Community Microgrid Suitability Analysis

A GIS Approach to Modernizing the Electric Grid

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Abstract

The concept of a Community Microgrid is currently seen as seminal, as only a few are currently operational. As the electrical grid becomes more modern, Community Microgrids will be progressively adopted in order to provide energy resilience to the increasing occurrences of natural disasters. Current methods for identifying potential Community Microgrids are slow and time-consuming processes that involve the inner workings of a complex group of stakeholders. In this paper, I establish a method for locating suitable Community Microgrid regions within a given study area. This method was designed to semi-automate the process and decrease the overall time it takes to identify suitable regions for Community Microgrid development that is based on numerous criteria. I successfully located 5 regions that have the highest suitability for Community Microgrids within a 950 mi^2 study area called the Goleta Load Pocket, which is located within the southern portion of Santa Barbara County, California. Each region contains 1 or more critical community facilities, is inside of a low-income community, and is in close proximity to an electrical feeder segment that has high operational flexibility for solar PV integration. A solar siting survey that identifies solar potential on rooftops, parking lots, and parking structures, at 1 MW or greater was also integrated into the study and overlaid over the suitable regions. This approach further identifies the potential for establishing enough renewable energy generation in order to validate a Community Microgrid approach to the identified region. This Community Microgrid Suitability Model was created to showcase a process that is replicable for any neighborhood, city, or county that has the available data. This study serves to aid municipalities in their approach to find a modern solution to power outages due to our aging electrical grid, while also serving communities of concern that are at the frontlines of the climate crises.

1. Introduction

Around 70 percent of our electric grid's transmission lines and power transformers are over 30 years old (Understanding Our Grid, 2014). This aging piece of infrastructure is one of the most complex and expansive constructions that man-kind has ever built. While in an era of technology advancement, new ways of designing and operating infrastructural systems are proliferating on a yearly basis. Distributed Energy Resources (DERs) which are defined as small, geographically dispersed generation resources, such as solar, installed and operated on the distribution system at voltage levels below the typical bulk power system levels of 100kV (Staff, 2018). Due to technology advances, DERs are becoming increasingly important in some areas of the United States as more people adopt to more local and environmentally friendly practices such as solar PV and energy storage at their place of residence. The existing electrical grid involves transporting electricity through high voltage electrical lines across long distances and disaster-prone areas. In November 2018, the Caribou-Palermo transmission line was identified as the cause of the Camp Fire, which incinerated the town of Paradise and is now marked as the state's most lethal blaze (Singh, 2019).

To reduce the probability that these high voltage electrical lines could cause future fires, the California Public Utilities Commission (CPUC) has authorized Investor Owned Utilities (IOU's) to implement de-energization procedures called Public Safety Power Shutoffs (PSPS) (CPUC, 2019). These shutoffs have already affected close to a million people across California, leaving even the most critical facilities without the ability to keep the lights on. This leaves the concept of energy resilience to hold a very high and variable value. Surfacing as a solution to PSPS and environmental disasters are Community Microgrids, which is a new approach for designing and operating the electric grid, stacked with local renewables and staged for resilience. Community Microgrid's key features include a targeted and coordinated distribution grid area served by one or more substations, high penetrations of local renewables and other DER, have a staged capability for indefinite renewables-driven backup power for critical community facilities across the grid area, and can be readily extended throughout a utility service territory (Clean Coalition, 2019). At this moment, most policy and market mechanisms do not permit Community Microgrids as IOU's utilize most of the existing distribution grid and are not permittable to this modern approach.

This study aims to follow the key features listed above to become a replicable model for locating regions that are ideal for the development of Community Microgrids. The Suitability Modeling approach using the ArcGIS Spatial Analysist toolset lead to the creation of a Community Microgrid suitability raster layer that displays higher values for meeting all established criteria of key features for a Community Microgrid. This approach diminishes the need to manually filter and explore dozens of different data sets. While the data inputs can be changed to meet the needs of a specific study area, the outputs can also be refined to show automated Community Microgrid regions, layered with a solar siting survey to identify solar potential for those regions. By doing so, this is expected to help municipalities prioritize specific regions within a county, city, or neighborhood boundary that can be further studied for the potential of establishing a Community Microgrid.

2. Study Area and Data

2.1 Study Area

The Goleta Load Pocket (GLP) in Southern Santa Barbara County, is a 70-mile stretch of California coastline that extends from Point Conception to Lake Casitas. This region contains the major electrical loads of Goleta, Santa Barbara, and Carpinteria. The GLP is disaster-prone and completely grid-dependent, getting most of its power from just one set of transmission lines that are hung on the same transmission towers and routed through 40 miles of mountainous terrain. These transmission towers also route directly through high fire, debris flow risk, and earthquake risk areas.

The reason for the GLP's namesake comes from the single point of interconnection that the transmission grid has to the GLP, which is located at the Goleta Substation, a transmission to distribution substation. This is due to the fact that Santa Barbara County is split between the two largest IOUs, Pacific Gas and Electric (PG&E) and Southern California Edison (SCE). SCE is the IOU that serves the GLP and they have stated that due to the rugged mountainous terrain, any required repair and replacement of transmission lines and transmission towers could take up to several weeks if a natural disaster, such as a landslide or earthquake, occurs (A Hernandez, 2019).

The study area includes the GLP (Figure 1), with a total area of 950 mi^2. The GLP includes a mixture of urban environment, coastal regions, mountainous terrain, and conservation land. The transmission line travels entirely through Tier 3 and Tier 2 Fire Threat areas (Figure 2) and partially through high debris flow risk areas (Figure 3). Historical data derived from the Berkeley Lab shows that there is approximately 30MW of solar that is already in existence in the GLP and that the number of installations is increasing on average every year (Figure 4).

Figure 1: The boundaries of the GLP within the southern portion of Santa Barbara County, California containing the vulnerable transmission line in purple and high voltage distribution lines in orange.

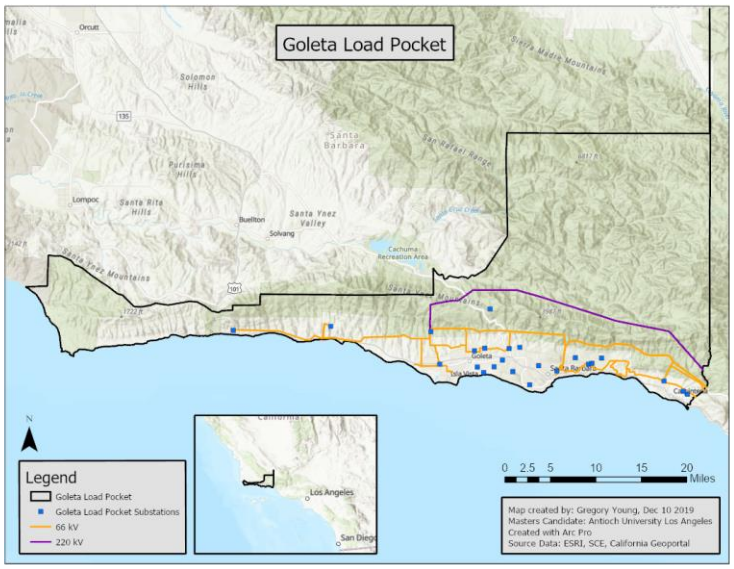


Figure 2: Tier 2 fire threat in orange and Tier 3 fire threat in red within the boundaries of the GLP and containing the transmission and distribution lines.

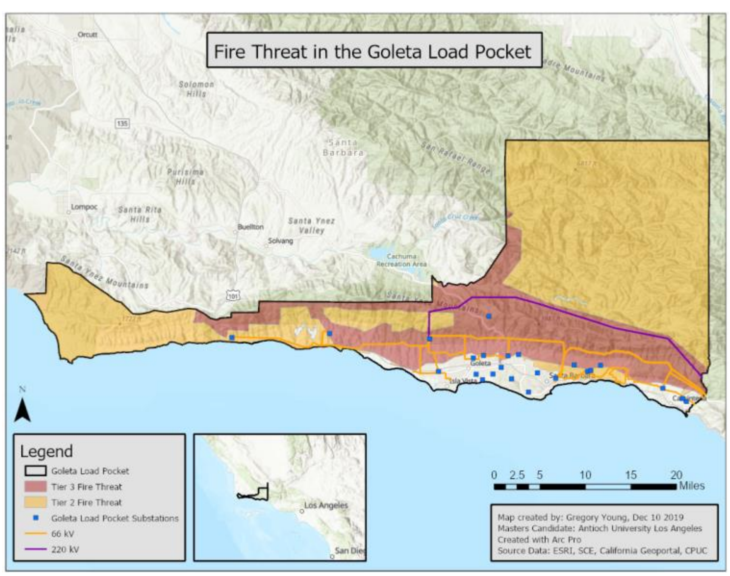


Figure 3: On the east side of the GLP, debris flow risk is the highest with some portions of the transmission line running through 80-100% likelihood of debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 24mm/h.

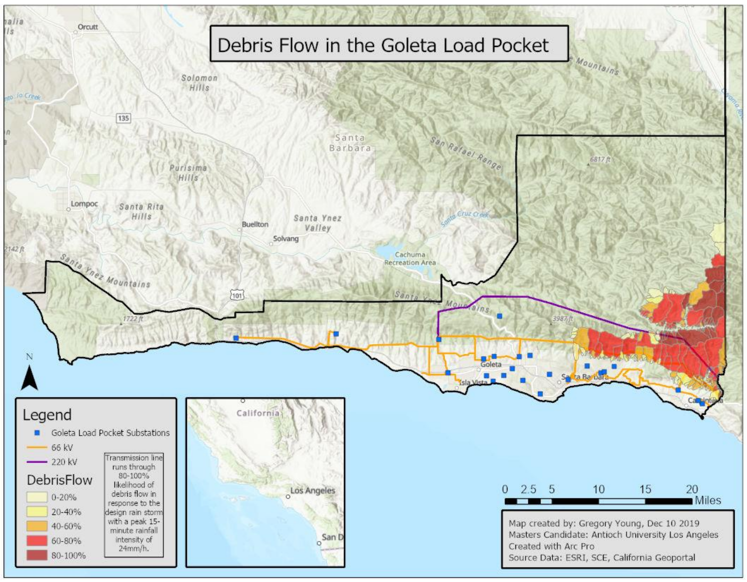


Figure 4: PV installations are increasing at a rapid rate within the GLP, with an estimated 3,250 occurring in 2019, seven times more than the amount of installations that occurred in 2003.

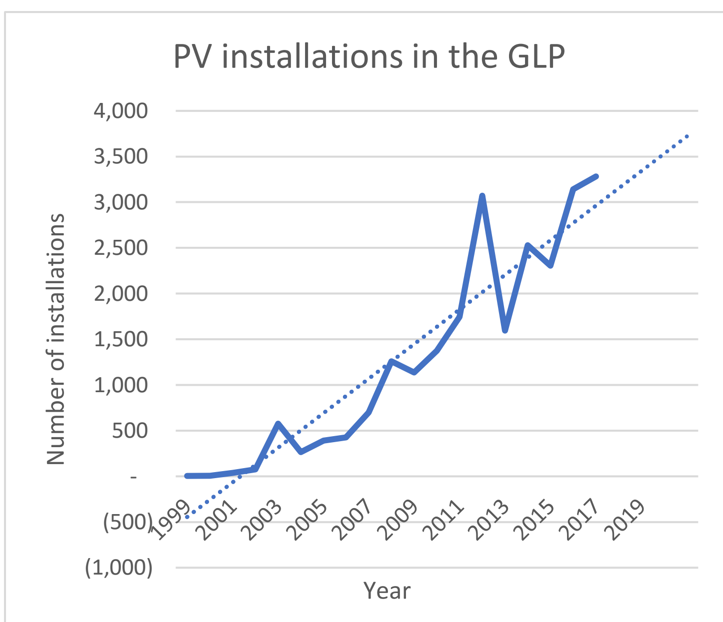


Table 1: Summary of data sets used in this study

Data Set	Acquisition Date	Application
Fire stations	11/10/19	Deriving suitability raster layer
Hospitals	11/10/19	Deriving suitability raster layer
Urgent care centers	11/10/19	Deriving suitability raster layer
Police stations	11/10/19	Deriving suitability raster layer
Critical sheltering sites	11/10/19	Deriving suitability raster layer
AB1550 areas	11/10/19	Deriving low income communities for suitability raster layer
SCE service layers (SCE Boundary, ICA segments, transmission and distribution lines, substations.	11/10/19	Defining study boundaries, important map elements, and suitability raster layer
SCAG California Counties	11/10/19	Defining study boundaries
CPUC Fire Threat areas	11/10/19	Defining study area
Solar Siting Survey points	11/10/19	Adding value to results
Debris flow risk	11/10/19	Defining study area

2.2 Study area data set

The study area was crafted through the combination of two layers, a Santa Barbara County boundary shapefile and a SCE boundary shapefile. The Santa Barbara County boundary shapefile was derived from the Southern California Association of Governments (SCAG) GIS Open Data Portal. While the SCE boundary shapefile was obtained through SCE's Distributed Energy Resource Interconnection Map (DERiM) found on ArcGIS Pro's catalog portal. The tier 2 and tier 3 fire threat layers were obtained from the California Public Utilities Commission and displayed in the study area to show the vulnerability of the transmission and distribution lines. While the debris flow risk layer was also obtained through the ArcGIS Pro's catalog portal and displayed to show vulnerability.

2.3 Critical community facilities data set

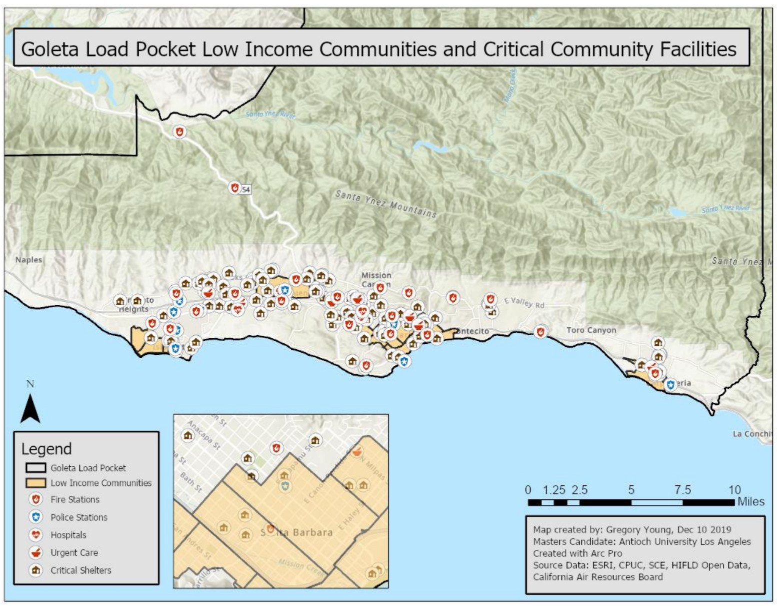
The fire stations, hospitals, urgent care centers, police stations, and critical sheltering sites were all collected through the Homeland Infrastructure Foundation – Level Data (HIFLD). All of these critical community facilities are key to understanding where high values of suitable regions will be located, as Community Microgrids will help provide these facilities with renewables driven backup power that is superior to diesel generators. In total, there were 161 critical community facilities used in the study with the following breakdown.

- 118 critical sheltering sites
- 22 fire stations
- 10 police stations
- 7 urgent care centers
- 4 hospitals

2.4 Low income community data set

Low income communities were derived from the California Environmental Protection Agency (CalEPA) AB1550 interactive map data. There are fourteen low income communities within the GLP and zero disadvantaged communities.

Figure 5: Critical community facilities layered over low income communities within the GLP.



2.5 Electrical infrastructure data set

Along with the SCE boundary, the electrical infrastructure layers were also obtained through SCE's DERiM found on ArcGIS Pro's catalog portal. The electrical infrastructure layers contain point and line feature classes for the substations, transmission lines, and ICA circuit segments. The ICA circuit segment layer was the only part of this data set that was used in the Community Microgrid suitability model.

Figure 6: ICA circuit segments layered within the GLP boundaries.

2.6 Solar siting survey data set

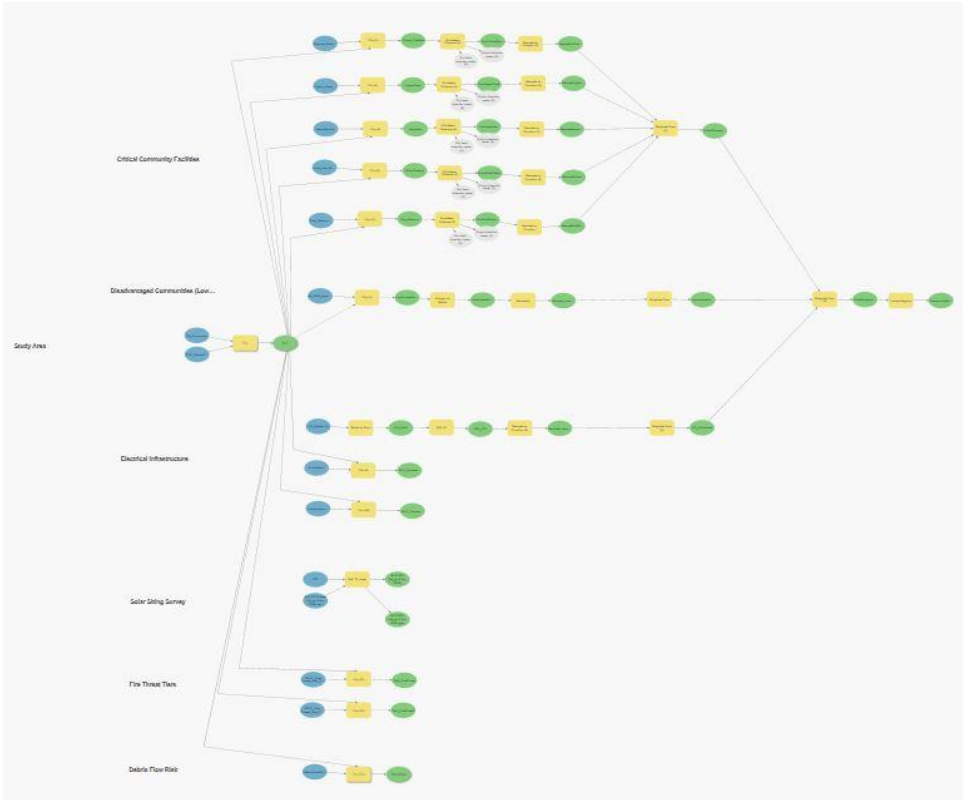
This data set was derived differently from the rest, as it was manually collected in Microsoft Excel and converted into a KML file to then be uploaded into Google Earth. Having originally gone through the process of collecting this data for a previous study, the data was then converted from a KML file to a layer file within ArcGIS Pro.

Table 1: Summary of structure type that includes the total structures and kW's surveyed

Summary by Structure Types

Roof_Flat	kW_Total	Roof_Angled	kW_Total	Pkg_Lot	kW_Total	Pkg_Garage	kW_Total	Sailing	kW_Total
455	78,108 kW	143	7,705 kW	380	173,400 kW	3	1,075 kW	-	- kW
63	11,775	12	1,823	35	17,686	-	-	-	-
40	4,320	29	932	39	20,786	2	733	-	-
17	3,042	12	273	23	5,934	-	-	-	-
26	2,508	21	569	24	10,112	-	-	-	-
38	8,348	1	91	37	17,940	-	-	-	-
211	38,182	26	1,757	162	80,108	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-

Figure 7: The entire model shown consists of the study area, Community Microgrid suitability model, solar siting survey, fire threat tiers, and debris flow risk



3. Methods

3.1 Creating the study area

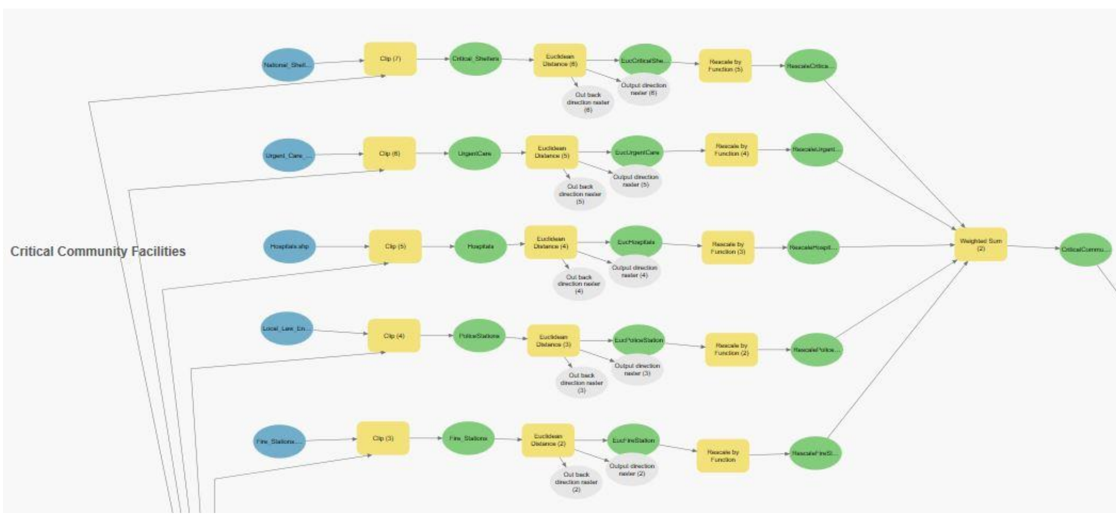
The GLP is defined as the SCE territory boundaries within Santa Barbara County. Deriving the GLP shapefile involved clipping the SCE boundary features to the Santa Barbara County boundary input features. A few minor adjustments to the outline thickness allowed for the GLP boundaries to stand out when layered over the default topographic map. The tier 2 fire threat layer, the tier 3 fire threat layer, and the debris flow layer were then created using the new GLP boundary input feature and the clip tool.

3.2 Creating the critical community facilities suitability sub model

The first part of the Community Microgrid suitability model involved creating the critical community facilities sub model. All of the critical community facility datasets encompassed the entire United States and had to be clipped down to the GLP study area. Once this was complete for fire stations, police stations, hospitals, urgent care centers, and critical community facilities, the distance away from these facilities had to be calculated. Using the Euclidean Distance tool with no maximum distance, allowing the tool to run to the extent of the study area, the resulting Euclidean Distance raster layers were created. The values of these raster layers then had to be transformed onto a specified continuous evaluation scale, so that all of the critical community facility raster layers had the same value from 1 to 10. These values indicate that cells closer to the critical community facilities receive higher values, with 10 being the highest value and 1 being the lowest. This was calculated using the Rescale by Function tool with a small transformation function, a lower threshold of 0 meters, and an upper threshold of 400 meters.

With five different critical community facility Rescale by Function rasters, they all had to be overlaid together into one raster, the suitability sub model. At this point in the model process, the values of each critical community facility could be weighted differently. For example, if the designer of the model wanted fire stations to receive higher values than all of the other critical community facilities, the designer would rate the weight higher for fire stations. This would make the final suitability raster favor fire stations more than other critical Community Facilities. This is done using the Weighted Sum tool and changing the weight for each input raster accordingly. For this suitability model, the weights for each critical community facility were kept the same, with the value of 1. The final critical community facilities suitability sub model was then produced by running the Weighted Sum tool.

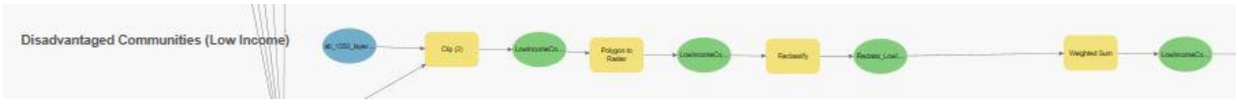
Figure 8: The critical community facilities suitability sub model, as described above.



3.3 Creating the low-income community's suitability sub model

The second part of the suitability model involved creating a low-income communities suitability sub model. This sub model only contains a single string of tools for its creation but could be expanded to include other disadvantaged community criteria in the future. Evaluating low-income communities in this model provides the opportunity for Community Microgrids to be established in regions where people may benefit the most. In order to assure that the model evaluates values within a low-income community, rather than outside of one, the polygon layer had to first be converted to a raster layer using the polygon to raster tool. Then using the Reclassify tool, the values were changed so that inside of low-income communities received a value of 10 and outside low-income communities received a value of 0. If more disadvantaged community criteria were added in the future, the Weighted Sum tool would be used to change the weight for each input. For this study, with only a single disadvantaged community criterion, the weighted sum tool was established just in case of future changes.

Figure 9: The low-income community suitability sub model, as described above.



3.4 Creating the ICA suitability sub model

The ICA suitability sub model involved a few different tools and steps compared to the other sub models. As a general understanding, certain circuit segments have higher operational flexibility than others do. Which means that a certain number of kilowatts from solar PV could be interconnected at that feeder segment without requiring a study to determine operational flexibility. With the release of IOU's ICA maps, the value of operational flexibility on every feeder segment is provided to the general public through an interactive map that the IOU's update. In SCE service territory this ICA map is called the Distributed Resources Plan External Port (DRPEP). While DERiM was where the data was sourced, the two are one in the same. Recently the ArcGIS DERiM map has been discontinued but the data still remains available through ArcGIS Pro's portal catalog.

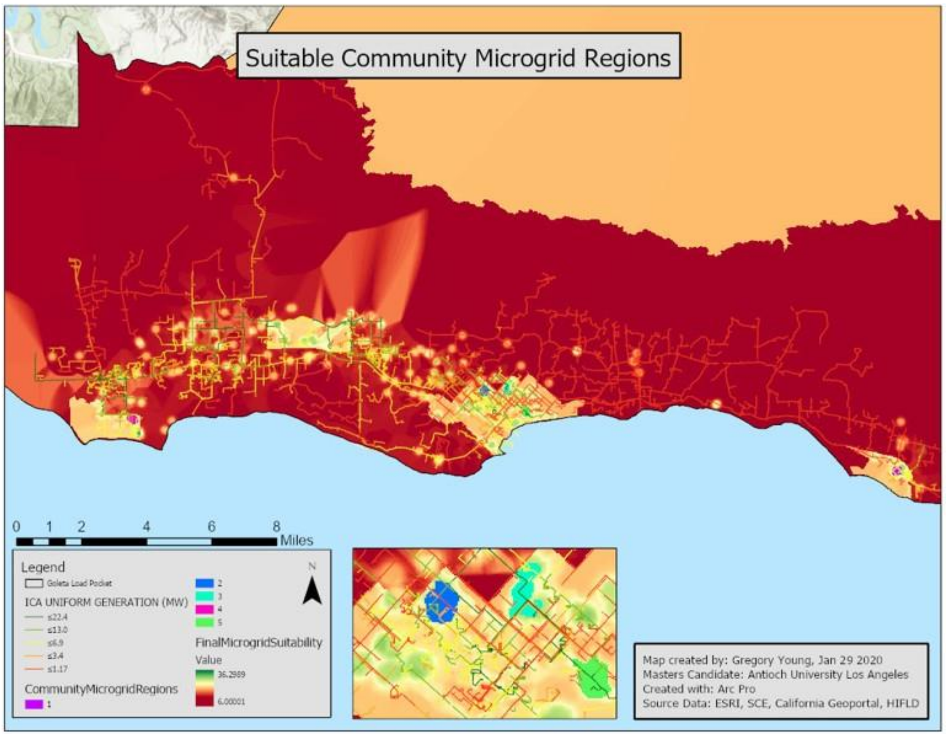
For the purpose of this study, the circuit segments with high operational flexibility were given higher values. This was accomplished by first converting the ICA circuit segment line feature class to a raster data set. This was done using the Raster to Point tool, so that the raster data set could then be converted to a point feature class. Once in a point feature class, a raster layer can be interpolated from those points using an inverse distance weighted technique, known as the IDW tool. The resulting IDW ICA raster layer displayed values surrounding the circuit segments that aligned with the segment's operational flexibility values. These results were then rescaled using a linear transformation function of the Rescale by Function tool. Lastly, like the low-income suitability sub model, the ICA suitability sub model is established so that associated criteria could be added on and included in the existing Weighted Sum tool.

Figure 10: The ICA suitability sub model, as described above.

3.5 Creating the final suitability raster

The final Community Microgrid suitability raster involved taking the weighted sums across all three sub models. At this point, all three rasters were given the same weight value of one. This created a final suitability raster in which a color ramp was added so that the color green is associated with higher values and the color red is associated with lower values.

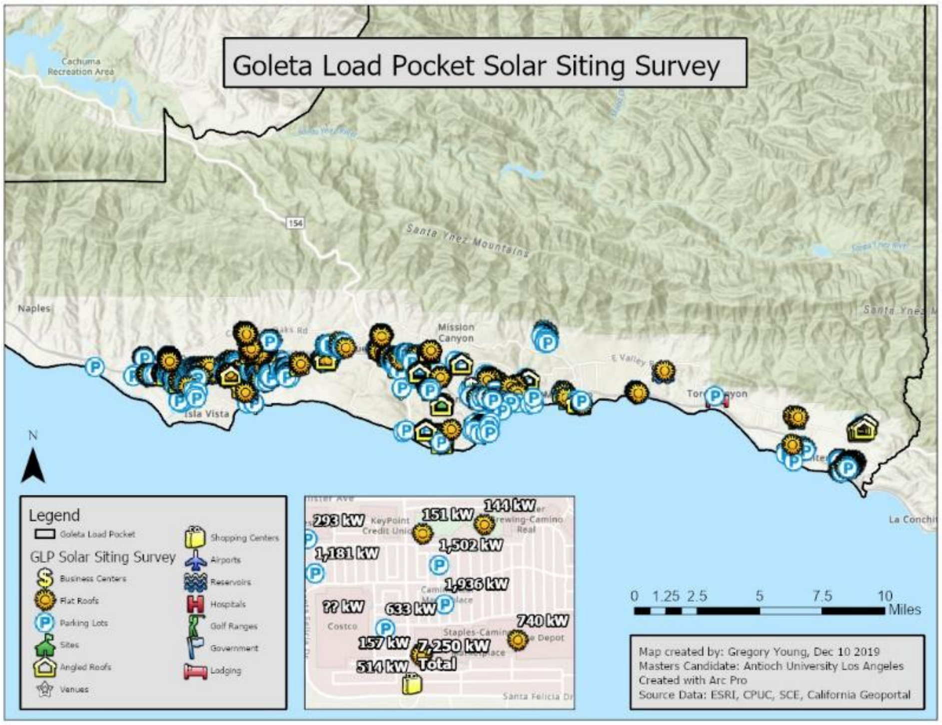
Figure 11: The final Community Microgrid suitability model, as described above



3.6 Creating and layering the solar siting survey

The data was collected through a solar siting survey methodology that involves measuring the square footage of built environments (rooftops, parking lots, and parking structures) and inputting those values into an Excel spreadsheet, which is programmed to display the total kilowatts per that square footage. Built environments within a given site that had a total of 1MW of potential, was surveyed. Over 300MW of solar siting potential was identified across the entire GLP with more than 50% of that potential existing on parking lots. Since this data was stored inside of a Microsoft Excel spreadsheet and then converted to a KML file to be uploaded into Google Earth, the KML file had to be converted to a shapefile with the KML to Shapefile tool. This new shapefile then allowed me to overlay it over the GLP study area.

Figure 12: Solar siting survey within the GLP study area



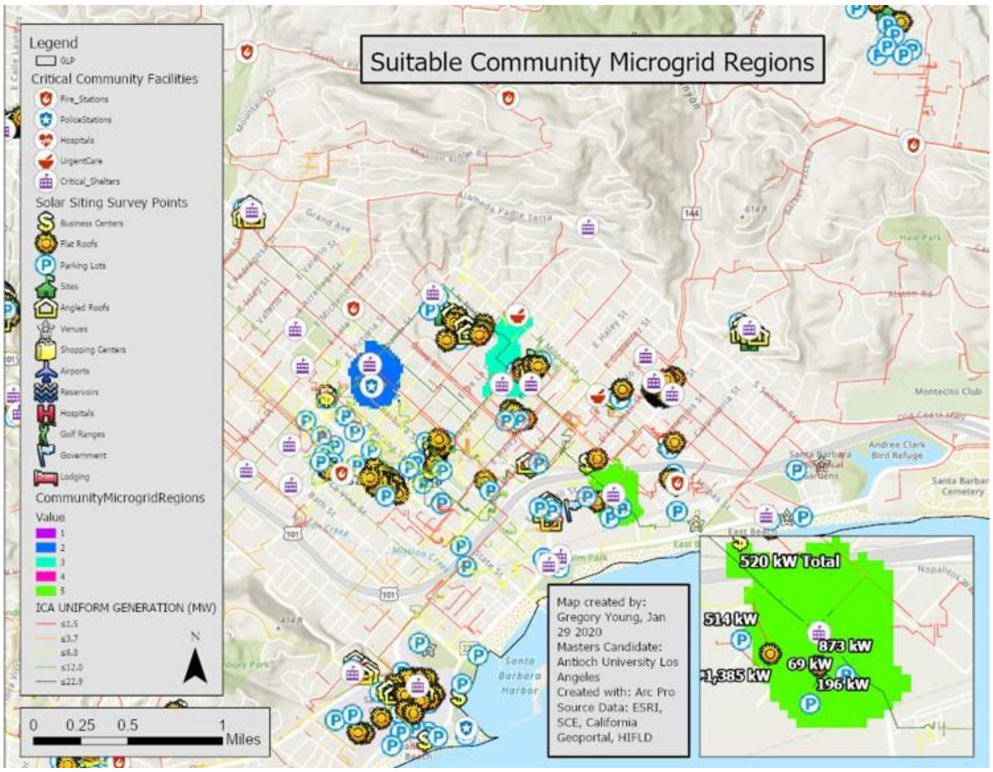
4. Results

4.1 Locating regions

While the final Community Microgrid suitability raster's ability to showcase values is unique, it is still relativity difficult to locate suitable regions with the naked eye. This is where the Locate Regions tool has been extremely effective in automating the process of finding regions most suitable for Community Microgrid development based on the established criteria. The total area included in the parameters of the Locate Regions tool was set at 2,000,000 square meters and the number of regions set at 5, with a region shape of a circle. The locate regions tool produced five regions throughout the GLP.

The solar siting survey and critical community facilities were then overlaid on top of the Community Microgrid Suitability regions to display the effective potential for solar PV within or near each region and the associated critical community facilities that was used to help define the region.

Figure 13: Community Microgrid suitability regions with solar siting potential



5. Conclusions

The Community Microgrid Suitability Modeling approach to locating regions of high suitability for the development of Community Microgrids has shown effective in its ability to automate an otherwise long and strenuous process. The model was also constructed so that it can be replicated anywhere in which the criteria are made available. The only one of these criteria that is expected to be problematic are the ICA maps. While SCE ICA maps are known to be available for this process, the ability to download and utilize PG&E's ICA maps is currently unknown. Also, some municipal utilities have not been held to the same standards as IOU's for sharing these ICA maps. However, the Community Microgrid Suitability Model still remains an effective approach to locating suitable regions for Community Microgrid development with or without ICA maps. The ICA suitability sub model could simply not be included, while other sub models could also be added. Further tweaking of certain parameters may also yield more favorable results and the Community Microgrid Suitability Model could be refined over time to become a more effective tool.

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