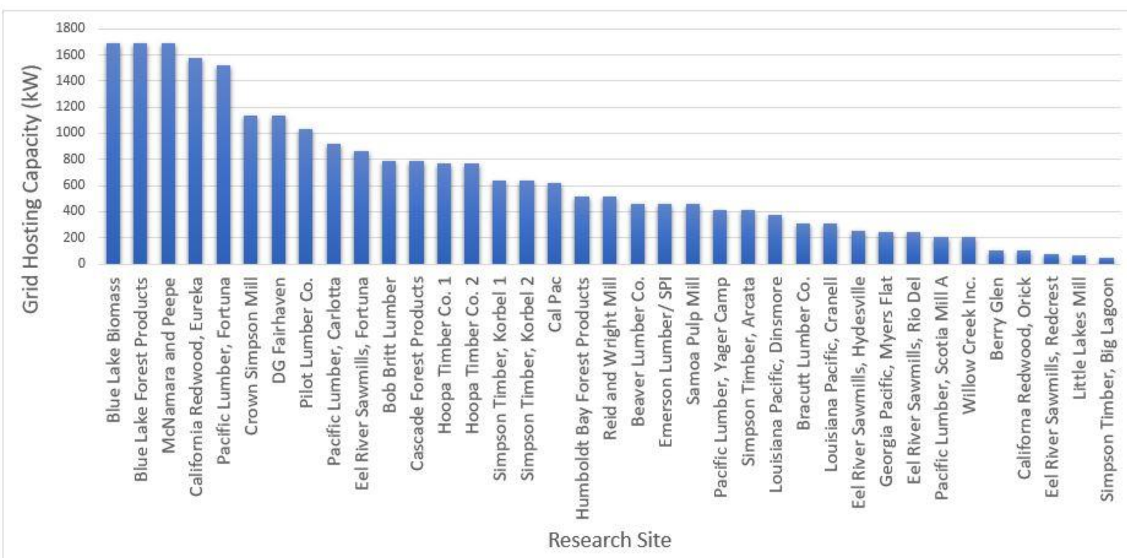

Figure 7 Research sites ranked left to right based on utility grid hosting capacity for PV.

Again, based on the average irradiance of 4.10 kWh/m^2/day and typical system losses of 14 percent and inverter efficiency of 96 percent, this could produce approximately 22 GWh/year. The total hosting capacity, average hosting capacity, the potential power that could be generated and the percentage of Humboldt County's annual energy consumption that could be offset are presented in Table 10 below.

Table 10 PV Hosting capacity and energy production based on grid constraints.

Average Hosting Capacity (MW)	Total Hosting Capacity (MW)	Potential Annual Energy Production (GWh)	Humboldt County Offset (%)
0.650	17.7	22	3

Distance to Substation

The distance from research sites to the nearest utility substation ranged from a low of 100 meters for the DG Fairhaven biomass plant, to over 15,000 meters for the Eel River Sawmills site in Redcrest. The minimum distance from research site to transformer was 100 meters, the maximum was 15,224 meters and the mean was 2,912 meters. The 25^{th} percentile was 1,151 meters and the 75^{th} percentile was 3,682 meters. Figure 8 below shows the results of the assessment of distance to the nearest utility substation for all 37 sites. Figure 9 shows the map of the research sites with the locations of PG&E's substations added to the map.

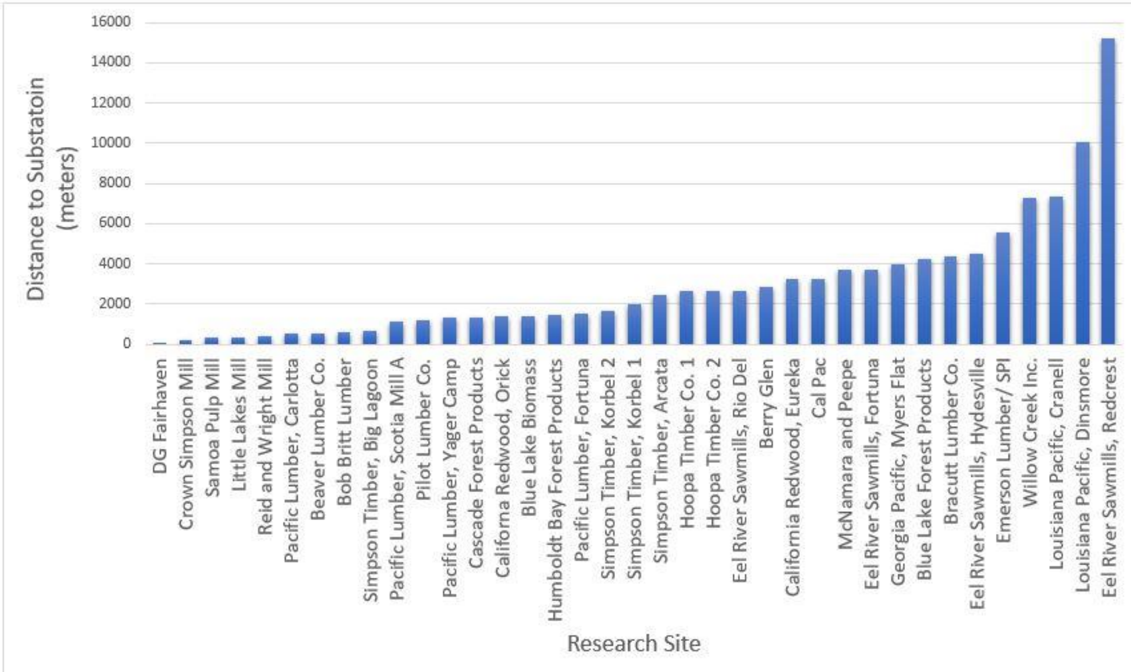

Figure 8 Research sites ranked left to right based on distance to utility substation.

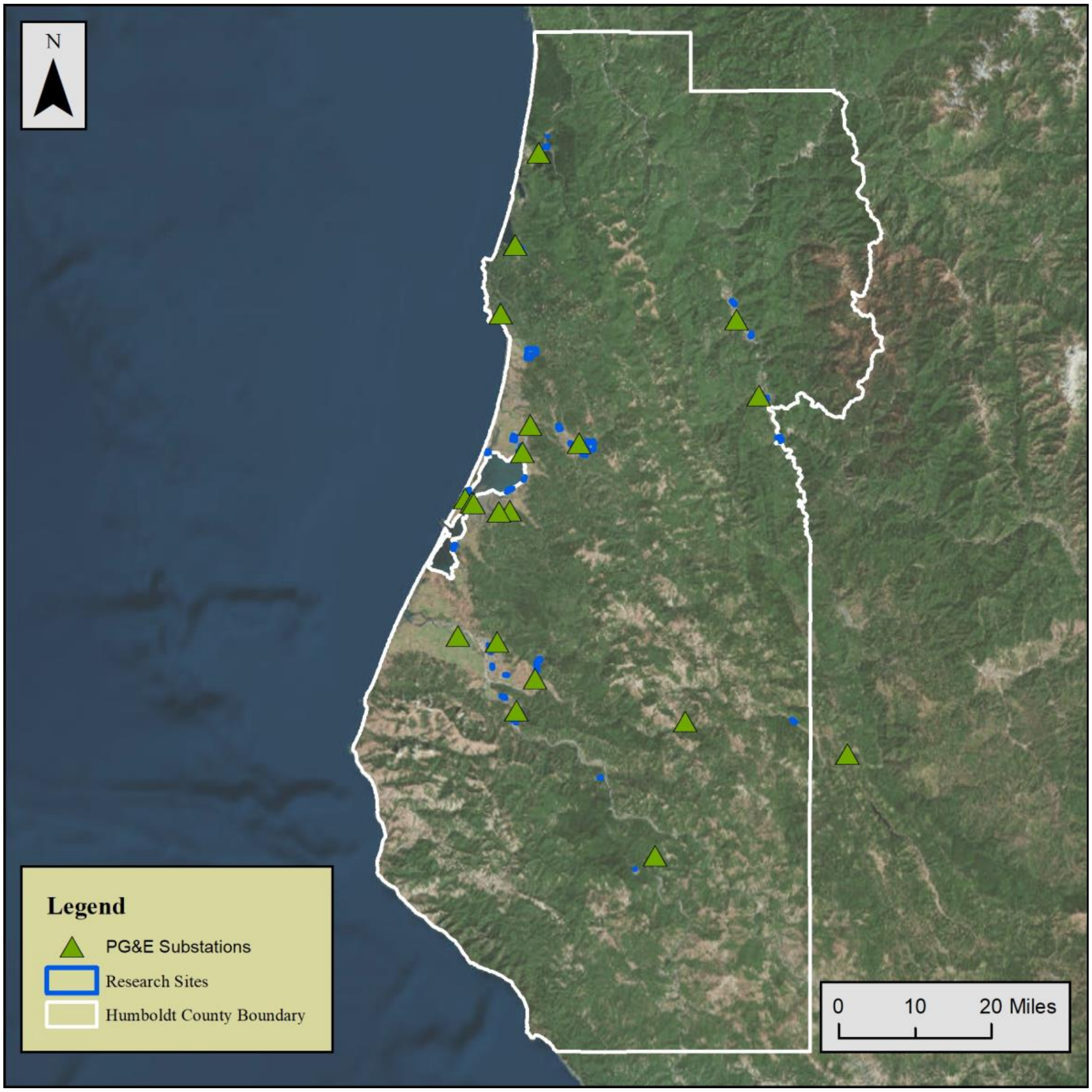

Figure 9 PG&E substation locations and research sites in Humboldt County, CA (map created by author with base map from Esri).

Land Acquisition Cost

The typical cost for land acquisition across all sites was estimated to be about $400/acre/month. The estimate for cost of land acquisition is based on assessed property value. Publicly owned properties are not assessed so they show up as no cost. This is an issue that will be addressed in the discussion section. Figure 10 shows the estimated cost for land acquisition for each site in terms of dollars/acre/month.

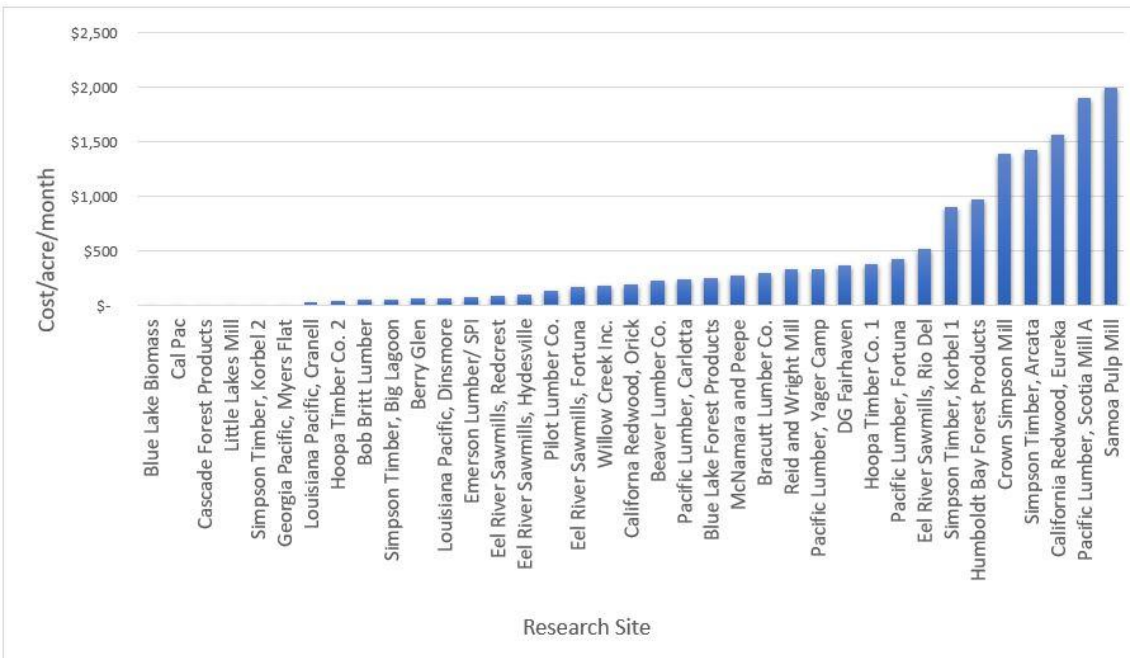

Figure 10 Research sites ranked left to right based on estimated cost of land acquisition.

Site Compatibility Index

Of the 37 sites, eight, (~22%) suffered from divided ownership; for the other 29 sites, all associated parcels were under unified ownership. Only five of the sites, (~14%),

were publicly owned. Nine of the sites, (~24%), were listed as EPA Brownfields on the Re-Powering Americas Land Initiative database. Most of the research sites, 29, (~78%) were zoned appropriately for industrial or commercial development, eight sites, (~22%) were on lands zoned rural or timber production zone. Figure 11 below shows the compatibility score for each site.

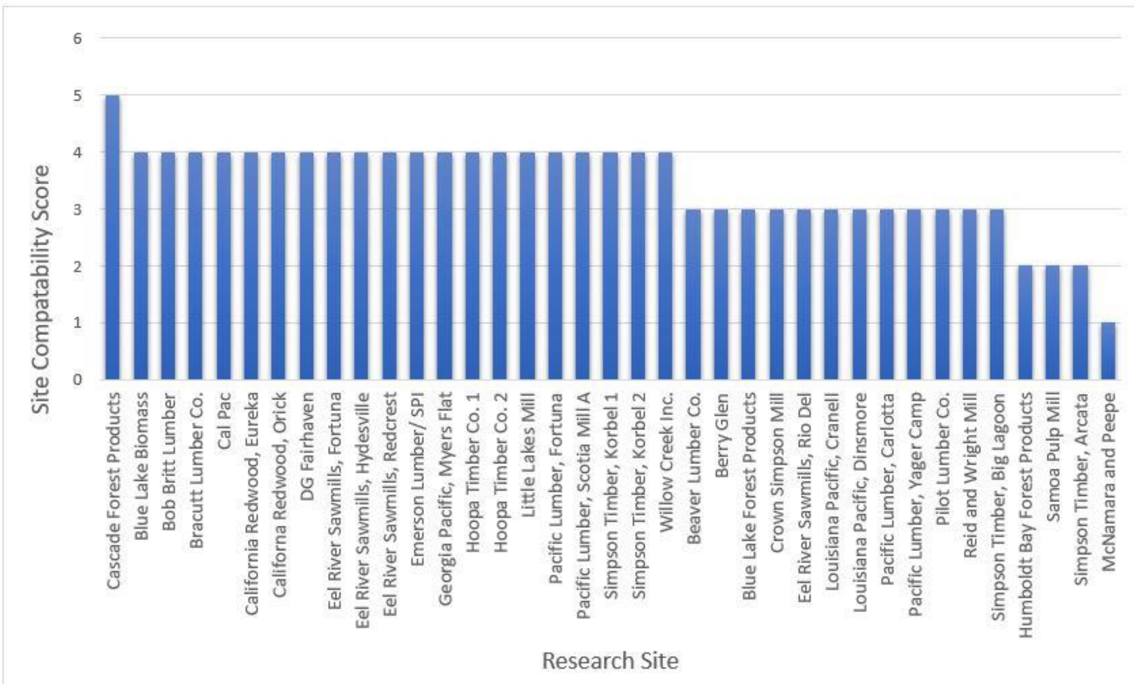

Figure 11 Research sites ranked left to right based on the score from the site compatibility index.

Site Ranking

The raw data for all six key criteria can be found in Appendix A. As discussed above in the Methods section, the raw data were translated to assessment criteria values between one and five. These data were then used to fill in the weighted criteria matrix. The completed weighted criteria matrix can be found in Appendix B of this document.

The weighting was applied and the process yielded the results in Figure 12 below ranking each site with a total weighted score for all criteria.

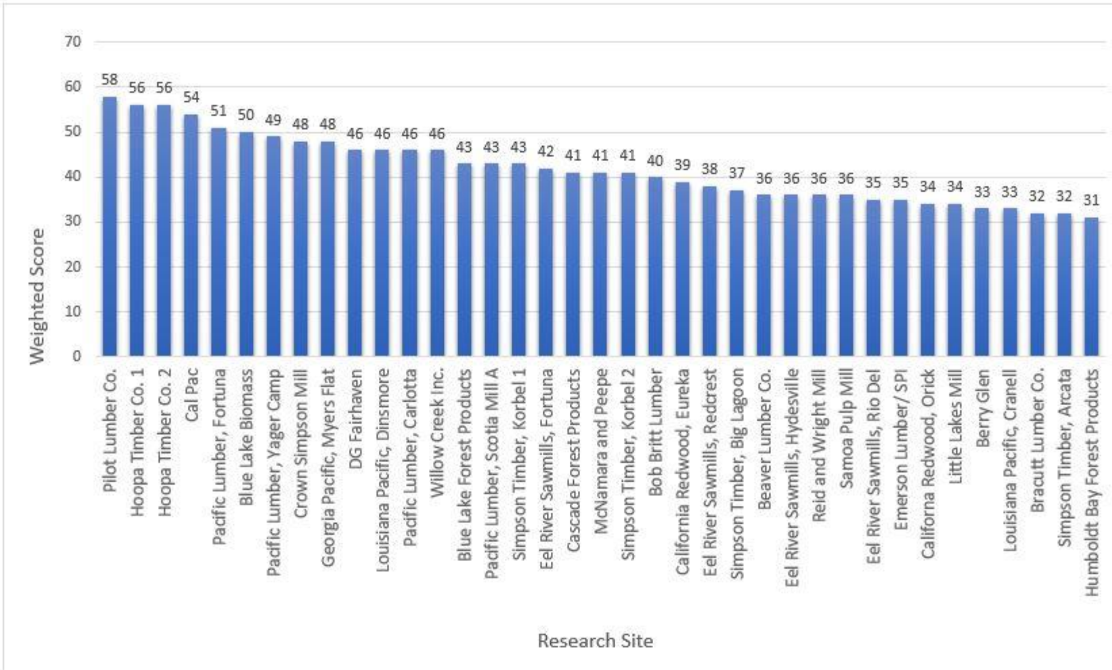

Figure 12 Sites ranked left to right based on weighted scores.

The unweighted scores were also used to rank sites. The unweighted scores produced very similar results. The top ten sites on each list are largely the same, both containing nine sites in common. Only one site, Cascade Forest Products, made the unweighted top ten but did not make the weighted top ten, moving from number nine on the unweighted list to 18 on the weighted list. Figure 13 shows the results of the unweighted scoring. The former Georgia Pacific site in Myers Flat is the only site to make the weighted top ten that did not make the unweighted top ten, moving from number 11 on the unweighted list to number nine on the weighted list Table 11 shows the comparison of top ten sites using the weighted and unweighted scores.

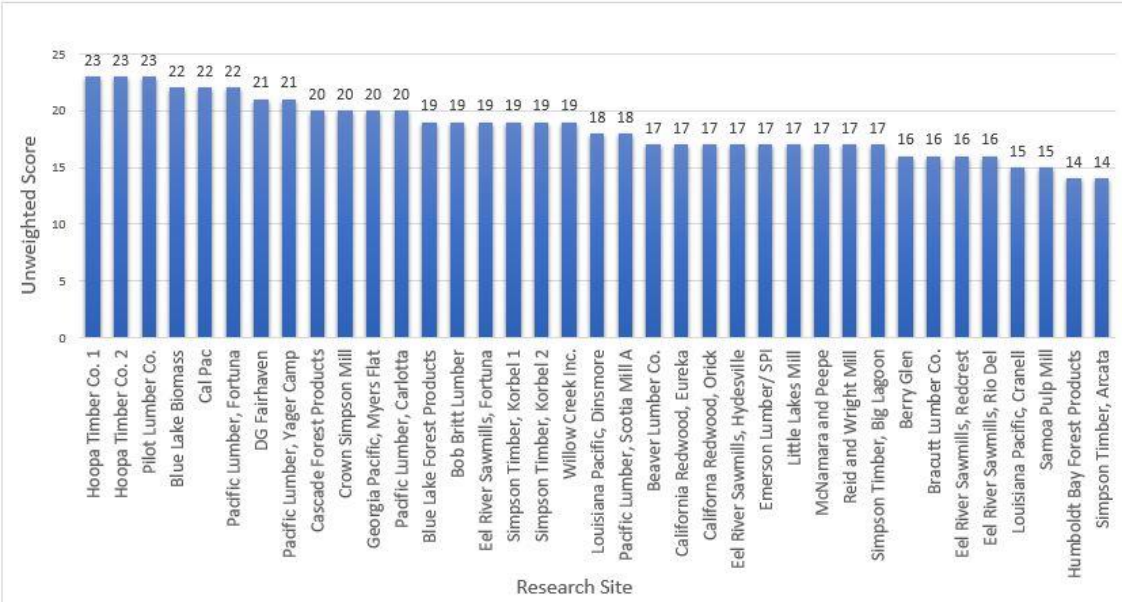

Figure 13 Research sites ranked left to right based on total weighted and unweighted score for each site.

Table 11 Ten most suitable PV hosting sites using weighted and unweighted scores, the darkened cells show the only sites not on both lists.

Unweighted Rank	Site Name	Unweighted Score	Weighted Rank	Site Name	Weighted Score
1	Hoopa Timber Co. 1	23	1	Pilot Lumber Co.	58
1	Hoopa Timber Co. 2	23	2	Hoopa Timber Co. 1	56
1	Pilot Lumber Co.	23	2	Hoopa Timber Co. 2	56
2	Blue Lake Biomass	22	3	Cal Pac	54
2	Cal Pac	22	4	Pacific Lumber, Fortuna	51
2	Pacific Lumber, Fortuna	22	5	Blue Lake Biomass	50
3	DG Fairhaven	21	6	Pacific Lumber, Yager Camp	49
3	Pacific Lumber, Yager Camp	21	7	Crown Simpson Mill	48
4	Cascade Forest Products	20	7	Georgia Pacific, Myers Flat	48
4	Crown Simpson Mill	20	8	DG Fairhaven	46

A complete list of all sites with weighted scores, unweighted scores and estimated annual energy production in MWh based on both area and grid constraints can be found in Appendix C.

DISCUSSION

There are several aspects of the methods and results of this study that are worthy of further discussion. Among those are the subjectivity of the weighting process and the site compatibility index, the difficulties in obtaining data and its implications on this work, and possible directions for future research. There is also a brief description of some of the potential benefits from pursuing a policy of redeveloping former mill sites as utility-scale PV hosting sites.

Sensitivity Analysis

The choices made in developing the methods for this study have impacts on the results that could be significant. To investigate this issue further, sensitivity analysis was performed to try to develop a better understanding of the weighting system and the site compatibility index. These two aspects of this study, the site compatibility index and the weighting system used to create the final weighted score for ranking sites, were fairly subjective and could have an effect on the results that would be worth understanding. A third area of sensitivity analysis will be to analyze the effects of choosing 7.6 acres/MW as the required land use area for utility-scale PV installations. This was a very conservative estimate that would have effects on the reported result of total hosting capacity based on available area.

Site Compatibility Index

The site compatibility index (SCI) was created to account for land use factors such as zoning and ownership status, and the assumptions will affect results. The data were analyzed without this criterion in to try to remove some of the subjective bias involved in its scoring. The same weights were applied to the remaining five criteria. Results from this process are shown in Figure 14 below.

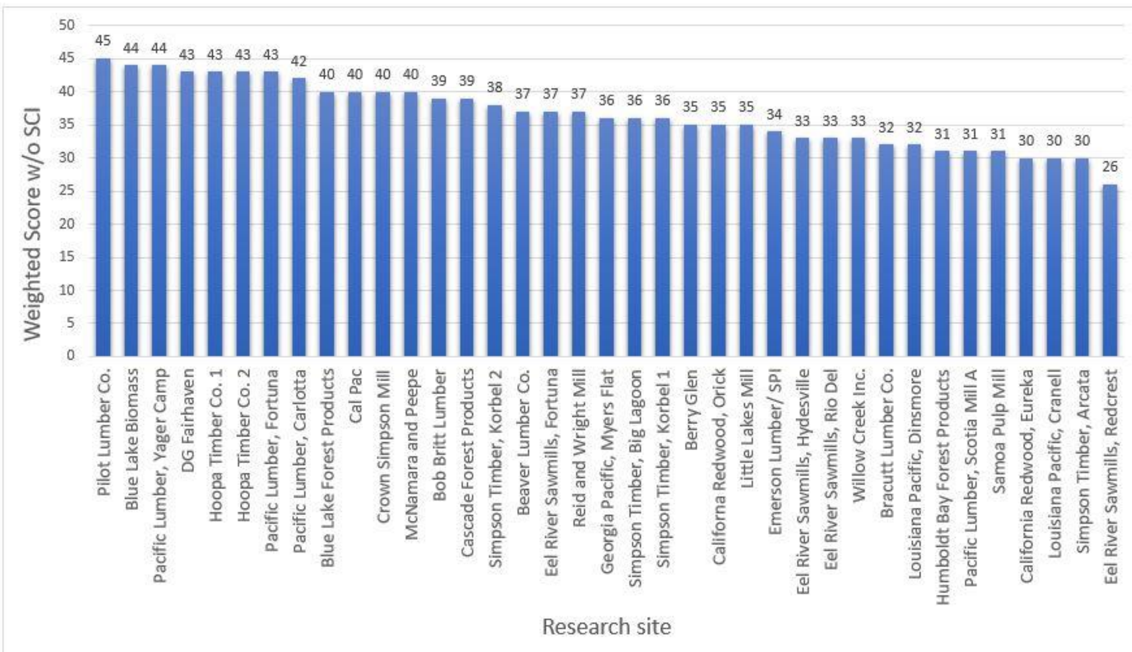

Figure 14 Research sites ranked left to right based on weighted scores of five key criteria.

The results from this analysis are very similar to the results of the weighted and unweighted scores. A comparison of the top ten sites without SCI shared eight of the top ten spots with the both the full weighted and full unweighted analyses, with the Pacific Lumber, Carlotta, and Blue Lake Forest Products sites making the top ten without SCI in place of Cascade Forest Products and the Crown Simpson Mill sites in the unweighted

analysis. The same sites, the Pacific Lumber, Carlotta and Blue Lake Forest Products mill sites replaced the Georgia Pacific site in Myers Flat and the Crown Simpson Mill from the weighted analysis. The comparison of top ten sites for weighted, unweighted and weighted without SCI scoring can be seen in the Table 12 below.

Table 12 Top ten sites based on weighted, unweighted and weighted without site compatibility index, darkened cells show sites not in common.

Site Name	Unweighted Score	Site Name	Weighted Score	Site Name	Total Score no SCI
Hoopa Timber Co. 1	23	Pilot Lumber Co.	58	Pilot Lumber Co.	45
Hoopa Timber Co. 2	23	Hoopa Timber Co. 1	56	Blue Lake Biomass	44
Pilot Lumber Co.	23	Hoopa Timber Co. 2	56	Pacific Lumber, Yager Camp	44
Blue Lake Biomass	22	Cal Pac	54	DG Fairhaven	43
Cal Pac	22	Pacific Lumber, Fortuna	51	Hoopa Timber Co. 1	43
Pacific Lumber, Fortuna	22	Blue Lake Biomass	50	Hoopa Timber Co. 2	43
DG Fairhaven	21	Pacific Lumber, Yager Camp	49	Pacific Lumber, Fortuna	43
Pacific Lumber, Yager Camp	21	Crown Simpson Mill	48	Pacific Lumber, Carlotta	42
Cascade Forest Products	20	Georgia Pacific, Myers Flat	48	Blue Lake Forest Products	40
Crown Simpson Mill	20	DG Fairhaven	46	Cal Pac	40

Weighting System

The weighting factors in the weighted criteria matrix are also subjective. The unweighted scores were also reported in the results. The similarity in the two sets of scores, with nine of the top ten scores in common, give some indication that the selected weights do not have a decisive effect on the results. As another way to test the influence

of the weighting system on the final result, a sensitivity analysis was performed in which the original weights were inverted, meaning items weighted one became four, those weighted two became three and so on. The original weights and the inverted weights can be seen in Table 13 below.

Table 13 Original weight and inverted weights used in sensitivity analysis.

Criterion	Available Area (acres)	Solar Resource (kWh/m^2/day)	Grid Hosting Capacity (kW)	Substation Distance (m)	Land Acquisition ($/acre/month)	Site Compatibility Index
Weight	3	4	3	2	2	1
Inverted weight	2	1	2	3	3	4

The results of the inverted weighting analysis are very similar to the original weighted scores and the unweighted scores. The inverse weighting shared nine of the top ten sites with the unweighted trial with the inverse weighting putting Bob Britt Lumber in the top ten in place of Crown Simpson Mill (both came in tenth in the respective analysis). The inverse weighting shared eight of the top ten with the weighted analysis, with Bob Britt Lumber and Cascade Forest Products making the top ten in the inverse weighting in place of the Georgia Pacific site in Myers Flat and the Crown Simpson Mill. The results of the inverted weights analysis are shown in Figure 15, below.

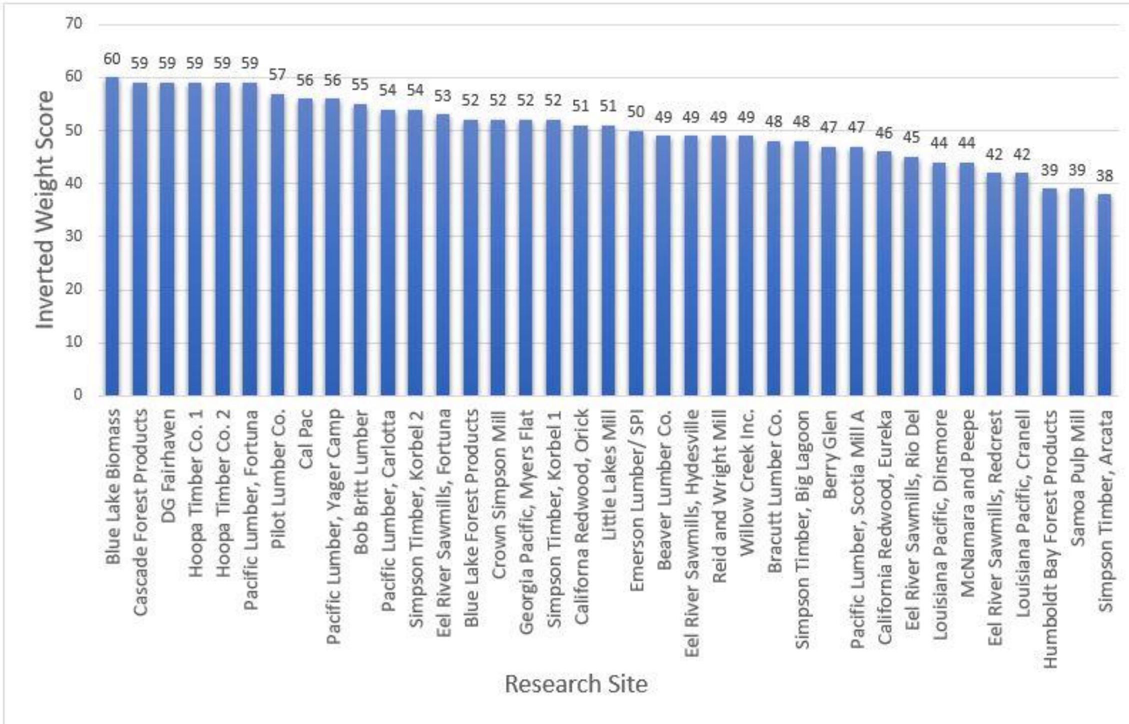

Figure 15 Research sites ranked left to right based on inverted weighting of criteria.

The different sensitivity analyses based on the data produced very similar results in terms of ranking sites. This similarity adds strength to the idea that these rankings are valid. The comparison of top ten sites for weighted, unweighted and inverse weighted scoring can be seen in Table 14 below.

Table 14 Comparison of top ten ranked sites based on weighted, unweighted and inverse weighted scores, darkened cells show sites that are not on all three lists.

Site Name	Unweighted Score	Site Name	Weighted Score	Site Name	Inverse Weighted Score
Hoopa Timber Co. 1	23	Pilot Lumber Co.	58	Blue Lake Biomass	60
Hoopa Timber Co. 2	23	Hoopa Timber Co. 1	56	Cascade Forest Products	59
Pilot Lumber Co.	23	Hoopa Timber Co. 2	56	DG Fairhaven	59
Blue Lake Biomass	22	Cal Pac	54	Hoopa Timber Co. 1	59
Cal Pac	22	Pacific Lumber, Fortuna	51	Hoopa Timber Co. 2	59
Pacific Lumber, Fortuna	22	Blue Lake Biomass	50	Pacific Lumber, Fortuna	59
DG Fairhaven	21	Pacific Lumber, Yager Camp	49	Pilot Lumber Co.	57
Pacific Lumber, Yager Camp	21	Crown Simpson Mill	48	Cal Pac	56
Cascade Forest Products	20	Georgia Pacific, Myers Flat	48	Pacific Lumber, Yager Camp	56
Crown Simpson Mill	20	DG Fairhaven	46	Bob Britt Lumber	55

Required Area

The National Renewable Energy Lab (NREL) estimates that small utility-scale, fixed-axis PV arrays require 5.5 acres/MW AC of direct area while the total area required is 7.6 acres/MW AC (Ong, Campbell, Denholm, Margolis, & Heath, 2013). This study used the more conservative estimate of 7.6 acres. If the direct area metric was chosen it would change the results of the hosting capacity of each site and the total hosting capacity of all sites based on available area. If Equation 5 below is applied a total of 1,167 acres of available area could host approximately 212 MW of installed PV capacity. Based on the average irradiance of 4.10 kWh/m^2/day and typical system losses of 14 percent and inverter efficiency of 96 percent, this could produce approximately 260

GWh/year, or about 33% of Humboldt County's annual electric consumption in 2016 (California Energy Commission, 2018).

Equation 5 Hosting capacity basedon 5.5 acres/MW

$$\frac{\sum_{i=1}^{n} Available\ Area\ (acres)}{5.5\ (\frac{acres}{MW})}$$

Based on the average area of 32 acres, a typical site in this study could host about 5.8 MW of utility-scale PV capacity. These results compare to the original results based on 7.6 acres/MW with a total hosting capacity of 148 MW capable of producing roughly 180 GWh/yr. (23% of annual consumption) with a typical site capable of hosting 4 MW.

Data Limitations

Finding accurate and up to date data was difficult for land acquisition costs. Only two of the research sites were listed for lease during the research for this study. The former Beaver Lumber Company site in Arcata was listed for lease for $2168 per month for approximately 11 acres. The former Samoa Pulp mill, now operated by the Humboldt Bay and Harbor Recreation and Construction District, rents out its yard space for $0.05/square foot/month. The information that was publicly available was assessed value of each parcel and the year of assessment. These data were used to put all assessed values in 2017 dollars. The assessed values were compared to the lease rates and used as the basis for the estimate of land acquisition costs. This process is flawed in many ways. The assessed values do not represent the actual market value of a property. The lease rates for some of the sites could be quite different than the assessed value as the assessed value

often includes the value of extensive mill equipment on site. This equipment would have no value to a solar PV developer, but old log decks that are now unused may be more appropriate for a PV installation. Ideally, actual lease rates would be used if available. Another flaw in this method is that all the sites that are owned by a municipality, tribe, or state agency are not assessed for tax purposes, so the cost of land acquisition for these sites is not representative of reality. In actuality, these sites may or may not be more affordable than a privately held piece of property. Public agencies often can benefit from getting lease income for otherwise unproductive lands and public agencies can leverage state and federal incentives to clean up contaminated lands. In these ways, public agencies often make good partners for PV development. However, the true cost of land acquisition from public agencies is not accurately reflected in the results.

Getting data about utility grid hosting capacity was also an issue. The PV RAM map does not provide circuit data in any tabular format, such as an Excel or .csv file, it does not allow data downloads in any format, and it does not provide any GIS shapefiles of their networks. A researcher or potential developer is forced to painstakingly copy and paste data into useful files and take screen shots of the location of feeders and substations to digitize them into a useable shapefile for GIS analysis. There is likely some random error in this process of transferring data. The PV RAM map was last updated on July 1, 2015. The results are based on a methodology that is being updated and more accurate results are expected to be available in 2018. Updating these values in this report would be a good next step for future research into these sites.

Potential Benefits

The potential benefits of utilizing former mill sites as renewable energy generating sites are three-fold. Utilizing former mill sites as PV hosting sites could facilitate Humboldt County's transition to local renewable electricity sources thereby reducing greenhouse gas emissions from electricity generation, reducing environmental impact from land conversion, and increasing economic productivity from vacant industrial lands. The potential benefits were analyzed assuming the entire 15MW of demand are met.

Based on site specific irradiance at each research site and typical system losses of 14 percent and inverter efficiency of 96 percent, 15 MW of solar PV could produce approximately 18.5 GWh/year. The life of a PV system is typically 25 years (PV O&M Working Group, 2016). This would result in approximately 463 GWh produced over the life of these installations. Table 15 below shows the parameters used to estimate lifetime system output of 15 MW of PV in Humboldt County.

Table 15 Parameters used to estimate lifetime output of 15 MW of PV.

Time Period	Installed Capacity (MW)	Solar Resource (kWh/m^2/day)	Days /year	Period of Operation (years)	System Losses	Inverter Efficiency	Lifetime System Output (MWh)
2020 - 2030	15	4.1	365	10	0.86	0.96	185,327
2030 - 2045	15	4.1	365	15	0.86	0.96	277,990

This power would offset electricity otherwise produced or procured by the local energy provider. This analysis assumes that this utility-scale PV power would replace RCEA's basic power mix which is 42% renewable, 40% large hydroelectric, and 18% unspecified sources of power and that by 2030 that mix will shift to 50% renewable, 40% large hydro and 10% unspecified in accordance with California's Renewable Portfolio Standards (Pacific Gas & Electric, 2017). In an inventory of its own greenhouse gas emissions, the state of California used a value of 427 kg CO_2e/ MWh of electricity from unspecified sources is California in 2014 (California Air Resources Board, 2016). The avoided emissions from unspecified sources will be analyzed using 427 kg CO_2e/MWh for all periods even though these unspecified sources will likely get cleaner over time. The analysis in this study assumed no emissions are produced by the renewable content or the large hydroelectric power. If the lifetime potential production of 463 GWh of electricity were to offset electricity that would otherwise be provided by RCEA, taking into account the increase in renewables in 2030, the potential lifetime greenhouse gas avoidance would be approximately 26,000 MT CO_2e. Table 16 below shows the estimation of greenhouse gas benefits from 15 MW of PV.

Table 16 Parameters used to estimate the greenhouse gas benefits of 15 MW of PV.

Electricity Source	Amount (%)	Emissions (kgCO2e/MWh)	Emissions Avoided (MTCO2e)
Renewables to 2030	42%	0	-
Renewables after 2030	50%	0	-
Large Hydroelectric	40%	0	-
Unspecified to 2030	18%	427	14,244
Unspecified after 2030	10%	427	11,870
Total avoided emissions			26,114

Another benefit of the reuse of former mill sites as PV hosting sites would be economic revitalization. Sawmills and other timber industry operations were once the engine of Humboldt County's economy, providing good employment in rural areas. Today many former mill sites are vacant properties that provide no economic benefit. One benefit of renewable energy technologies is that the jobs to energy ratio is high compared to other sources of electricity. For example, 1.25 jobs/GWh are typically created for solar PV versus 0.108 jobs/GWh for coal and 0.115 jobs/GWh for natural gas (Huntington, 2009). Another study estimates that, on average, utility-scale solar PV plants produce 0.87 jobs/GWh over the life of a project in the form of construction, installation, manufacturing, operations, and maintenance jobs (Wei, Patadia, & Kammen, 2010). Based on the low end of these estimations, 15 MW of utility-scale solar PV could

produce as many as 400 clean energy jobs. While many of these will be manufacturing jobs that will be out of the area, as many as half of the jobs created would be in construction and ongoing operations and maintenance. This would be a benefit to the rural economy of Humboldt County.

A final added benefit of using former mill sites as PV hosting sites would be the avoidance of any environmental impacts of land conversion that would be required to meet the 15 MW of local demand for solar PV if virgin pasture or agricultural lands were used. The total land area required would be about 120 acres. Typical environmental impacts at utility-scale PV plants include soil erosion, habitat loss and fragmentation and spread of invasive species (Macknick, Beatty, & Hill, 2013).

Future Research

This study provides useful information to future energy planners about the sites studied, however, further investigation will be required to determine their value as PV hosting sites. The solar resource would likely need to be verified by on site measurements using a pyranometer, often this type of data would be collected for a year to enable energy forecasts that are bankable and allow developers to get funding for projects (International Finance Corportation, 2015). The available area does not account for shading which is very difficult to assess remotely. Future research into these sites would benefit from an on-site shading analysis using a tool like the Solar Pathfinder. The available area may be reduced considerably by shading. This is especially true in some of the river valley locations and locations that have mature forest on or adjacent to the

property. Grid hosting capacity is another area where future research could be conducted. As mentioned earlier, PG&E's PV RAM map is scheduled to be updated sometime in 2018. At its best the PV RAM map is the product of a theoretical methodology that only estimates the hosting capacity of a given circuit. Most sites would likely require a detailed solar generation interconnection study. In PG&E territory, that study is called a Rule 21 Pre-application Report. These reports provide information such as total capacity, allocated capacity, queued capacity and available capacity at the substation level as well as nominal circuit voltage, line section peak load and minimum load estimates, limiting conductor rating and existing or known constraints at the proposed point of interconnection (Pacific Gas and Electric, 2018). These data as well as those provided by more in depth studies were not used for this analysis because of the cost associated with the studies but they would be justified if a site is being considered for development. Land acquisition costs will need to be assessed in terms of actual lease rates offered by owners. Future research would be warranted in the form of a survey of or solicitation to the identified land owners associated with the research sites to determine actual or potential lease rates.

CONCLUSIONS

Based on the results of this study, there is good evidence to support the idea that Humboldt County's former mill sites could provide enough hosting capacity to meet the local goal of installing 15 MW of utility-scale solar PV. The total available area summed across the 37 sites is approximately 1,170 acres, based on an average land use requirement of 7.6 acres/MW, roughly 148 MW of utility-scale PV could be hosted by the research sites in this study. The 37 sites studied could host almost 18 MW of PV installed with "minimal impacts" to the utility distribution grid based on the results of analysis of data from PG&E's PV RAM map. The local demand for utility-scale PV installations, represented by RCEA's stated goal of bringing 15 MW of local solar onto the grid by 2023, could be accommodated by Humboldt County's former mill sites using either criterion as a limiting factor.

Some sites have a greater potential for hosting utility-scale PV installations than others. This study attempts to rank the research sites in terms of the sites suitability for hosting utility-scale PV installations. The results of the ranking process from this study are susceptible to changes based on the priorities assigned to the criteria weighting process, however multiple analyses based on the data produced very similar results in terms of ranking sites. Based on the similarity of the results and the overlap of the top ten sites, it would make sense to focus future research on the fourteen sites that showed up in the top ten sites based on unweighted, weighted, inverse weighted or weighted without

site compatibility scores. There was a total of 14 sites that were ranked in the top ten based on one of the four scoring methods analyzed; they are presented in Table 16 below.

Table 17 The fourteen sites that most warrant future research.

Id	Site Name	Weighted Rank	PV Hosting Capacity (MW, based on 7.6 acres/MW)	Annual Generation Potential Limited by Area (MWh/year)
3	Blue Lake Biomass	5	1.8	2,210
4	Blue Lake Forest Products	9	2.5	3,070
5	Bob Britt Lumber	12	3.0	3,620
7	Cal Pac	3	5.2	7,160
10	Cascade Forest Products	11	2.3	2,660
11	Crown Simpson Mill	7 (T)	24.9	29,610
12	DG Fairhaven	8 (T)	5.3	6,220
18	Georgia Pacific, Myers Flat	7 (T)	0.8	1,110
19	Hoopa Timber Co. 1	2 (T)	2.6	3,550
20	Hoopa Timber Co. 2	2 (T)	3.6	4,900
26	Pacific Lumber, Carlotta	8 (T)	7.1	8,860
27	Pacific Lumber, Fortuna	4	8.2	10,080
29	Pacific Lumber, Yager Camp	6	7.1	8,860
30	Pilot Lumber Co.	1	2.1	2,890

Detailed descriptions and site maps for the sites in Table 16 can be found in Appendix D of this document. The results presented here strongly suggest that Humboldt County’s former mill sites should be considered as options for redevelopment as utility-scale PV hosting sites. Energy planners could use the results in this report to guide future research into selecting optimal sites to meet the regional demand for local, renewable energy generation from utility-scale solar PV installations. Pursuing a policy of

redevelopment of former mill sites as renewable energy generation sites could yield many environmental and economic benefits such as greenhouse gas reductions and local job creation and would avoid the impacts of developing utility-scale PV on otherwise pristine or productive lands.

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APPENDICES

Appendix A: Raw data

This appendix includes raw data for the 37 sites considered in the study (Table A.1).

Appendix A Raw data for six key criteria used in this study for all sites.

Id	Site Name	Avail. Area (acres)	Solar Resource ($kWh/m^2/day$)	Grid Hosting Capacity (kW)	Substation Distance (m)	Land Acquisition ($/acre/month)	Site Compatibility Index
1	Beaver Lumber Co.	10.3	3.93	463	550	$229.85	3
2	Berry Glen	1.4	3.83	101	2840	$67.13	3
3	Blue Lake Biomass	13.6	4.10	1693	1364	$-	4
4	Blue Lake Forest Products	19.4	3.99	1693	4250	$256.26	3
5	Bob Britt Lumber	23.0	3.96	793	580	$59.52	4
6	Bracutt Lumber Co.	10.2	3.93	309	4377	$294.45	4
7	Cal Pac	39.6	4.56	617	3240	$-	4
8	California Redwood, Eureka	40.6	3.90	1577	3218	$1,567.15	4
9	California Redwood, Orick	28.1	3.83	101	1362	$189.39	4
10	Cascade Forest Products	17.1	3.93	793	1333	$-	5
11	Crown Simpson Mill	189.6	3.94	1139	215	$1,396.67	3
12	DG Fairhaven	40.0	3.92	1139	100	$365.50	4
13	Eel River Sawmills, Fortuna	6.8	4.10	867	3682	$170.52	4
14	Eel River Sawmills, Hydesville	18.4	4.10	256	4500	$103.77	4
15	Eel River Sawmills, Redcrest	13.5	4.53	76	15224	$85.65	4
16	Eel River Sawmills, Rio Del	31.5	4.10	240	2676	$519.89	3
17	Emerson Lumber/ SPI	17.2	3.90	463	5547	$76.22	4
18	Georgia Pacific, Myers Flat	6.1	4.61	246	3978	$3.71	4
19	Hoopa Timber Co. 1	19.6	4.56	772	2636	$381.98	4
20	Hoopa Timber Co. 2	27.1	4.56	772	2636	$43.43	4
21	Humboldt Bay Forest Products	17.7	3.93	514	1468	$970.44	2
22	Little Lakes Mill	11.5	3.93	62	350	$-	4
23	Louisiana Pacific, Cranell	5.5	4.07	309	7371	$26.94	3
24	Louisiana Pacific, Dinsmore	28.5	4.72	372	10074	$68.15	3

Id	Site Name	Avail. Area (acres)	Solar Resource (kWh/m^2/day)	Grid Hosting Capacity (kW)	Substation Distance (m)	Land Acquisition ($/acre/month)	Site Compatibility Index
25	McNamara and Peepe	17.7	3.96	1693	3680	$280.71	1
26	Pacific Lumber, Carlotta	53.8	4.15	917	542	$244.51	3
27	Pacific Lumber, Fortuna	62.0	4.10	1520	1500	$424.95	4
28	Pacific Lumber, Scotia Mill A	8.1	4.22	206	1151	$1,909.23	4
29	Pacific Lumber, Yager Camp	53.8	4.15	412	1308	$335.02	3
30	Pilot Lumber Co.	15.9	4.58	1029	1217	$137.88	3
31	Reid and Wright Mill	3.8	3.93	514	425	$334.66	3
32	Samoa Pulp Mill	119.6	3.90	458	320	$2,000.00	2
33	Simpson Timber, Arcata	70.9	3.90	412	2473	$1,424.22	2
34	Simpson Timber, Big Lagoon	2.1	4.12	46	685	$60.56	3
35	Simpson Timber, Korbel 1	82.1	4.10	638	1965	$906.89	4
36	Simpson Timber, Korbel 2	20.2	4.10	638	1637	$1.31	4
37	Willow Creek Inc.	20.2	4.58	206	7290	$185.85	4

Appendix B: Weighted matrix Table B.1

This appendix shows the criteria, their weights and final weighted scores (Table B.1)

Appendix B Weighted matrix and final scores for all sites.

Criterion	Available Area (acres)		Solar Resource (kW/m²/day)		Grid Hosting Capacity (kW)		Substation Distance (meters)		Land Acquisition Cost ($/acre/month)		Compatible Use Index		Total Score
Scoring Values	**1-5**		**1-5**		**1-5**		**1-5**		**1-5**		**1-5**		
Weight	**3**		**4**		**3**		**2**		**2**		**1**		
	Score		**Score**		**Score**		**Score**		**Score**		**Score**		
Site #	**Raw**	**Wtd**	**Raw**	**Wtd**	**Raw**	**Wtd**	**Raw**	**Wtd**	**Raw**	**Wtd**	**Raw**	**Wtd**	
1	1	3	1	4	2	6	5	10	5	10	3	3	36
2	1	3	1	4	1	3	5	10	5	10	3	3	33
3	1	3	2	8	5	15	5	10	5	10	4	4	50
4	1	3	1	4	5	15	4	8	5	10	3	3	43
5	1	3	1	4	3	9	5	10	5	10	4	4	40
6	1	3	1	4	1	3	4	8	5	10	4	4	32
7	2	6	5	20	2	6	4	8	5	10	4	4	54
8	2	6	1	4	5	15	4	8	1	2	4	4	39
9	1	3	1	4	1	3	5	10	5	10	4	4	34
10	1	3	1	4	3	9	5	10	5	10	5	5	41
11	5	15	1	4	4	12	5	10	2	4	3	3	48
12	2	6	1	4	4	12	5	10	5	10	4	4	46
13	1	3	2	8	3	9	4	8	5	10	4	4	42
14	1	3	2	8	1	3	4	8	5	10	4	4	36
15	1	3	4	16	1	3	1	2	5	10	4	4	38
16	1	3	2	8	1	3	5	10	4	8	3	3	35
17	1	3	1	4	2	6	4	8	5	10	4	4	35
18	1	3	5	20	1	3	4	8	5	10	4	4	48
19	1	3	5	20	3	9	5	10	5	10	4	4	56
20	1	3	5	20	3	9	5	10	5	10	4	4	56
21	1	3	1	4	2	6	5	10	3	6	2	2	31
22	1	3	1	4	1	3	5	10	5	10	4	4	34

Criterion	Available Area (acres)		Solar Resource ($kW/m^2/day$)		Grid Hosting Capacity (kW)		Substation Distance (meters)		Land Acquisition Cost ($/acre/month)		Compatible Use Index		Total Score
Scoring Values	**1-5**		**1-5**		**1-5**		**1-5**		**1-5**		**1-5**		
Weight	**3**		**4**		**3**		**2**		**2**		**1**		
	Score		**Score**		**Score**		**Score**		**Score**		**Score**		
Site #	**Raw**	**Wtd**	**Raw**	**Wtd**	**Raw**	**Wtd**	**Raw**	**Wtd**	**Raw**	**Wtd**	**Raw**	**Wtd**	
23	1	3	2	8	1	3	3	6	5	10	3	3	33
24	1	3	5	20	2	6	2	4	5	10	3	3	46
25	1	3	1	4	5	15	4	8	5	10	1	1	41
26	2	6	2	8	3	9	5	10	5	10	3	3	46
27	2	6	2	8	5	15	5	10	4	8	4	4	51
28	1	3	3	12	4	12	5	10	1	2	4	4	43
29	2	6	2	8	4	12	5	10	5	10	3	3	49
30	1	3	5	20	4	12	5	10	5	10	3	3	58
31	1	3	1	4	2	6	5	10	5	10	3	3	36
32	4	12	1	4	2	6	5	10	1	2	2	2	36
33	2	6	1	4	2	6	5	10	2	4	2	2	32
34	1	3	2	8	1	3	5	10	5	10	3	3	37
35	3	9	2	8	2	6	5	10	3	6	4	4	43
36	1	3	2	8	2	6	5	10	5	10	4	4	41
37	1	3	5	20	1	3	3	6	5	10	4	4	46

Appendix C: Weighted and unweighted scores

This appendix provides a comparison of weighted and unweighted scores (Table C.1)

Appendix C Unweighted score, weighted score, and annual generation potential as limited by area and by grid constraints.

Id	Site Name	Unweighted Score	Weighted Score	Annual Generation Potential Limited by Area (MWh/yr.)	Annual Generation Potential Limited by Grid (MWh/yr.)
1	Beaver Lumber Co.	17	36	1,599	548
2	Berry Glen	16	33	220	117
3	Blue Lake Biomass	22	50	2,209	2,094
4	Blue Lake Forest Products	19	43	3,068	2,038
5	Bob Britt Lumber	19	40	3,618	946
6	Bracutt Lumber Co.	16	32	1,587	366
7	Cal Pac	22	54	7,160	848
8	California Redwood, Eureka	17	39	6,275	1,851
9	California Redwood, Orick	17	34	4,271	117
10	Cascade Forest Products	20	41	2,662	938
11	Crown Simpson Mill	20	48	29,610	1,352
12	DG Fairhaven	21	46	6,224	1,347
13	Eel River Sawmills, Fortuna	19	42	1,100	1,070
14	Eel River Sawmills, Hydesville	17	36	2,981	316
15	Eel River Sawmills, Redcrest	16	38	2,424	104
16	Eel River Sawmills, Rio Del	16	35	5,116	296
17	Emerson Lumber/ SPI	17	35	2,651	544
18	Georgia Pacific, Myers Flat	20	48	1,113	342
19	Hoopa Timber Co. 1	23	56	3,547	1,061
20	Hoopa Timber Co. 2	23	56	4,901	1,061
21	Humboldt Bay Forest Products	14	31	2,759	608
22	Little Lakes Mill	17	34	1,788	73
23	Louisiana Pacific, Cranell	15	33	888	379
24	Louisiana Pacific, Dinsmore	18	46	5,343	529
25	McNamara and Peepe	17	41	2,783	2,020
26	Pacific Lumber, Carlotta	20	46	8,858	1,146

Id	Site Name	Unweighted Score	Weighted Score	Annual Generation Potential Limited by Area (MWh/yr.)	Annual Generation Potential Limited by Grid (MWh/yr.)
27	Pacific Lumber, Fortuna	22	51	10,079	1,877
28	Pacific Lumber, Scotia Mill A	18	43	1,355	262
29	Pacific Lumber, Yager Camp	21	49	8,856	515
30	Pilot Lumber Co.	23	58	2,890	1,419
31	Reid and Wright Mill	17	36	594	608
32	Samoa Pulp Mill	15	36	18,471	538
33	Simpson Timber, Arcata	14	32	10,954	484
34	Simpson Timber, Big Lagoon	17	37	339	57
35	Simpson Timber, Korbel 1	19	43	13,367	789
36	Simpson Timber, Korbel 2	19	41	3,279	789
37	Willow Creek Inc.	19	46	3,676	284

Appendix D Detailed description of the 14 highest scoring sites.

This appendix includes detailed summary information and a site map for each of the 14 highest scoring sites included in this study.

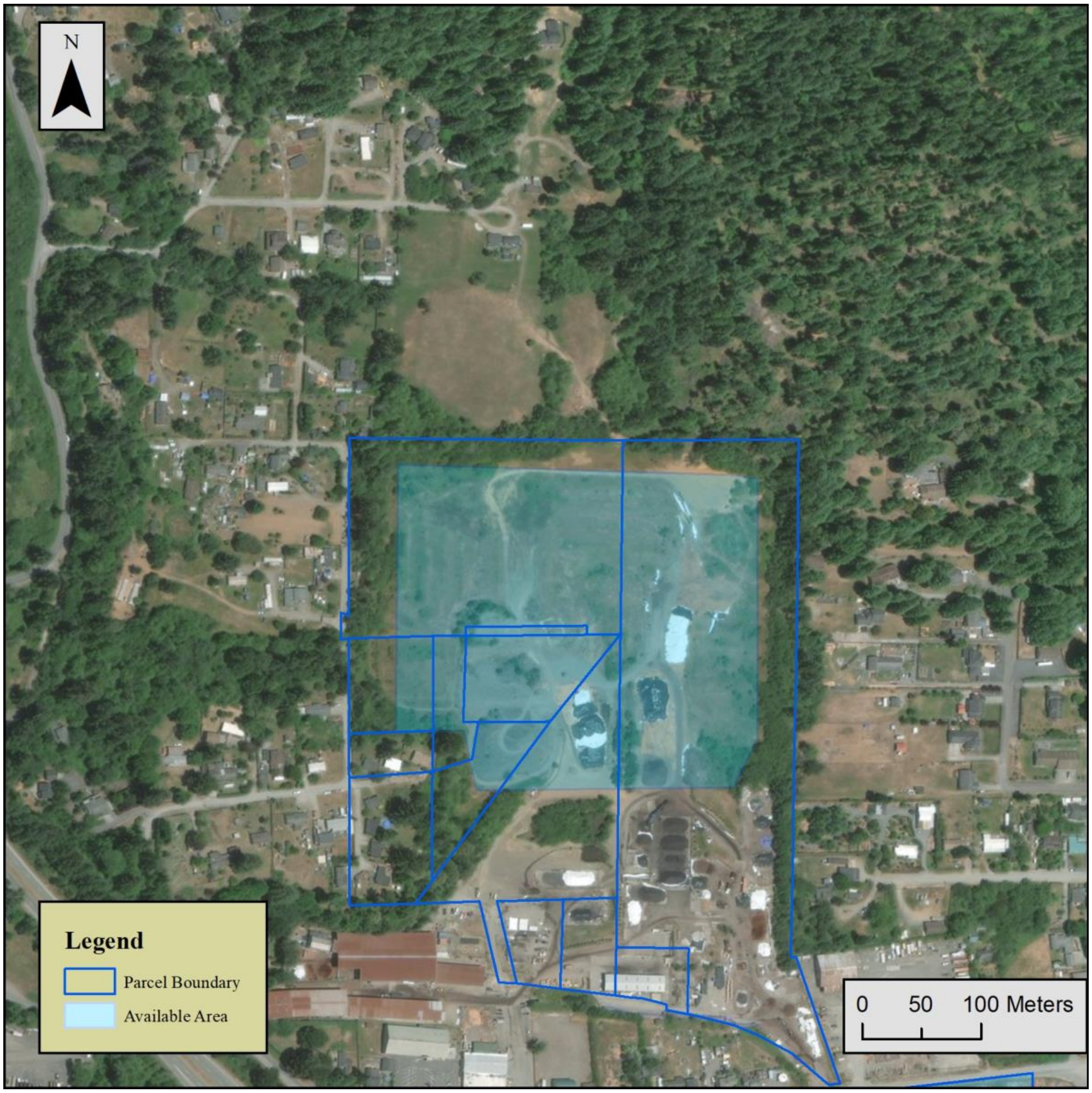
Site 3: Blue Lake Biomass Plant

Site Name	Blue Lake Biomass
Available Area (acres)	13.6
Solar Resource (kWh/m^2/day)	4.10
Grid Hosting Capacity (kW)	1693
Substation Distance (m)	1364
Location	Blue Lake
Address	200 Taylor Way, Blue Lake CA 95525
Area (acres)	15.33
APNs	312161016, 312161019
Owner	City of Blue Lake, PO Box 458, Blue Lake, CA 95525
Use Description	Public Lands, Schools, Tribal
Assessed Land Value	$-
Assessed Structure Value	$-
Total Assessed Value	$-
Year Assessed	1993
Feeder Number	192181102
Nominal Circuit Voltage (kv)	12
Circuit Capacity (MW)	10.8
Circuit Projected Peak Load (MW)	4.34
Substation Bank	1
Substation Bank Capacity (MW)	11.76
Substation Bank Peak Load (MW)	3.8
Existing Distributed Generation (MW)	1.2712
Queued Distributed Generation (MW)	0
Total Distributed Generation (MW)	1.2712
Zone Id	192181102.001
Identified EPA Brownfield	No

Site 3: Blue Lake Biomass Plant, Blue Lake, California (map created by author with base map from Esri.)

Site 4: Blue Lake Forest Products

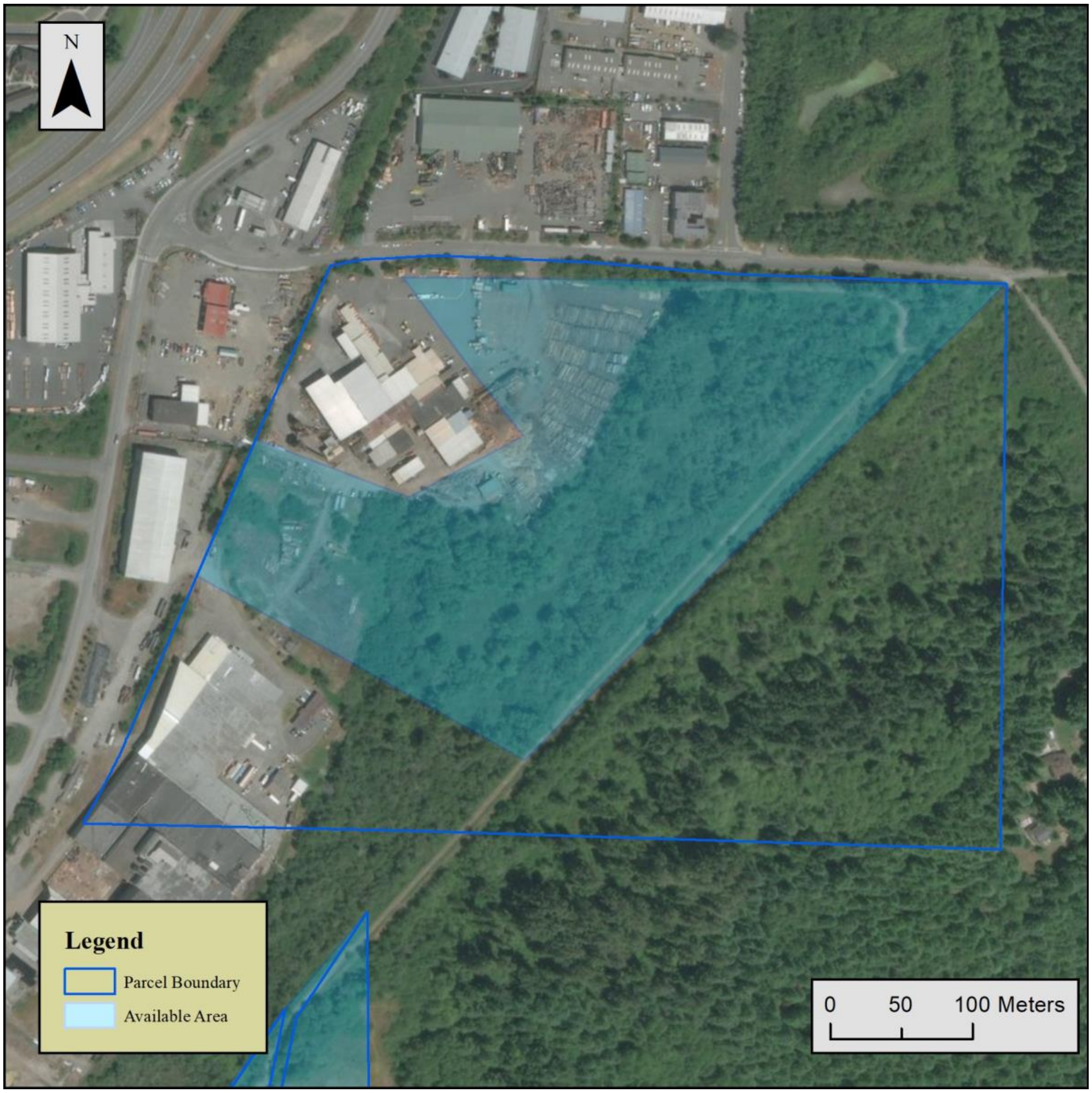
Site Name	**Blue Lake Forest Products**
Available Area (acres)	19.4
Solar Resource (kWh/m^2/day)	3.99
Grid Hosting Capacity (kW)	1693
Substation Distance (m)	4250
Location	Glendale
Address	1589 Glendale Dr, McKinleyville, CA 95519
Area (acres)	39.64
APNs	516101060, 516101040, 516101081, 516101068, 516101063, 516101064, 516101084, 516111062, 516101017, 516111063
Owner	Aalfs, Charles and Rebecca HWCP, 5211 Morning Dew Way, Redding, CA, 96001
Use Description	Vacant Industrial
Assessed Land Value	$1,341,439.32
Assessed Structure Value	$-
Total Assessed Value	$1,341,439.32
Year Assessed	1998
Feeder Number	192171103
Nominal Circuit Voltage (kv)	12
Circuit Capacity (MW)	7.41
Circuit Projected Peak Load (MW)	2.84
Substation Bank	1
Substation Bank Capacity (MW)	6.49
Substation Bank Peak Load (MW)	4.6
Existing Distributed Generation (MW)	0.1471
Queued Distributed Generation (MW)	0
Total Distributed Generation (MW)	0.1471
Zone Id	192171103.027
Identified EPA Brownfield	Yes



Site 4: Blue Lake Forest Products, near Blue Lake, CA (map created by author with base map from Esri).

Site 5: Bob Britt Lumber

Site Name	**Bob Britt Lumber**
Available Area (acres)	23.0
Solar Resource (kWh/m²/day)	3.96
Grid Hosting Capacity (kW)	793
Substation Distance (m)	580
Location	Arcata
Address	105 Alder Grove Rd Arcata, CA 95521
Area (acres)	55.05
APNs	507121036
Owner	Martin, Louis A, 1480 Peterson Ln, Santa Rosa CA, 95403
Use Description	Vacant Industrial
Assessed Land Value	$311,587.00
Assessed Structure Value	$-
Total Assessed Value	$311,587.00
Year Assessed	2017
Feeder Number	192391102
Nominal Circuit Voltage (kv)	12
Circuit Capacity (MW)	10.8
Circuit Projected Peak Load (MW)	1.56
Substation Bank	1
Substation Bank Capacity (MW)	9.29
Substation Bank Peak Load (MW)	4.8
Existing Distributed Generation (MW)	0.0796
Queued Distributed Generation (MW)	0
Total Distributed Generation (MW)	0.0796
Zone Id	192391102.001
Identified EPA Brownfield	No



Site 5: Bob Britt Lumber, Arcata, California (map created by author with base map from Esri).

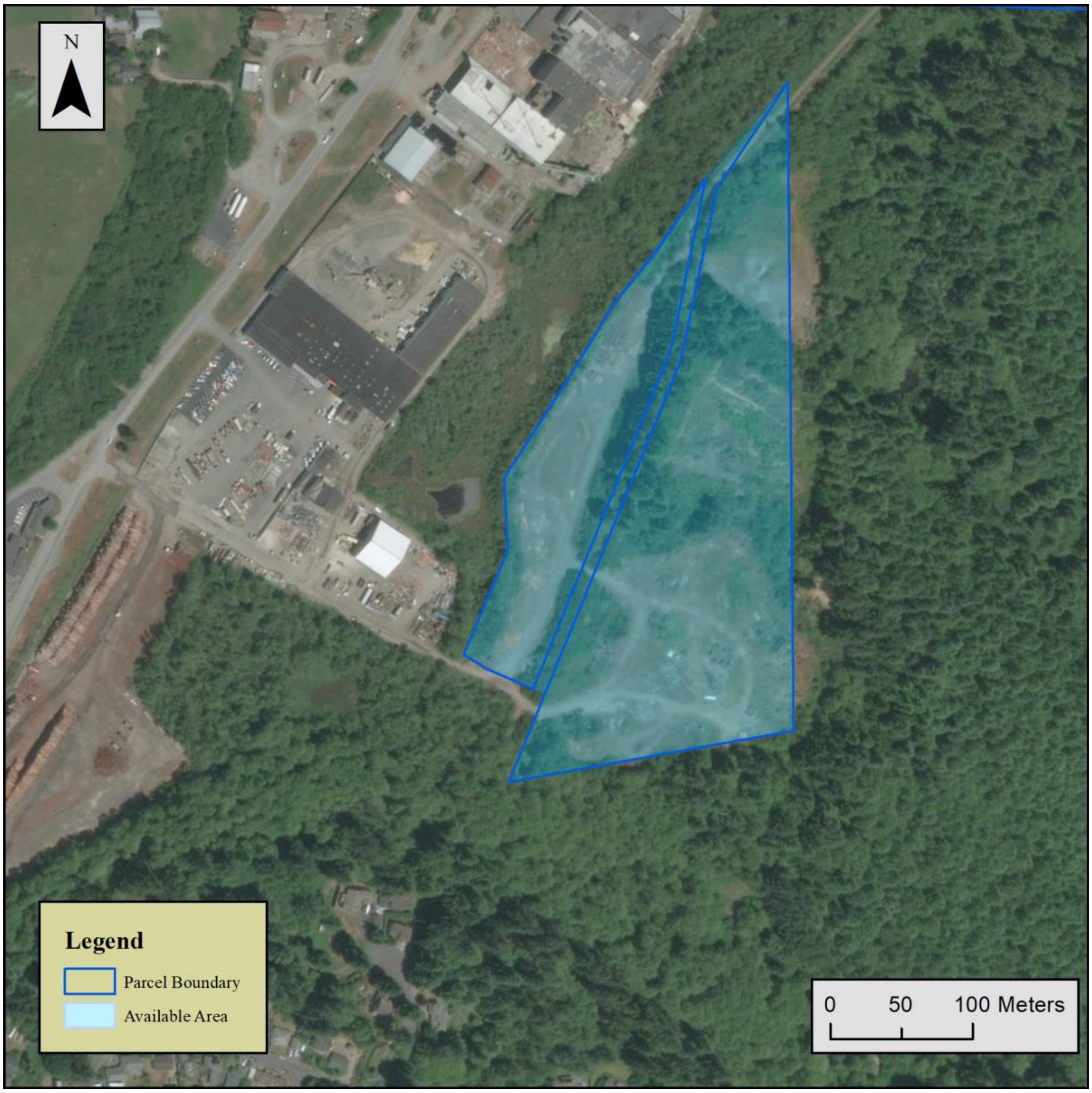
Site 7: Cal Pac

Site Name	**Cal Pac**
Available Area (acres)	39.6
Solar Resource (kWh/m^2/day)	4.56
Grid Hosting Capacity (kW)	617
Substation Distance (m)	3240
Location	Hoopa
Address	Moon Lane, Hoopa, CA 95546
Area (acres)	51.19
APNs	525331009
Owner	Hoopa Valley Tribe of Indians, PO Box 1130 Hoopa, CA 95546-1130
Use Description	Public land, Schools, Non-Taxable Entities
Assessed Land Value	$-
Assessed Structure Value	$-
Total Assessed Value	$-
Year Assessed	1990
Feeder Number	192401101
Nominal Circuit Voltage (kv)	12
Circuit Capacity (MW)	6.26
Circuit Projected Peak Load (MW)	4.11
Substation Bank	1
Substation Bank Capacity (MW)	4.95
Substation Bank Peak Load (MW)	3.8
Existing Distributed Generation (MW)	0.2048
Queued Distributed Generation (MW)	0
Total Distributed Generation (MW)	0.2048
Zone Id	192401101.008
Identified EPA Brownfield	Yes

Site 7: Cal Pac Mill in Hoopa California (map created by author with base map from Esri).

Site 10: Cascade Forest Products

Site Name	**Cascade Forest Products**
Available Area (acres)	17.1
Solar Resource (kWh/m^2/day)	3.93
Grid Hosting Capacity (kW)	793
Substation Distance (m)	1333
Location	Arcata
Address	West End Rd, Arcata CA 95521
Area (acres)	16.16
APNs	507081038
Owner	City of Arcata Pl, C/O Finance Director Janet M Luzzi, 736 F St, Arcata, CA 95521
Use Description	Public Lands
Assessed Land Value	$-
Assessed Structure Value	$-
Total Assessed Value	$-
Year Assessed	2016
Feeder Number	192391102
Nominal Circuit Voltage (kv)	12
Circuit Capacity (MW)	10.8
Circuit Projected Peak Load (MW)	1.56
Substation Bank	1
Substation Bank Capacity (MW)	9.29
Substation Bank Peak Load (MW)	4.8
Existing Distributed Generation (MW)	0.0796
Queued Distributed Generation (MW)	0
Total Distributed Generation (MW)	0.0796
Zone Id	192391102.005
Identified EPA Brownfield	No



Site 10: Cascade Forest Products, Arcata, California (map created by author with base map from Esri).

Site 11: Crown Simpson Mill

Site Name	**Crown Simpson Mill**
Available Area (acres)	189.6
Solar Resource (kWh/m^2/day)	3.94
Grid Hosting Capacity (kW)	1139
Substation Distance (m)	215
Location	Fairhaven
Address	405 Bay Street, Fairhaven
Area (acres)	248.46
APNs	401121008, 401162001, 401131004, 401301010, 401301016, 401301015
Owner	Sequoia Investment, 323 5th St, Eureka, CA 95501
Use Description	Vacant Industrial
Assessed Land Value	$2,299,501.00
Assessed Structure Value	$3,525,631.00
Total Assessed Value	$5,825,132.00
Year Assessed	2005
Feeder Number	192451104
Nominal Circuit Voltage (kv)	12
Circuit Capacity (MW)	8.1
Circuit Projected Peak Load (MW)	2.82
Substation Bank	1
Substation Bank Capacity (MW)	7.08
Substation Bank Peak Load (MW)	2.8
Existing Distributed Generation (MW)	0.0072
Queued Distributed Generation (MW)	0
Total Distributed Generation (MW)	0.0072
Zone Id	192451104.001
Identified EPA Brownfield	No

Site 11: Crown Simpson Mill in Fairhaven, California (map created by author with base map from Esri).

Site 12: DG Fairhaven

Site Name	**DG Fairhaven**
Available Area (acres)	40.0
Solar Resource (kWh/m^2/day)	3.92
Grid Hosting Capacity (kW)	1139
Substation Distance (m)	100
Location	Fairhaven
Address	1920 Vance Ave, Samoa
Area (acres)	52.55
APNs	401121011, 401121012
Owner	DG Fairhaven Power, 303 Fellowship Rd Ste 105, Mt Laurel NJ 08054
Use Description	Miscellaneous Light Industrial
Assessed Land Value	$956,093.00
Assessed Structure Value	$891,763.00
Total Assessed Value	$1,847,856.00
Year Assessed	1990
Feeder Number	192451104
Nominal Circuit Voltage (kv)	12
Circuit Capacity (MW)	8.1
Circuit Projected Peak Load (MW)	2.82
Substation Bank	1
Substation Bank Capacity (MW)	7.08
Substation Bank Peak Load (MW)	2.8
Existing Distributed Generation (MW)	0.0072
Queued Distributed Generation (MW)	0
Total Distributed Generation (MW)	0.0072
Zone Id	192451104.001
Identified EPA Brownfield	No

Site 12: DG Fairhaven Biomass plant in Fairhaven, California (map created by author with base map from Esri).

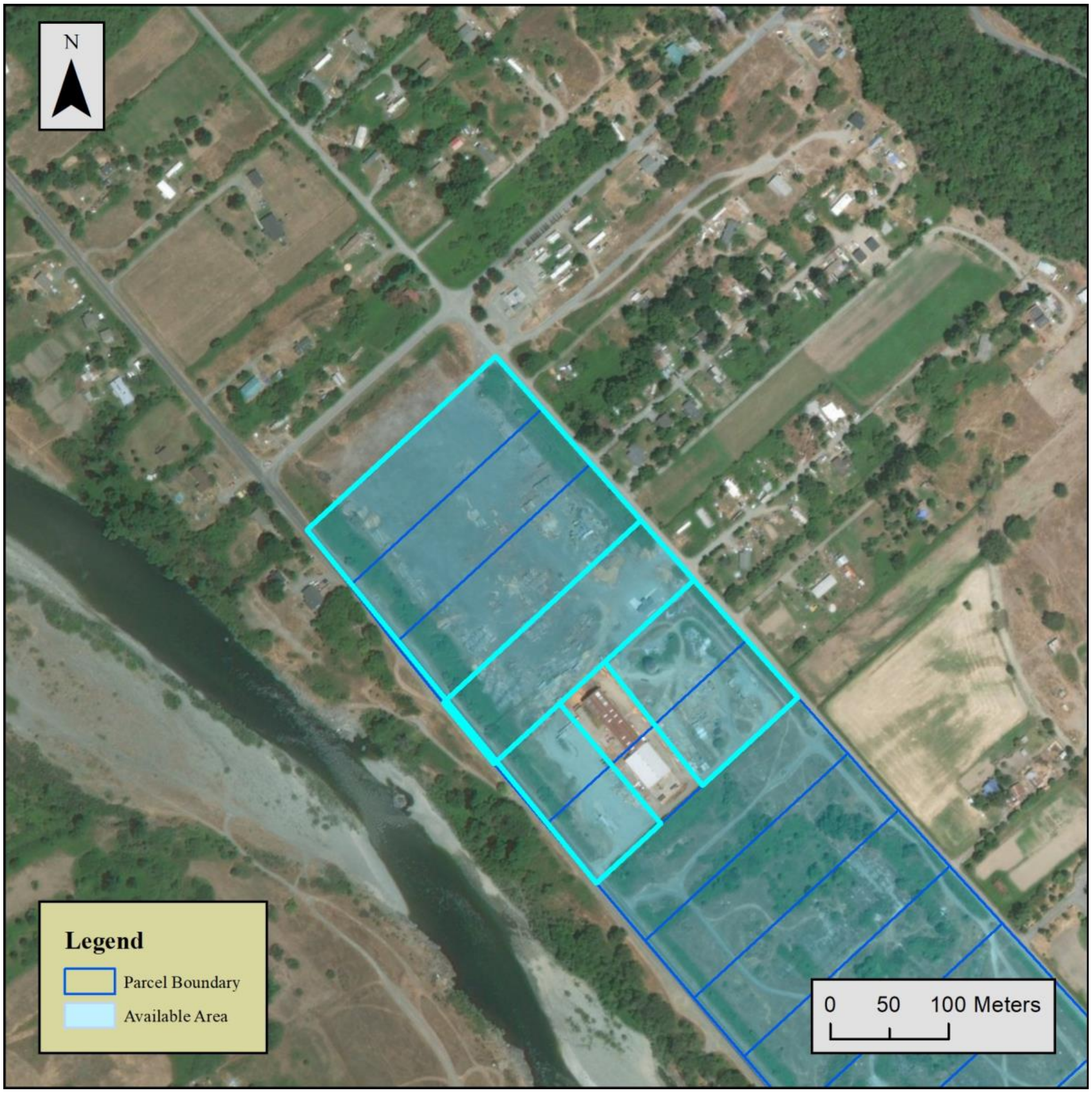
Site 18: Georgia Pacific, Myers Flat

Site Name	**Georgia Pacific, Myers Flat**
Available Area (acres)	6.1
Solar Resource (kWh/m^2/day)	4.61
Grid Hosting Capacity (kW)	246
Substation Distance (m)	3978
Location	Myers Flat
Address	12939 Avenue of the Giants, Myers Flat, CA 95554
Area (acres)	6.07
APNs	081021038
Owner	Meagher, William
Use Description	Vacant Commercial
Assessed Land Value	$13,625.00
Assessed Structure Value	$-
Total Assessed Value	$13,625.00
Year Assessed	2000
Feeder Number	192311141
Nominal Circuit Voltage (kv)	12
Circuit Capacity (MW)	6.39
Circuit Projected Peak Load (MW)	1.26
Substation Bank	1
Substation Bank Capacity (MW)	4.7
Substation Bank Peak Load (MW)	4.4
Existing Distributed Generation (MW)	0.0069
Queued Distributed Generation (MW)	0
Total Distributed Generation (MW)	0.0069
Zone Id	192311141.018
Identified EPA Brownfield	No

Site 18: Georgia Pacific Mill (aka Morrison-Jack Mill) in Myers Flat, California (map created by author with base map from Esri).

Site 19: Hoopa Timber 1

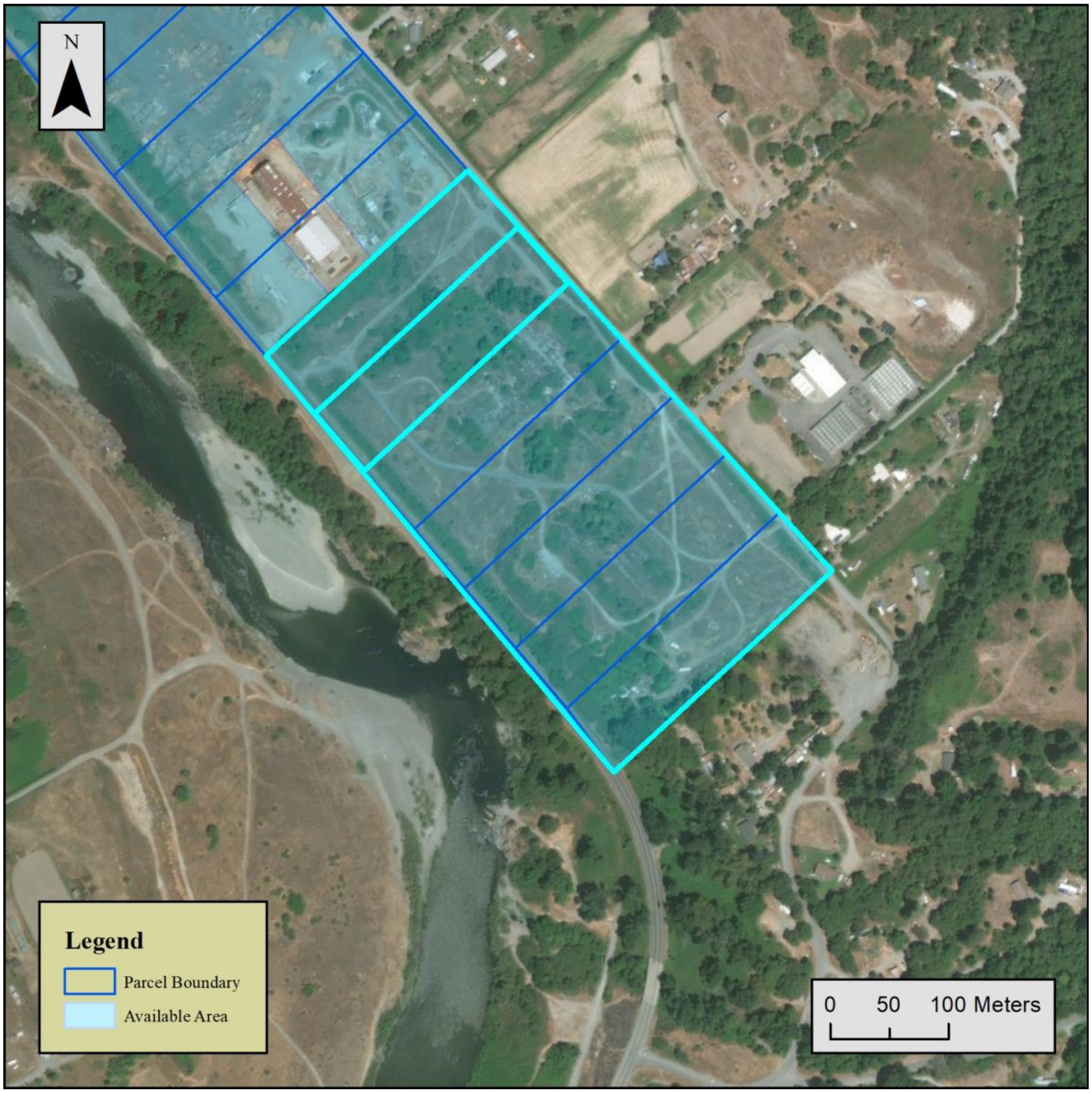
Site Name	**Hoopa Timber Co. 1**
Available Area (acres)	19.6
Solar Resource (kWh/m^2/day)	4.56
Grid Hosting Capacity (kW)	772
Substation Distance (m)	2636
Location	Hoopa
Address	13653 State Highway 96, Hoopa CA 95546
Area (acres)	21.45
APNs	526081022, 526081023, 526081024, 526081025, 526081026, 526081027
Owner	Hoopa Tribal Council Timber Corp., C/O Hoopa Land Management, PO Box 1130, Hoopa, CA 95546-1130
Use Description	Industrial-Vacant
Assessed Land Value	$107,272.00
Assessed Structure Value	$-
Total Assessed Value	$107,272.00
Year Assessed	1978
Feeder Number	192401101
Nominal Circuit Voltage (kv)	12
Circuit Capacity (MW)	6.26
Circuit Projected Peak Load (MW)	4.11
Substation Bank	1
Substation Bank Capacity (MW)	4.95
Substation Bank Peak Load (MW)	3.8
Existing Distributed Generation (MW)	0.2048
Queued Distributed Generation (MW)	0
Total Distributed Generation (MW)	0.2048
Zone Id	192401101.001
Identified EPA Brownfield	Yes



Site 19: Hoopa Timber Company 1 in Hoopa, California (map created by author with base map from Esri).

Site 20: Hoopa Timber 2

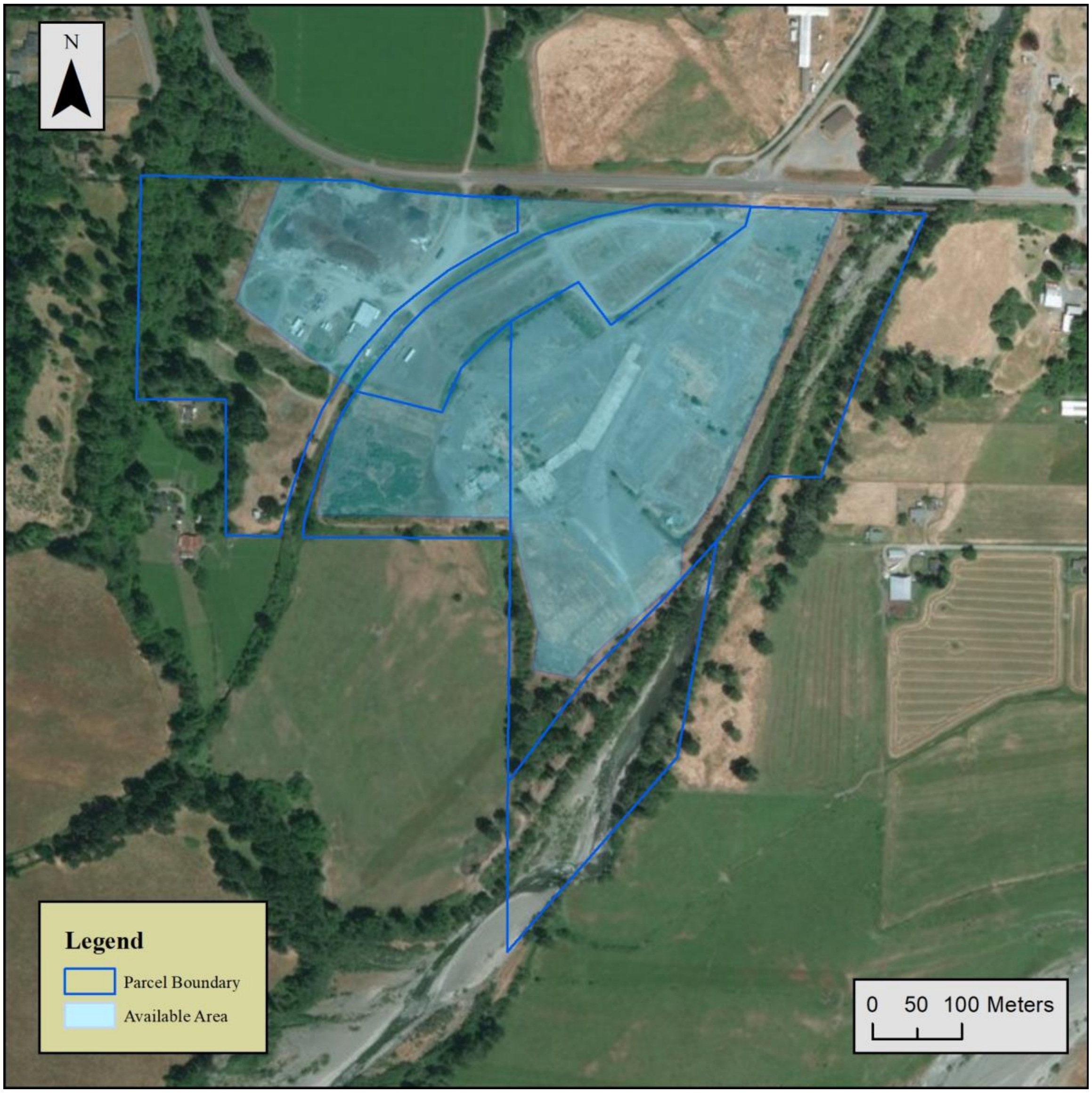
Site Name	**Hoopa Timber Co. 2**
Available Area (acres)	27.1
Solar Resource (kWh/m^2/day)	4.56
Grid Hosting Capacity (kW)	772
Substation Distance (m)	2636
Location	Hoopa
Address	13653 State Highway 96, Hoopa CA 95546
Area (acres)	26.85
APNs	526081028, 526081029, 526081030, 526081031, 526081032, 526081033, 526081034
Owner	Wagner, Mitchel H, TR, C/O Darlene Bowman, 2228 Wagner Rd, Camano Island, WA 98282
Use Description	Industrial-Vacant
Assessed Land Value	$137,459.00
Assessed Structure Value	$-
Total Assessed Value	$137,459.00
Year Assessed	1994
Feeder Number	192401101
Nominal Circuit Voltage (kv)	12
Circuit Capacity (MW)	6.26
Circuit Projected Peak Load (MW)	4.11
Substation Bank	1
Substation Bank Capacity (MW)	4.95
Substation Bank Peak Load (MW)	3.8
Existing Distributed Generation (MW)	0.2048
Queued Distributed Generation (MW)	0
Total Distributed Generation (MW)	0.2048
Zone Id	192401101.001
Identified EPA Brownfield	Yes



Site 20: Hoopa Timber Company 2 in Hoopa, California (map created by author with base map from Esri).

Site 26: Pacific Lumber Company, Carlotta

Site Name	**Pacific Lumber, Carlotta**
Available Area (acres)	53.8
Solar Resource (kWh/m^2/day)	4.15
Grid Hosting Capacity (kW)	917
Substation Distance (m)	542
Location	Carlotta
Address	4790 State Highway 36, Carlotta, CA 95540
Area (acres)	87.14
APNs	204251001, 204121005
Owner	Rice, Ryan P and Robin K HWJT, PO Box 817, Fortuna, CA 95540
APNs	204251010, 204121004, 206351004
Owner	Carlotta Mill LLC Co, PO Box 369, Scotia, CA 95565
Use Description	Vacant Industrial/Paving
Assessed Land Value	$1,178,106.00
Assessed Structure Value	$69,380.00
Total Assessed Value	$1,247,486.00
Year Assessed	2016
Feeder Number	192291121
Nominal Circuit Voltage (kv)	12
Circuit Capacity (MW)	6.37
Circuit Projected Peak Load (MW)	2.25
Substation Bank	1
Substation Bank Capacity (MW)	3.2
Substation Bank Peak Load (MW)	0.9
Existing Distributed Generation (MW)	0.1199
Queued Distributed Generation (MW)	0
Total Distributed Generation (MW)	0.1199
Zone Id	192291121.001
Identified EPA Brownfield	No



Site 26: Pacific Lumber Company Mill in Carlotta, California (map created by author with base map from Esri).

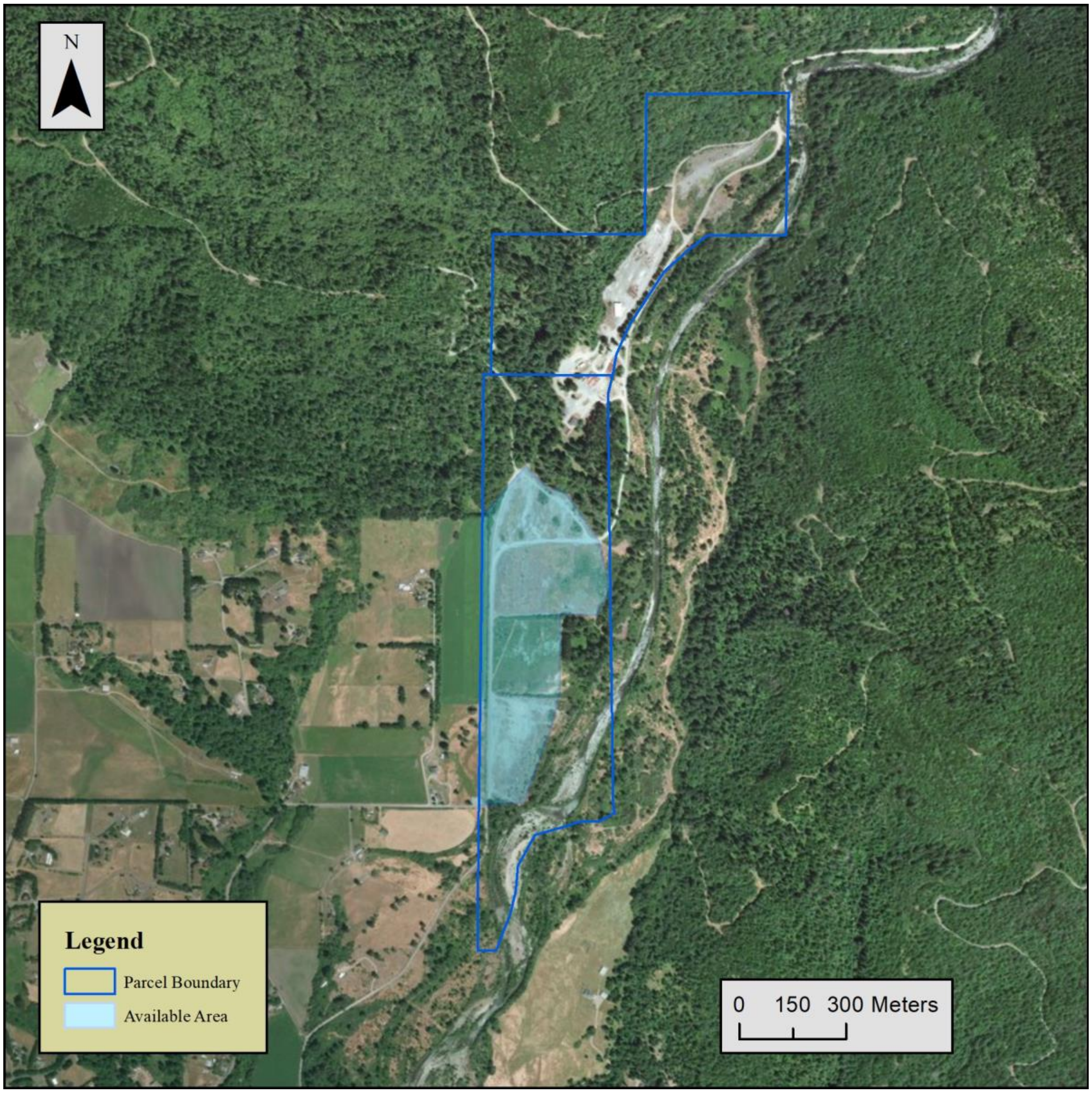
Site 27: Pacific Lumber Company, Fortuna

Site Name	**Pacific Lumber, Fortuna**
Available Area (acres)	62.0
Solar Resource (kWh/m^2/day)	4.10
Grid Hosting Capacity (kW)	1520
Substation Distance (m)	1500
Location	Fortuna
Address	1400 Newburg Rd, Fortuna CA, 95540
Area (acres)	65.48
APNs	202011023, 202011031, 202021017, 202021010, 201331002, 201331005, 200363006, 202021005, 200363007
Owner	Town of Scotia Company LLC, PO Box 245, Scotia, CA 95565-0245
Use Description	Heavy Industrial, Wood Product
Assessed Land Value	$1,231,124.00
Assessed Structure Value	$722,737.00
Total Assessed Value	$1,953,861.00
Year Assessed	2008
Feeder Number	192151132
Nominal Circuit Voltage (kv)	12
Circuit Capacity (MW)	10.09
Circuit Projected Peak Load (MW)	5.52
Substation Bank	2
Substation Bank Capacity (MW)	10.4
Substation Bank Peak Load (MW)	5.5
Existing Distributed Generation (MW)	0.1772
Queued Distributed Generation (MW)	0
Total Distributed Generation (MW)	0.1772
Zone Id	192151132.025
Identified EPA Brownfield	No

Site 27: Pacific Lumber Company, Fortuna (map created by author with base map from Esri).

Site 29: Pacific Lumber Company, Yager Camp

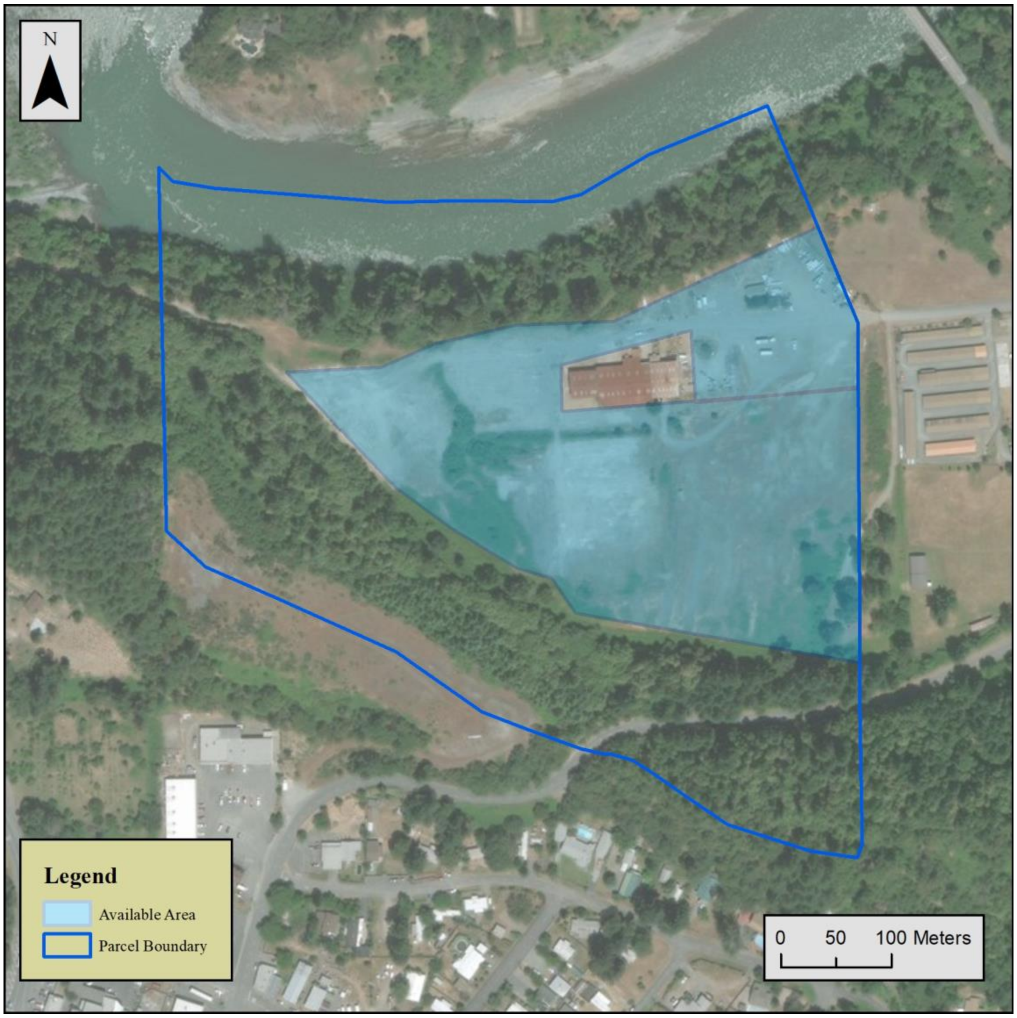
Site Name	**Pacific Lumber, Yager Camp**
Available Area (acres)	53.8
Solar Resource (kWh/m^2/day)	4.15
Grid Hosting Capacity (kW)	412
Substation Distance (m)	1308
Location	Carlotta/ Hydesville
Address	3717 Fisher Rd Carlotta
Area (acres)	204.69
APNs	204034002, 204033002
Owner	Humboldt Redwood Company, PO Box 996, Ukiah, CA 95482
Use Description	Improved
Assessed Land Value	$749,736.00
Assessed Structure Value	$790,655.00
Total Assessed Value	$1,540,391.00
Year Assessed	2008
Feeder Number	192291121
Nominal Circuit Voltage (kv)	12
Circuit Capacity (MW)	6.37
Circuit Projected Peak Load (MW)	2.25
Substation Bank	1
Substation Bank Capacity (MW)	3.2
Substation Bank Peak Load (MW)	0.9
Existing Distributed Generation (MW)	0.1199
Queued Distributed Generation (MW)	0
Total Distributed Generation (MW)	0.1199
Zone Id	192291121.026
Identified EPA Brownfield	No



Site 29: Pacific Lumber Company, Yager Camp in Carlotta, California (map created by author with base map from Esri).

Site 30: Pilot Lumber Company

Site Name	**Pilot Lumber Co.**
Available Area (acres)	15.9
Solar Resource (kWh/m^2/day)	4.58
Grid Hosting Capacity (kW)	1029
Substation Distance (m)	1217
Location	Willow Creek
Address	130 Flower McNeil Rd, Willow Creek, CA 95573
Area (acres)	42.33
APNs	522201001
Owner	S & S Cornerstone Developments LLC CO, C/O Kenny Smith, PO Box 904, Willow Creek, CA 95573-0904
Use Description	Heavy Industrial, Wood Product
Assessed Land Value	$331,170.00
Assessed Structure Value	$331,170.00
Total Assessed Value	$662,340.00
Year Assessed	2011
Feeder Number	192171103
Nominal Circuit Voltage (kv)	12
Circuit Capacity (MW)	7.41
Circuit Projected Peak Load (MW)	2.84
Substation Bank	1
Substation Bank Capacity (MW)	6.49
Substation Bank Peak Load (MW)	4.6
Existing Distributed Generation (MW)	0.1471
Queued Distributed Generation (MW)	0
Total Distributed Generation (MW)	0.1471
Zone Id	192171103.027
Identified EPA Brownfield	Yes



Site # 30: Pilot Lumber Company, Willow Creek, California (map created by author with base map from Esri).