# Sierra Nevada Biomass to Energy Location Optimization Tool
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Sierra Nevada Conservancy & TSS Associates

http://conservation3.arcgisonline.com/Apps/BiomassOptimization/

**Purpose for developing the Biomass to Energy Location Optimization Tool:**
The vast majority of Sierra Nevada forests are extremely dense and structurally homogenous compared to their historical average and are in need of forest management actions to provide resiliency to the increased frequency of large wildfires & climate change[1,2,3]. The bulk of available forest carbon is stored in large, mature trees, while younger, smaller diameter trees are the focus that store significantly less carbon are the focus of forest management activities[2,3]. There is significant interest amongst a variety of stakeholders in finding value added uses for excess forest biomass material generated as a byproduct of forest management activities in the Sierra Nevada Region. In order to analyze value-added opportunities (including bioenergy generation), an awareness of the potential availability of forest biomass feedstock and existing power distribution infrastructure is a key first step. The Biomass to Energy Optimization Tool was designed to provide communities, forest landowners, forest managers, project developers and others with a high-level, back of the envelope estimate of forest biomass availability in areas proximate to electrical distribution infrastructure and roads. Using this tool as a coarse filter, interested stakeholders will be able to quickly identify the biomass potential at a particular site. Additional resources are identified to guide the user down the appropriate avenue to discover more about a potential site.

**Criteria used:**
The first step in developing the biomass to energy location optimization tool was to identify the purpose of the tool along with the level of detail that could be achieved in identifying potential available biomass for value-added processing enterprises such as small scale bioenergy facilities and the audience who would use the map. The purpose of the location optimization tool is to provide a high-level overview of key attributes that allows users to compare locations for siting value-added processing enterprises that utilize excess forest biomass material. The term forest biomass is used to refer to the carbon in forests as measured by the US Forest Service as part of their Forest Inventory and Analysis (FIA) Forest Carbon Estimation Program. First, the criteria that could yield a "no-go" outcome (e.g., if there are no proximate electrical distribution lines, the project parcel is zoned residential or the biomass is located in a wilderness area, a biomass to electricity project will not work) were identified. The criteria that were desired to be included in the location optimization tool were compared with the available GIS (mapping) data that could be used in a spatial analysis to produce a map of the potentially available biomass (i.e. and where a facility may possibly be located). The four criteria that were ultimately selected based on the availability of GIS data included:

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[1] Lydersen, J., North, M., Knapp, E. and B. Collins. 2013. Quantifying spatial patterns of tree groups and gaps in mixed-conifer forests: Reference conditions and long-term changes following fire suppression and logging. Forest Ecology and Management (304): 370-382.
[2] Stephens, S., Moghaddas, J., Hartsough, B., Moghaddas, E., and N. Clinton. 2009. Fuel treatment effects on stand-level carbon pools, treatment-related emissions, and fire risk in a Sierra Nevada mixed-conifer forest. Canadian Journal of Forest Research 39(8): 1538-1547.
[3] Hurteau M, North M. 2009. Fuel treatment effects on tree-based forest carbon storage and emissions under modeled wildfire scenarios. Front. Ecol. Environ. 7: 2-7.

- Forest biomass located within ½ mile of existing roads and on landscapes that support active forest management (e.g., outside federal or state parks and wilderness areas);
- Proximity to existing power distribution infrastructure;
- Topography (slope conditions) that is under 30% slope; and
- Current market demand for forest biomass based on existing bioenergy infrastructure.

Other criteria that were considered, but ultimately deferred to a second-level more detailed review process were:

- Power purchase agreement (contract that a biomass facility has to sell power to a utility) life of existing neighboring biomass facilities
- Zoning data
- Availability of the parcel for lease or purchase
- Site ownership
- IOU service territory – PGE and SCE service areas?
- Willingness of utilities to negotiate power purchase agreements
- Fuel-shed ownership
- Community support
- Location relative to disadvantaged communities
- Potential for grant funding
- Existing infrastructure
- Closed or abandoned sawmill sites
- Air quality considerations
- Proximity to fire threat treatment areas
- Proximity to population centers

This location optimization tool is intended to be a scoping tool to begin the process of considering whether or not to site a small scale, biomass to energy facility; the factors mentioned about must be carefully considered in conducting a finer scale feasibility analysis for a potential facility.

**Description of the Biomass to Energy Optimization Location optimization tool:**
The Sierra Nevada Conservancy (SNC) Biomass optimization location optimization tool is a web browser GIS map which allows the user to preliminarily screen and compare potential sites for small biomass power plants scaled at 3 mega watts (MW) and less in the Sierra Nevada region. It is best viewed in the Google Chrome or Mozilla Firefox browsers. The location optimization tool displays three primary values: a map of available biomass (biomass index, carbon in forests), a map of potential existing biomass consumption (annual feedstock consumption index) and a map combining the availability and consumption of biomass (biomass optimization index) in one theme or map "layer". This location optimization tool is not a tool for conducting a feasibility analysis or estimating the actual economic feasibility of a successful bioenergy facility at any location. Power plant economic feasibility is a complex interaction of feedstock availability, existing consumption, biomass collection, processing and transportation costs, electric distribution system capacity and interconnection costs, along with socio-political, planning and regulatory factors.

**GIS Methodology to Develop the Online Biomass to Energy Optimization Mapping Tool:**

We used GIS map layers that represented the criteria selected to identify potentially available biomass for a small scale bioenergy facility. These layers and the spatial analyses used to identify potentially available biomass in the SNC Region in GIS (ArcMap, Spatial Analyst) are described in greater detail below. In summary, the map of potentially available biomass for bioenergy consumption was produced in GIS by extracting areas where a facility cannot be sited and biomass cannot be acquired: the annual feedstock consumption occurring by operating facilities; land more than a half mile from distribution lines & roads; land on slopes greater than 30%; and protected areas (lands not available to biomass extraction such as wilderness or roadless areas), from the available forest biomass.

**Biomass Data Source**

The map of available biomass is derived from biomass data from the USDA Forest Service Forest Inventory and Analysis (FIA) Forest Carbon Estimation Program[4]. The U.S. Forest Service has been providing national-scale estimates of forest carbon stocks and stock change to meet United Nations Framework Convention on Climate Change reporting requirements. Although these estimates are currently provided as national estimates by pool and year to meet greenhouse gas monitoring requirements, there is growing need to disaggregate these estimates to finer scales to enable strategic forest management and monitoring activities focused on various ecosystem services such as carbon (C) storage enhancement. (USFS FIA web site)

The FIA data was used to create a new project biomass GIS raster layer from the total forest carbon in all stocks raster for areas within the SNC boundary on slopes less than 30%, within 0.5 miles of a road, and not within federal or state parks or designated wilderness areas (Figure 1).

The data sources used to produce the biomass GIS rater layer included:
Forest Carbon Estimation
http://www.fia.fs.fed.us/Forest%20Carbon/default.asp

Forest Service Research Data Archive - RDS-2013-0004
Forest carbon stocks of the contiguous United States (2000-2009) (Published 2013)
http://www.fs.usda.gov/rds/archive/Product/RDS-2013-0004

The following link describes the metadata (citation information) regarding the GIS layer used: Forest carbon stocks of the contiguous United States (2000-2009)
http://www.fs.usda.gov/rds/archive/products/RDS-2013-0004/_metadata_RDS-2013-0004.html

[4] The USFS summarizes the process to produce the forest carbon estimation as follows: through application of a nearest-neighbor imputation approach in GIS, mapped estimates of forest carbon density were developed for the contiguous United States using the annual forest inventory conducted by the USDA Forest Service Forest Inventory and Analysis (FIA) program, MODIS satellite imagery, and ancillary geospatial datasets. This data product contains the following eight raster maps: total forest carbon in all stocks, live tree aboveground forest carbon, live tree below-ground forest carbon, forest down dead carbon, forest litter carbon, forest standing dead carbon, forest soil organic carbon, and forest understory carbon.

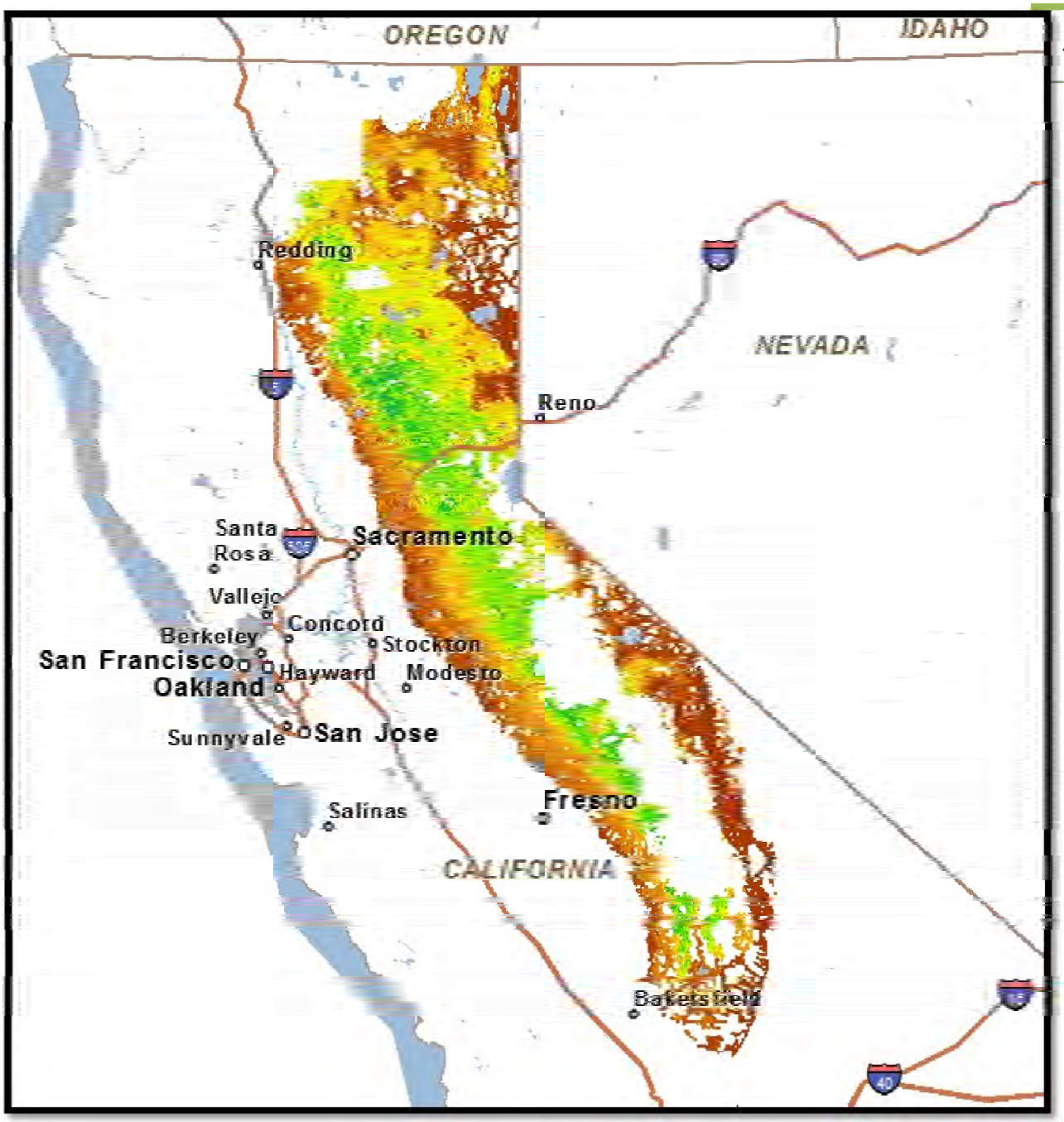


Figure 1: USFS biomass (brown=least to green=most) within the SNC boundary on slopes less than 30%, within 0.5 miles of a road, and not within federal or state parks or designated wilderness areas.

**Biomass power plant optimization project boundary**

Small-scale, bioenergy facilities power plants should be located close to power distribution lines. In addition, forest biomass material available as feedstock should be located within a ½ mile corridor of existing roads and within a 30 mile radius of a potential site in order to mitigate collection and transportation costs. Transportation costs are typically the single most significant cost when procuring forest biomass feedstock.

Distribution line data was provided by Pacific Gas & Electric and Southern California Edison for the SNC Region. The distribution lines were buffered by a ½ mile distance. The roads were also buffered by ½ mile as well and used to clip or extract the buffered distribution lines to produce a project area map of the lands within ½ mile of a distribution line and within ½ mile from a road (Figure 2).

Figure 2: Biomass power plant optimization project area map of the lands (green) within ½ mile of a distribution line and within ½ mile from a road.

**Biomass Availability and Biomass Index**

For each hectare within the project area (Figure 2) the total biomass from the project biomass raster (Figure 1) was summed for a 30 mile radius working circle to produce a map of available biomass in tons per acre. The available forest biomass raster was reclassified into 100 equal interval classes from the lowest available biomass to the highest; each class was numbered from 1 to 100 to produce the available biomass index. We converted the total summed 30 mile radius biomass to an biomass availability index because this tool should not be used to estimate commercial biomass harvest availability. The tool is designed to give comparative site to site biomass availability rankings.

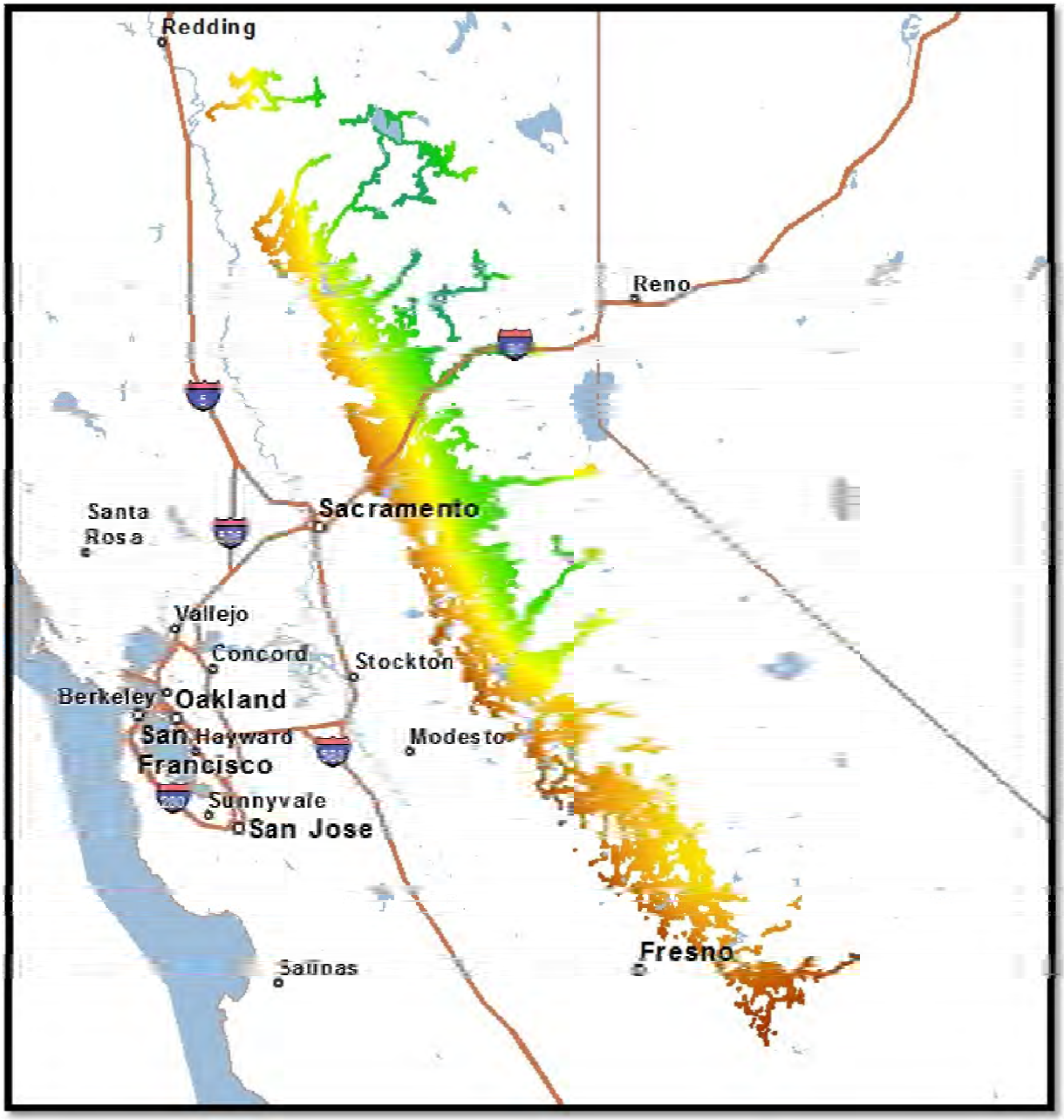


Figure 3: Available biomass index (brown=least to green=most) within 30 mile radius circle for each location in the biomass power plant optimization project area (Figure2).

**Existing Biomass Power Plant Annual Feedstock Consumption (AFC)**
Existing biomass power plants were identified within the SNC region and adjacent areas and their working circles and forest biomass consumption was estimated based on current markets.

Each existing biomass power plant was buffered by their working circle. The working circles were clipped by the boundary of the project area biomass raster (See Figure1 for the areas within the SNC boundary on slopes less than 30%, within 0.5 miles of a road, and not within federal or state parks or designated wilderness areas). An annual feedstock consumption (AFC) raster layer with the tons per acre of AFC was created for the clipped working circles.

Figure 4: Annual Feedstock Consumption (lowest=brown, highest=blue) in tons per acre

**Annual Feedstock Consumption (AFC) Index**

For each hectare within the biomass power plant optimization project area (Figure2), the total AFC from the AFC raster (Figure 4) was summed for a 30 mile radius working circle to produce a map of working circle and AFC in tons per acre.

The working circle AFC raster was reclassified into 100 equal interval classes from the lowest working circle AFC to the highest; each class was numbered from 1 to 100 to produce the available AFC index.

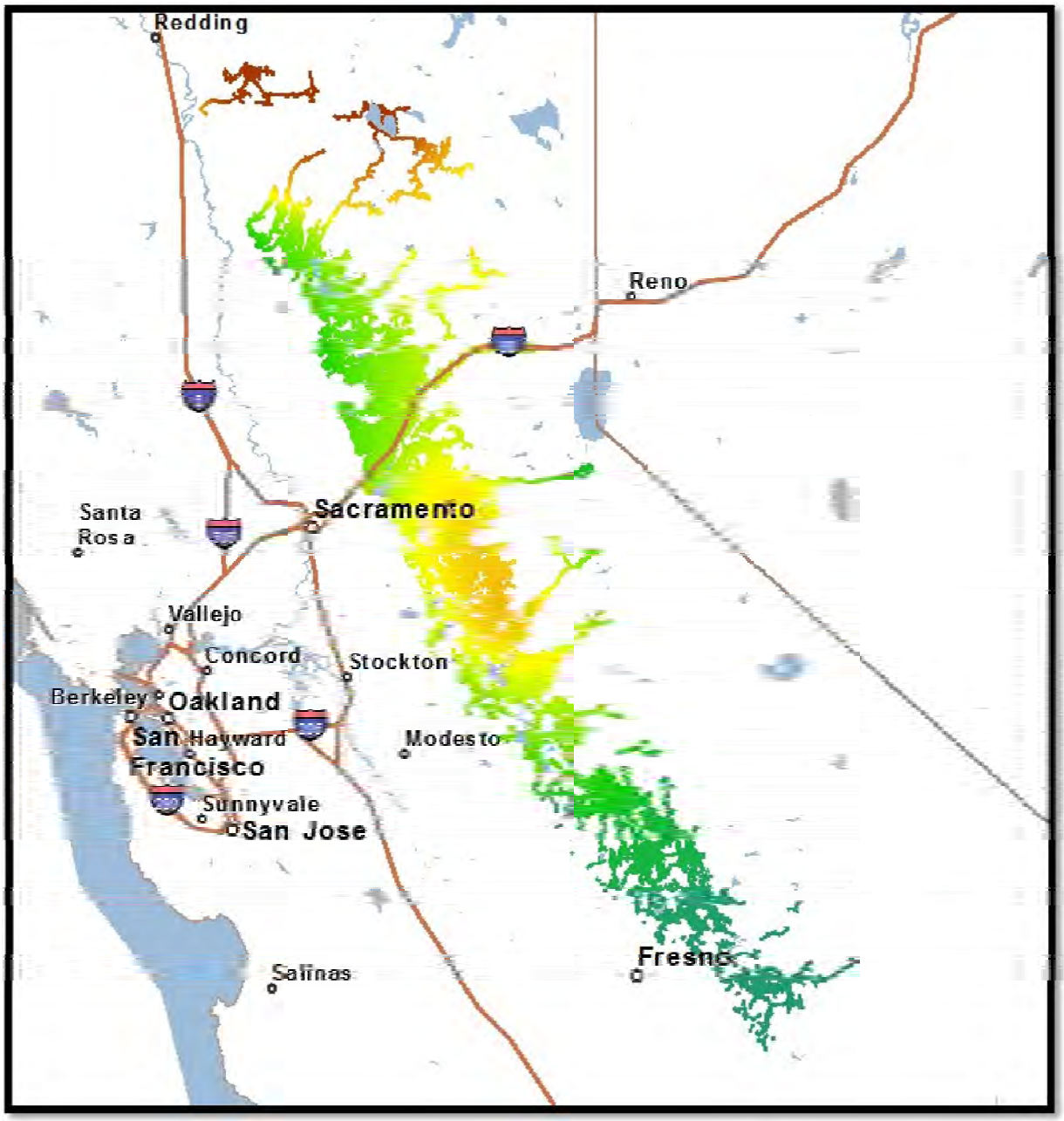


Figure 5: Annual Feedstock Consumption Index (lowest consumption=green, middle consumption= yellow, highest consumption=reddish-brown) within 30 mile radius circle for each location in the biomass power plant optimization project area (Figure2).

**Biomass Optimization Index**

The biomass optimization index is a raster layer derived in GIS from the biomass index (Figure 2) and the AFC index (Figure 5) as follows:

Biomass Optimization Index = Biomass Index – AFC Index

The values of the biomass optimization index range from -30 to +71. Lower numbers represent areas with less optimal sites, higher numbers, more optimal sites. Negative values at a site mean that the AFC (annual feedstock consumption) Index is larger than the Biomass Index at that site.

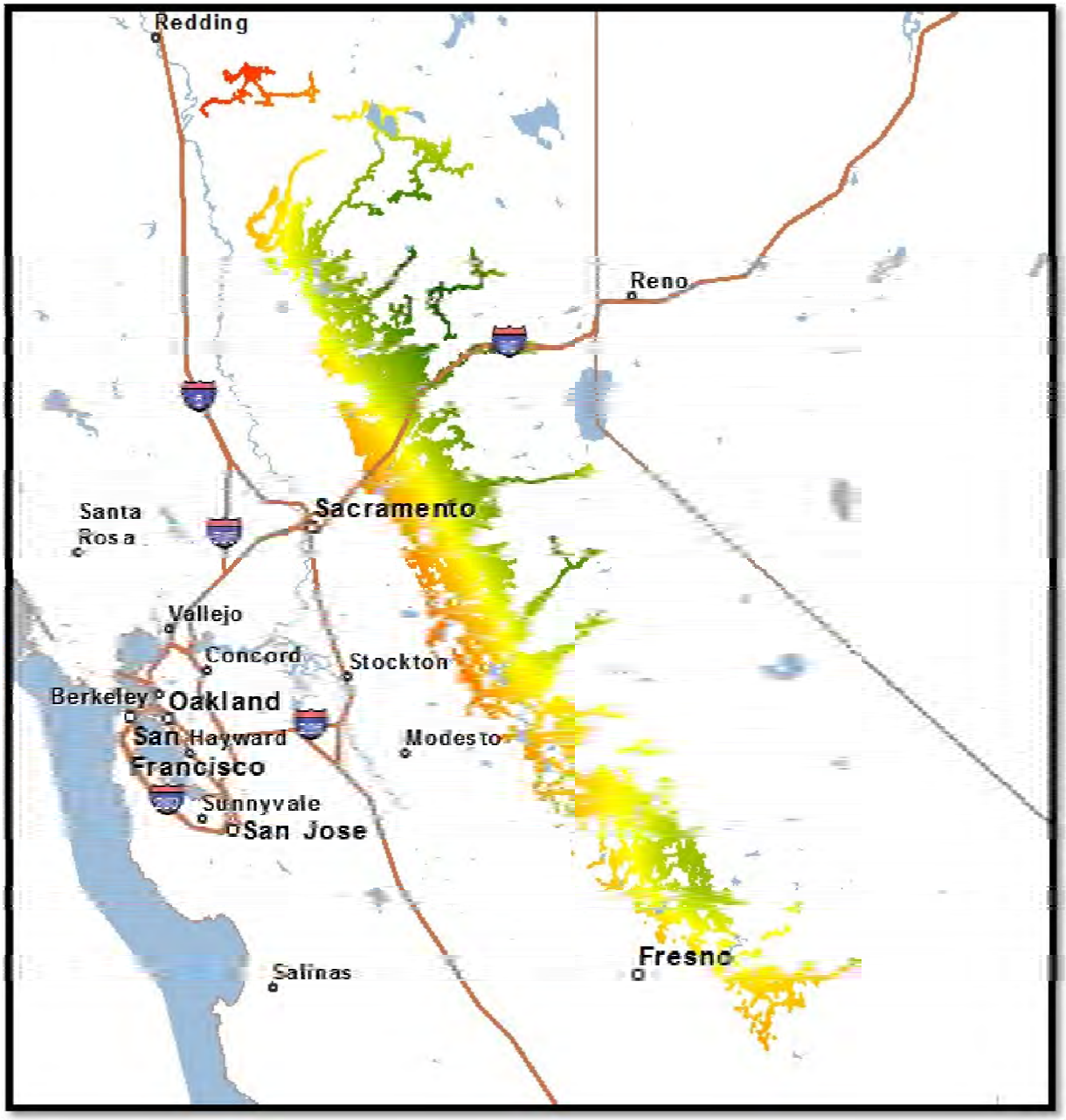


Figure 6: Biomass Optimization Index

**Layer Sources**

The data sources for all of the layers included in the location optimization tool are provided below:

Counties (for planning information):
County spatial data from CAL-ATLAS, planning information gathered by Liz van Wagtendonk from each County Planning Departments website for the 22 counties within the SNC Region

Roads Buffer (one half mile)
Roads data from Esri and USFS

PG&E Distribution Line Buffer (one half mile):
From PG&E

Southern California Edison (SCE) Line Buffer (one half mile):
From SCE