Solar PV Siting Survey for Anchorage, Alaska

Study Report

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Abstract: The purpose of this project is to build a model using ArcGIS. The model will be used to determine appropriate sites for installing commercial-scale solar photovoltaic (PV) of 1,000 kW (AC) or larger throughout Anchorage, Alaska, with lower cost and higher efficiency. This work is based on previous East Bay Community Energy (EBCE) project by Clean Coalition. Light Detection and Ranging (LiDAR) data from 2015 covering Anchorage was provided and analyzed. Final siting map is generated and shown in .kml file.

1. Introduction

Increasing interest in utilizing solar power has gone up in Alaska due to the increasing cost of other energy resources and some environmental concerns. Anchorage used to be a relatively small market of solar energy. However, it has been developing rapidly since 2011 as solar technology has improved to better take advantage of long summer in Alaska and make it work in winter. Therefore, the need to determine where to set up new solar panels more quickly brought about this project to build a model using ArcGIS, which, provided LiDAR data, could accurately find high-quality sites for solar panels.

LiDAR is a remote sensing method that uses pulsed laser to measure variable distances from the earth. Combining the data from Airborne System, it could give precise three-dimensional information about the shape of Earth and its surface characteristics [1].

The approach starts with raw LiDAR, dividing the points into different classes: building, vegetation, bare ground etc., and creating shape files of feature classes. Then the buildings will be picked for further analysis to choose usable rooftops according to information such as minimum and maximum elevations (showing pitched or flat roof), aspect, their area, etc. The parking lots are processed similarly. However, because of their diverse and complex structures, it is hard to generate classification function to automatically assign a structure to parking lot class. The parking lots were manually picked using parking signs on the map. Furthermore, fire tracks also needed more attention when dealing with parking lots [2], [3].

2. Data and Methodology

The LiDAR survey, covering area around 957 square miles in and around Anchorage Alaska, was performed by Merrick and Company (Merrick), who was contracted with Municipality of Anchorage (MOA). The current coordinate system is NAD_1983_StatePlane_Alaska_4_FIPS_5004(US feet). Approximately 240 .las files from the entire dataset were employed based on Anchorage community councils. The targeted density of the LiDAR point cloud was planned at a minimum of two points per square meter (2 ppsm) and four points per square meter (4 ppsm), while the Vertical Accuracy = 9.25 cm in the interest of meeting a 1-foot contour accuracy specification [4].

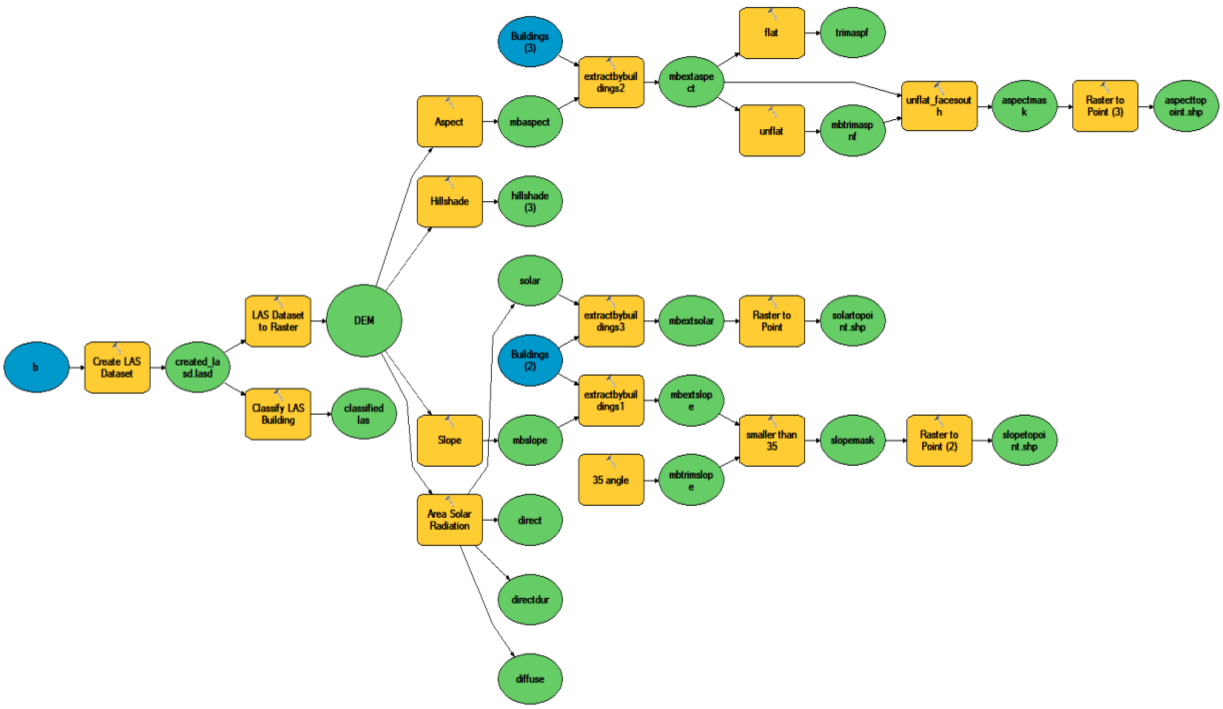

Figure 1 Model Builder to generate shapefiles

The figure above shows the process of the model to decide if the rooftop of a building is suitable for desired solar panel installation.

First, a LAS dataset is generated using the LAS files picked. There are several tools in ArcGIS could finish this task. The context menu of ArcMap catalogue or Arc Catalogue could create one new LAS dataset directly. Las dataset has file extension '. lasd'. A LAS dataset could store reference to more than one LAS files at once and quickly display lidar data as point clouds or a triangulated surface in 2D and 3D.

The LAS dataset then be used to classify buildings. A set of numeric codes were assigned to each LiDAR points with 1 as unassigned and 6 as building. Those points with code 6 were just filtered and selected. Those points with code were classified with the help of GDB file for buildings. All the other points were then dropped.

In addition, LAS dataset was also used to generate additional surfaces such as DEMs (LAS Dataset to Raster geoprocessing tool). LAS dataset is used as input, a digital elevation model (DEM) was then derived and saved as a floating-point raster image. The last returns of raw data were retained during the interpolation process and DEM is three-dimensional representing 'bare-earth surface' [5]. The raster was georeferenced using the Georeferencing toolbar in ArcGIS [6].

A solar map was generated using Area Radiation Tool from georeferenced images. The Area Solar Radiation tool estimates total insolation as sum of diffuse and direct radiation. For this tool, American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) algorithm was adopted [6]. It has more complicated equations compared to other algorithms such as Master's algorithm. The parameters are: area of each surfaces; X and Y coordinates of center points; elevation of center point; tilt and azimuth (change of elevation) of each surface. Tilt and Azimuth are calculated as following: Select three points A, B and C with same original FID; Tilt angle is calculated by between normal vector N (of AB and AC) and unit vector K (0,0,1); azimuth is calculated between N and unit vector J (0,1,0). With these two parameters calculated, the direct, diffuse and ground-reflected irradiances on the surface are calculated using equations below:

$$\mathrm{Et,b} = \mathrm{Eb} \times \cos\theta$$

$$\mathrm{Et,d} = \mathrm{Ed} \times \max(0.45{,}0.55 + 0.437\cos\theta + 0.313cos^2\theta)$$

$$\mathrm{Et,r} = (\mathrm{Eb}\sin\beta + \mathrm{Ed})\rho\mathrm{g}(1 - \cos\sum)/2$$

where Et_b, Et_d, and Et_r are direct, diffuse and ground-reflected irradiances on a surface respectively; Eb and Ed are direct normal and diffuse horizontal irradiances, which could be obtained from GIS-based software; θ is the angle of incidence of the surface; β is solar altitude angle; ř is surface tilt angle; and ρg is ground reflectance [7].

While using the tool, the mean latitude was automatically calculated using input spatial raster. The other specific parameters used are as following: the resolution was set to 300; The time configuration(period) was specified as from the 5th and 160th day of 2018; Day interval used for calculation was set to 15 while hour interval set to 0.5; The slope and aspect rasters are calculated from the input surface raster. The other parameters were default set by program. It could be told that this solar map takes into account the position of sun, the azimuth (change of elevation) and any shading effect caused by buildings or other objects in the input raster that blocks the sunlight.

Four masks were produced in the use of selecting desired characteristics of the locations. Aspect masks works to choose suitable aspects. Since Anchorage is in the northern hemisphere. Solar panel should be south-facing to get higher solar power. It was generated from georeferenced image and it was binary: 1 for pass and 0 for fail. More specifically, aspect with between 112.5 to 247.5 was suitable since it represents the south. Other masks were generated similarly: Slope masks chose flat rooftop with slope less than 35 degree; Radiation mask set the minimum radiation threshold based on the efficiency of the solar panels; Hillshade mask decides the minimum number of days the position was in the shade [6].

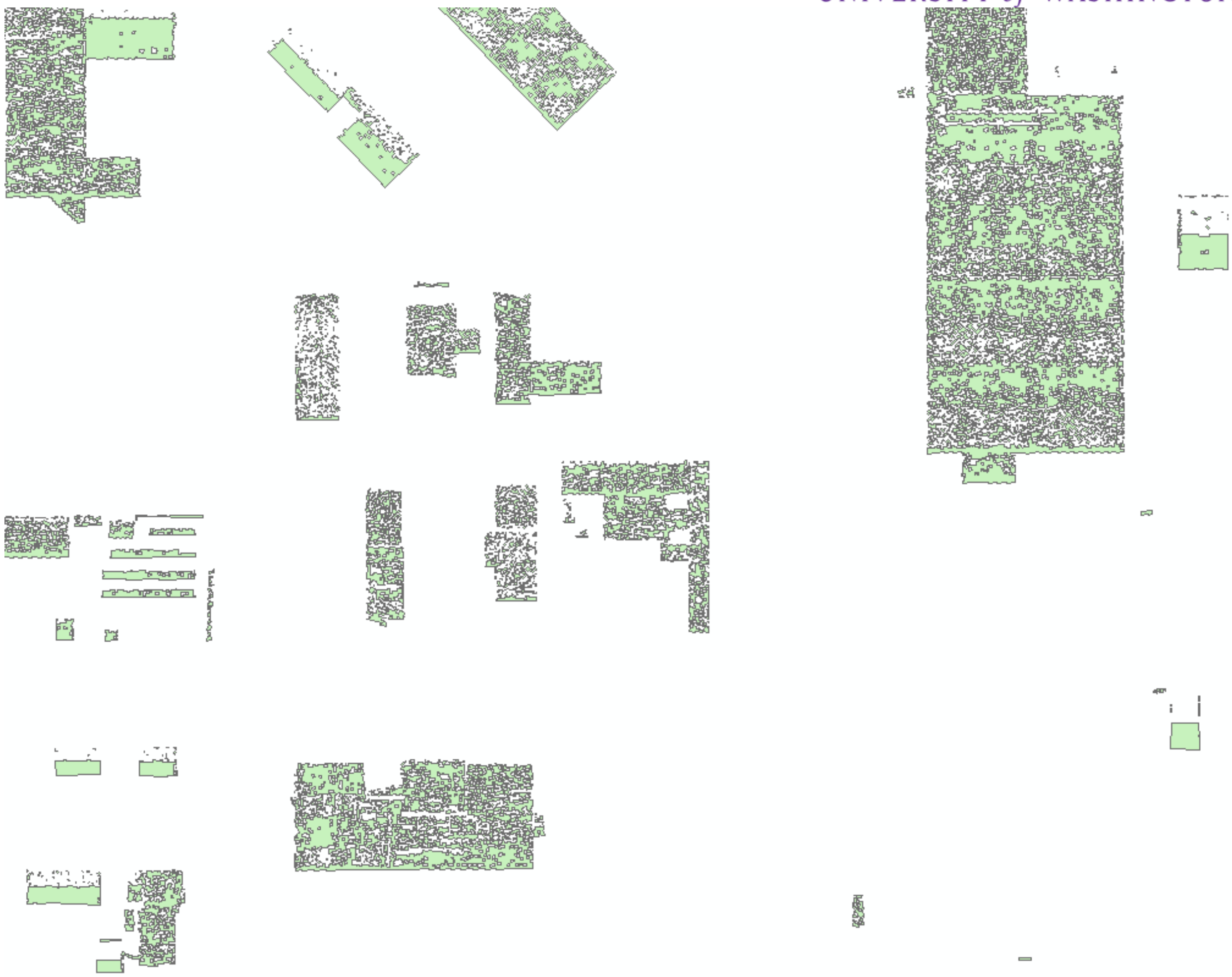

Figure 2 Example of regularized total mask

The Extract by Mask tool was then utilized to extract the cells of a raster that correspond to the areas defined by a mask. This will be used as input of Raster to Point tool generating feature shape files for suitable places (point features). The Aggregate points tool was then employed to summarize a set of point features, before zonal statistics were calculated. The results of statistics would be used on the basis of the standard of the solar panels to do one more filtering and selecting processes. One-and-a-half square meters was used as the required area for each solar panel.

3. Results

The following deliverables for case study are built:

a) .kml (Keyhole Markup Language) files for case study area, which can be displayed on Google Earth or imported into Google Maps;

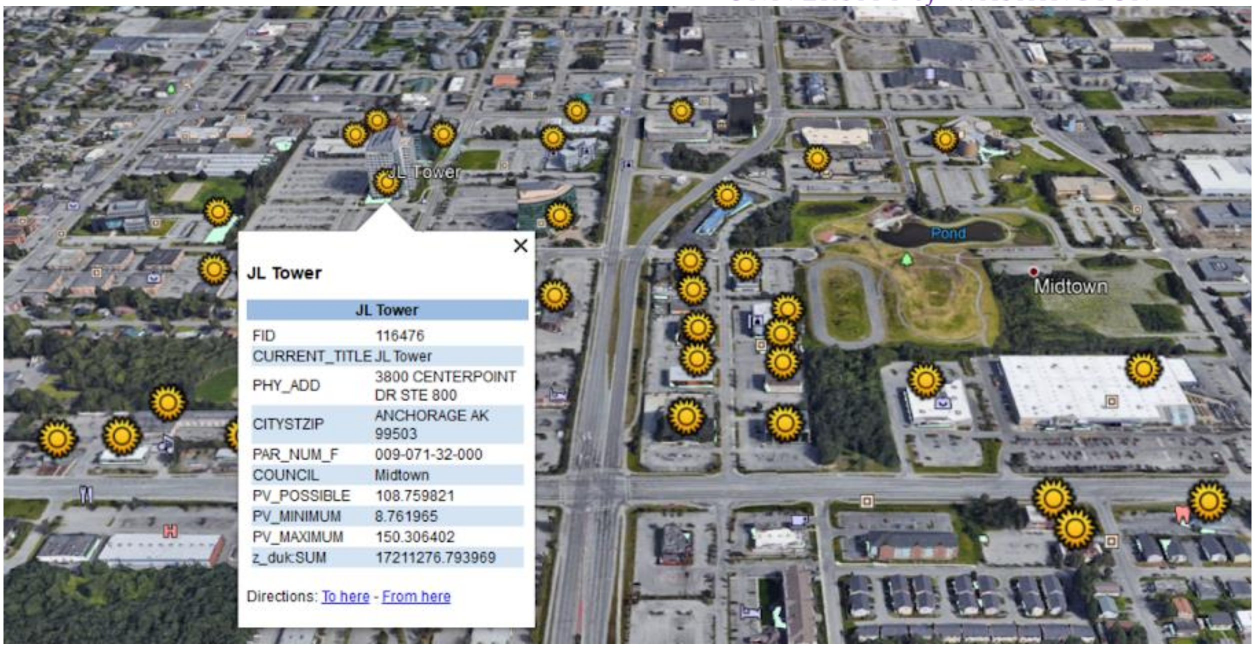

Figure 3 Example of Google Earth Pro Display

b) xslx (Excel) spreadsheet containing all the data used to generate the .kml file, as well as summary breakdowns of the findings.

FID	Shape	CURRENT_TITLE	PHY_ADD	CITYSTZIP	PAR_NUM_F	COUNCIL	PV_POSSIBL	PV_MINIMUM	PV_MAXIMUM
68680	Polygon		333 E TUDOR RD	ANCHORAGE AK 99503	009-132-11-000	Midtown	1561.631008	36.566584	1959.5471
65811	Polygon	Loussac Library	3600 DENALI ST	ANCHORAGE AK 99503	009-081-11-000	Midtown	598.462784	86.767881	770.538873
65848	Polygon	Frontier Building	3601 C ST STE 1140A	ANCHORAGE AK 99503	009-071-18-000	Midtown	517.470729	105.875623	661.621087
117064	Polygon		3750 CENTERPOINT DR	ANCHORAGE AK 99503	009-071-31-000	Midtown	510.331749	145.311395	640.498323
68679	Polygon	Office Depot	201 E TUDOR RD	ANCHORAGE AK 99503	009-132-13-000	Midtown	321.679884	50.09892	409.74063
66093	Polygon	Us Post Office	3720 BARROW ST	ANCHORAGE AK 99503	009-081-23-000	Midtown	319.898084	58.463652	402.210144
119737	Polygon	West Center	4503 BERING ST	ANCHORAGE AK 99503	009-153-39-000	Midtown	315.888314	56.574373	387.870878
116477	Polygon		3801 CENTERPOINT DR	ANCHORAGE AK 99503	009-071-34-000	Midtown	252.486286	56.666249	354.330071
119540	Polygon		3700 CENTERPOINT DR	ANCHORAGE AK 99503	009-071-31-000	Midtown	214.278365	41.625915	305.969848
65722	Polygon	Debenham Plaza	300 W 36TH AVE STE 3	ANCHORAGE AK 99503	009-071-14-000	Midtown	241.530675	85.202938	290.069075
68699	Polygon		341 W TUDOR RD STE 205	ANCHORAGE AK 99503	009-141-37-000	Midtown	211.345536	45.209305	272.600701
68448	Polygon		4333 BERING ST	ANCHORAGE AK 99503	009-142-02-000	Midtown	197.250497	127.860098	240.293357
69084	Polygon		4400 BUSINESS PARK BLVD STE 34	ANCHORAGE AK 99503	009-151-04-000	Midtown	167.191744	52.262544	208.406519
67995	Polygon	State Farm Insurance	4215 CREDIT UNION DR	ANCHORAGE AK 99503	009-141-35-000	Midtown	152.41903	73.97301	183.128991
67244	Polygon		4040 B ST	ANCHORAGE AK 99503	009-141-30-000	Midtown	135.045015	52.641103	168.907887
117401	Polygon		4101 CREDIT UNION DR	ANCHORAGE AK 99503	009-141-34-000	Midtown	130.499436	18.527726	157.04747
67111	Polygon		531 W 41ST AVE	ANCHORAGE AK 99503	009-143-36-000	Midtown	129.305651	75.648497	156.534579
67111	Polygon		531 W 41ST AVE	ANCHORAGE AK 99503	009-143-36-000	Midtown	129.305651	75.648497	156.534579
116476	Polygon	JL Tower	3800 CENTERPOINT DR STE 800	ANCHORAGE AK 99503	009-071-32-000	Midtown	108.759821	8.761965	150.306402
67812	Polygon		4140 B ST	ANCHORAGE AK 99503	009-141-28-000	Midtown	109.809765	27.104634	147.736892
69319	Polygon		4501 BUSINESS PARK BLVD STE 24	ANCHORAGE AK 99503	009-151-11-000	Midtown	121.821985	48.139717	146.716445
69319	Polygon		4501 BUSINESS PARK BLVD STE 24	ANCHORAGE AK 99503	009-151-11-000	Midtown	121.821985	48.139717	146.716445
67703	Polygon		4141 B ST STE 405	ANCHORAGE AK 99503	009-141-29-025	Midtown	110.420099	24.168913	134.951754
65989	Polygon		3695 SPRINGER ST	ANCHORAGE AK 99503	009-072-29-000	Midtown	106.049832	41.245089	134.420041
67345	Polygon		510 W 41ST AVE STE F	ANCHORAGE AK 99503	009-143-36-000	Midtown	108.414896	29.456581	132.686156
69256	Polygon		4411 BUSINESS PARK BLVD STE 46	ANCHORAGE AK 99503	009-151-12-000	Midtown	107.046007	44.367056	130.385508
67535	Polygon		4102 B ST	ANCHORAGE AK 99503	009-141-13-000	Midtown	108.502286	53.083068	129.102278
67535	Polygon		4102 B ST	ANCHORAGE AK 99503	009-141-13-000	Midtown	108.502286	53.083068	129.102278
67535	Polygon		4102 B ST	ANCHORAGE AK 99503	009-141-13-000	Midtown	108.502286	53.083068	129.102278
67216	Polygon		4000 CREDIT UNION DR STE 635	ANCHORAGE AK 99503	009-141-38-000	Midtown	98.624192	7.205935	126.943251
67227	Polygon		4041 B ST STE 104	ANCHORAGE AK 99503	009-141-11-000	Midtown	94.920412	16.327522	125.241538
68103	Polygon		4240 B ST STE 100	ANCHORAGE AK 99503	009-141-21-000	Midtown	102.150415	50.59078	124.767145
68349	Polygon	Hampton Inn	4301 CREDIT UNION DR	ANCHORAGE AK 99503	009-141-39-000	Midtown	113.014883	30.164139	122.878843
68866	Polygon		110 W TUDOR RD	ANCHORAGE AK 99503	009-151-31-000	Midtown	100.928188	43.300892	122.311236
68503	Polygon		4341 B ST STE 303	ANCHORAGE AK 99503	009-141-03-000	Midtown	97.668975	48.059617	119.044543
68875	Polygon		4420 BERING ST APT 3	ANCHORAGE AK 99503	009-153-18-000	Midtown	95.548988	38.141997	117.347386
68875	Polygon		4420 BERING ST APT 3	ANCHORAGE AK 99503	009-153-18-000	Midtown	95.548988	38.141997	117.347386
68875	Polygon		4420 BERING ST APT 3	ANCHORAGE AK 99503	009-153-18-000	Midtown	95.548988	38.141997	117.347386
65733	Polygon	Akusa Financial Center	500 W 36TH AVE STE 12	ANCHORAGE AK 99503	009-071-30-000	Midtown	86.739328	12.320406	114.548901
66656	Polygon	Office Building -Arctic Slope R	3900 C ST	ANCHORAGE AK 99503	009-071-26-000	Midtown	87.582439	7.391545	111.557998
67104	Polygon		521 W 41ST AVE STE 101	ANCHORAGE AK 99503	009-143-36-000	Midtown	86.819286	35.223942	103.745763
67204	Polygon		501 W 41ST AVE STE D	ANCHORAGE AK 99503	009-143-36-000	Midtown	84.166726	33.918391	102.569046
67204	Polygon		501 W 41ST AVE STE D	ANCHORAGE AK 99503	009-143-36-000	Midtown	84.166726	33.918391	102.569046
67204	Polygon		501 W 41ST AVE STE D	ANCHORAGE AK 99503	009-143-36-000	Midtown	84.166726	33.918391	102.569046
67204	Polygon		501 W 41ST AVE STE D	ANCHORAGE AK 99503	009-143-36-000	Midtown	84.166726	33.918391	102.569046
67106	Polygon		511 W 41ST AVE STE 101	ANCHORAGE AK 99503	009-143-36-000	Midtown	74.413826	34.820618	89.683591
67883	Polygon		4201 B ST	ANCHORAGE AK 99503	009-141-07-000	Midtown	73.786535	35.612018	88.351973
67883	Polygon		4201 B ST	ANCHORAGE AK 99503	009-141-07-000	Midtown	73.786535	35.612018	88.351973

Figure 4 Example of table obtained

c) Python Scripts that could be used for other area.
All python code and module can be seen in our GitHub Repository. The GitHub URL is https://github.com/Yueningwang/ASAP

4. Discussion and Conclusion

There are several limitations for this study. First, the unclassified buildings were selected with building GDB files provided. Thus, this approach is not going to work well if the building data is not available. Besides, there are noises not able to be eliminated completely, such as big trucks classified as buildings. The other limitation is shading effect was not fully analyzed by just using Hillshade mask. More elements are needed considering. For example, what time during the day is the location in shade. The other thing needed improving is the consideration of the budget.

5. References

[1]. Nation Ocean Service. *What is Lidar?* NOAA. Online. https://oceanservice.noaa.gov/facts/lidar.html

[2]. Tuan B. Le, Danial Kholdi, Hongjie Xie, Bing Dong and Rolando E. Vega. *LiDAR-Based Solar Mapping for Distributed Solar Plant Design and Grid Integration in San Antonio, Texas*. Remote Sens. 2016, 8, 247; doi:10.3390/rs8030247.

[3]. Clean Coalition. Solar Siting Survey Draft Final Summary Report: Solar Photovoltaic (PV) Commercial-Scale Sites for 1,000 kW (AC) and Larger. August 2017. www.clean-coalition.org

[4]. Robert Wheelwright. *LiDAR Quality Assessment Report*. USGS. 2017-01-12.

[5]. Christopher James Griesbach*. Improving LiDAR Data Post-Processing Techniques for Archaeological Site Management and Analysis: A Case Study from Canaveral National Seashore Park*. 2015. Graduate Theses and Dissertations. http://scholarcommons.usf.edu/etd/5491

[6]. Andrea Chaves and A. Terry Bahill. *Locating Sites for Photovoltaic Solar Panels Pilot study uses DEM derived from LiDAR.* ArcUser Fall 2010.

[7]. *ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers). Fundamentals: Chapter 14—Climatic Design Information. In ASHRAE Handbook;* ASHRAE: Atlanta, GA, USA, 2009.