Potential Solar Energy Production in Salt Lake City

Abstract

The goal of this project was to analyze the solar energy production potential of urban and residential buildings in Salt Lake City. With the availability of .5m Lidar digital surface models provided by the Utah Geological Survey, I was able to analyze the yearly solar radiation in Salt Lake City. With this information I found the most suitable locations within the city to place solar panels and their potential yearly output. In total Salt Lake City has a mean potential green energy production of 34 Megawatts each year, enough to power roughly 4-5% of Salt Lake City's total energy consumption.

1. Motivation

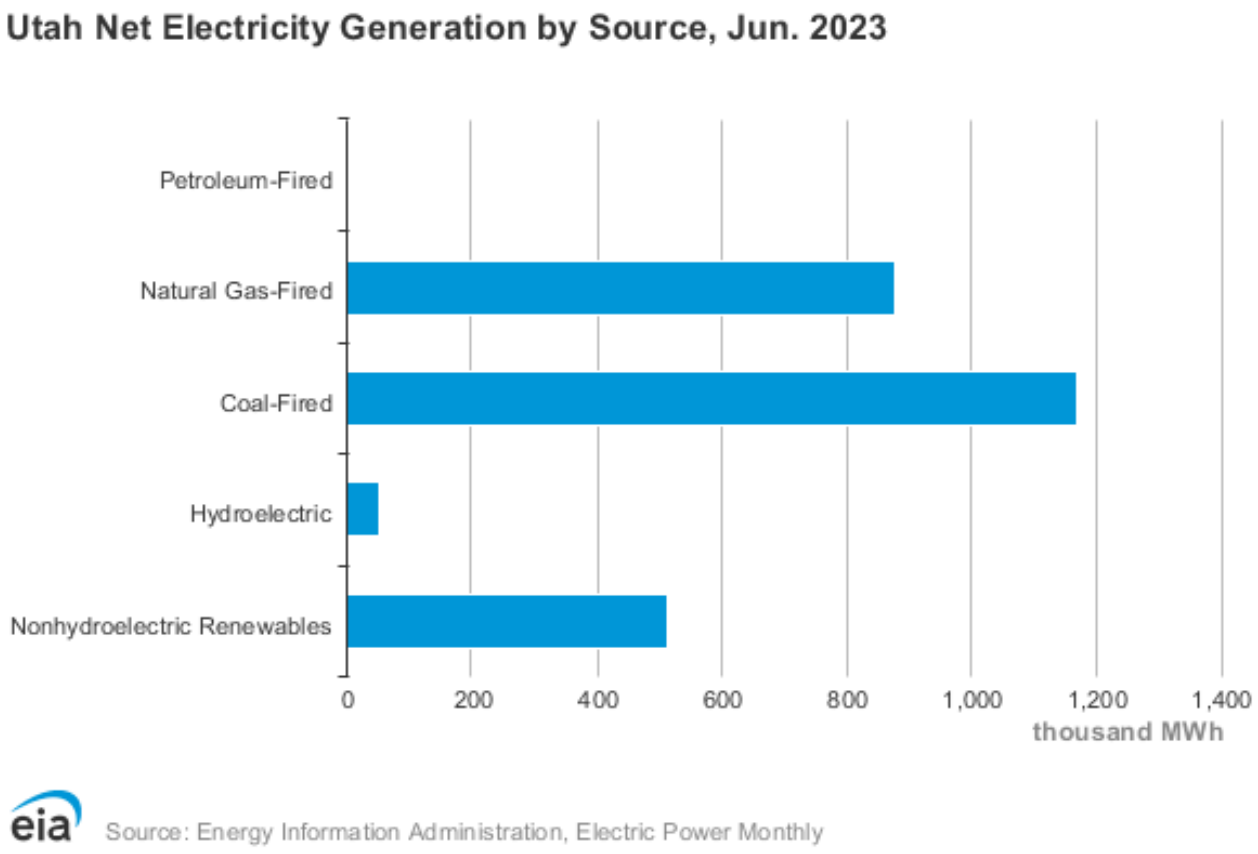
1.1 Introduction

In our time, during this global climate criss, we are faced with many environmental problems primarily caused by our greenhouse gas emissions and reliance on outdated methods of energy production. In Utah we can already visibly see the consequences of these emissions, during our winters we are forced to essentially live in a polluted city with poor air quality that presents great health risks. The pollution which is occuring all year round but is more exacerbate due to inversion in this primarily contributed to fossil fuel and wood fuel burning.

A potential solution to solving this pollution problem is to switch to an alternate method of producing energy. Currently the whole state of Utah consumes 500 trillion Btu of coal

and natural gas and produces 2,000,000 megawatt-hours from these methods as well. While only 500,000 megawatt-hours from renewable resources.

Therefore, this project sets out in search of a potential renewable energy production. To do this I will model annual solar radiation in Salt Lake City and determine which buildings would be most efficient to capture this radiation and turn it into energy using solar panels.



2. Methods

2.1 Data Collection

For this project the primary data needed is a digital surface model of Salt Lake Valley, building footprints for Salt Lake City, our power transmission infrastructure, and Salt Lake municipal boundaries.

I was able to find .5 meter resolution digital surface models(DSM) provided by the Utah Geological Survey. This data was part of a project by UGS in which they mapped the whole Wasatch front using Lidar during 2013 - 2014. I downloaded 13km^2 of Lidar data covering Salt Lake City. The building footprints, municipal boundaries, and power transmission lines were all provided by the Utah Automated Geographic Reference Center. Although this may not seem like a lot of data, the Lidar DSM dataset will go on to produce a wealth of additional information.

I created a new project in ArcGIS Pro and connected the folders containing each set of data to later be used in different maps.

2.2 Digital Surface Model Processing

2.2.1 DSM Mosaic

The majority of this project consisted of analyzing the DSMs. Each new layer produced by an analysis would then be analyzed to get more and more refined data.

The first step was to take the 13 individual DSMs and combine them into a single DSM. To do this I used the Mosaic-to-new raster tool. After many different attempts trying to find the best value settings I was successful. After Selecting all the mosaics, applying the correct projected coordinate system and additional values(NAD 1983 (2011) UTM Zone 12N), 1 band, 32 bit float. It created an accurate single DSM of the whole city. This will make processing the DSMs much more efficient.

2.2.2. Exploring the model

To get a better understanding of the model and to visualize our future outcome I ran a hillshade analysis and added the building footprints. This created a 3D representation of Salt Lake City terrain and how it relates to man-made structures.

2.3 Mapping Solar Radiation

To find out the solar energy production potential of Salt Lake City, I first needed to find out how much solar radiation is emitted into the city which could then be captured using solar panels.

To do this, ArcGIS Pro has an incredible tool, the Raster Solar Radiation tool. This tool will simulate the sun's radiating onto our raster of the city for a whole year. I made sure to use the building footprints as the input mask so that it only analyzed solar radiation onto the top of buildings. This took an extreme amount of time to process, about an hour and a half. I also had many mistakes and had to run it about 3 times until I got it right. The output looked almost like a slope map as it stretched the values over a blue to orange color scheme. The value range was very large as it calculated the radiation in watts so I used the raster calculator to convert this to kilowatts.

2.3.1 Removing Unsuitable Rooftops

To maximize solar energy production from the solar panels, we want them to be on a reasonable slope(ideally 45 degrees or less) and not North facing as North facing objects receive less sunlight.

To do this I first created a slope and an aspect layer of the DSM to be used later. Using the Con tool I removed areas that had a slope higher than 45 degrees, making sure to use our solar raster as the input true raster.

I used the same con tool to only show areas not facing North (between 22 and 337 degrees).

I also removed areas with low solar radiation(less than 1000 KWh/m^2)

The remaining rooftop areas will be suitable for solar panel installation.

2.4 Power Potential

To get an idea of the power potential of each building's rooftop we will need to multiply the suitable area by the mean of solar radiation. I used the zonal statistics as a table tool to do this and it outputted a table with the suitable area and solar radiation mean.

To keep it all in one table and easier to work with I joined this table with our building footprints attribute table.

2.4.1 Suitable Buildings

I exported the buildings from the footprints table that had enough area to make the installation of solar panels worth it (20+ meters). With this new table we can start to

calculate the power potential. Firstly, I added a Solar Radiation field to the table to then calculate how much radiation each building gets. The calculation will be the mean multiplied by the area and then divided by 1000 to get MWh/m^2.

I then calculated the energy production for each building using a similar method, this time adding a field and calculating using calculations provided by the EPA:

“r = 16.3% solar panel efficiency of PV module (NREL 2022, Annual Technology Baseline, Solar Distributed Commercial PV – mean capacity factor for Resource Class 5 [ATB benchmark], representing the national-average solar resource)” and “ PR = 85.92% performance ratio (NREL 2022, PVWatts Calculator: 14.08% system losses)”

In the attribute table this looked like (solar_rad * 0.16 * 0.86).

After graduating the layer by color we now have a visual representation of the rooftop solar power production potential in Salt Lake City.

3.0 Maps

3.1 Solar Energy Potential of Salt Lake City Map

My primary map represents the buildings in Salt Lake City with a suitable amount of solar energy production potential. Also included are non-suitable buildings and an inset map of the Wasatch valley highlighting our study area.

3.2 Largest Potential Producers

This map represents the largest potential energy producers in the city and their proximity to state power transmission lines.

3.3 Largest Potential Producers 3D

This provides an interesting and more contrasted representation of our largest potential producers in 3D.

3.4 Layer Transformation

4.0 Results

According to the data produced by the solar radiation model, Salt Lake City has the potential to produce 34 Megawatts of clean renewable energy each year.
Of the 76,341 buildings including in the analysis, 40,299 were suitable for solar panel installation.

Mean	34.12844271750005	34.12844271750005
Median	13.675751895195647	13.675751895195647
Std. Dev.	140.39024671911426	140.39024671911426
Rows	40299	40299
Count	40299	40299
Nulls	0	0
Min	3.7269797030269634	3.7269797030269634
Max	12682.588798350609	12682.588798350609
Sum	1375342.1130725346	1375342.1130725346
Skewness	31.3029532795458 57	31.302953279545857
Kurtosis	2013.9001083057578	2013.9001083057578

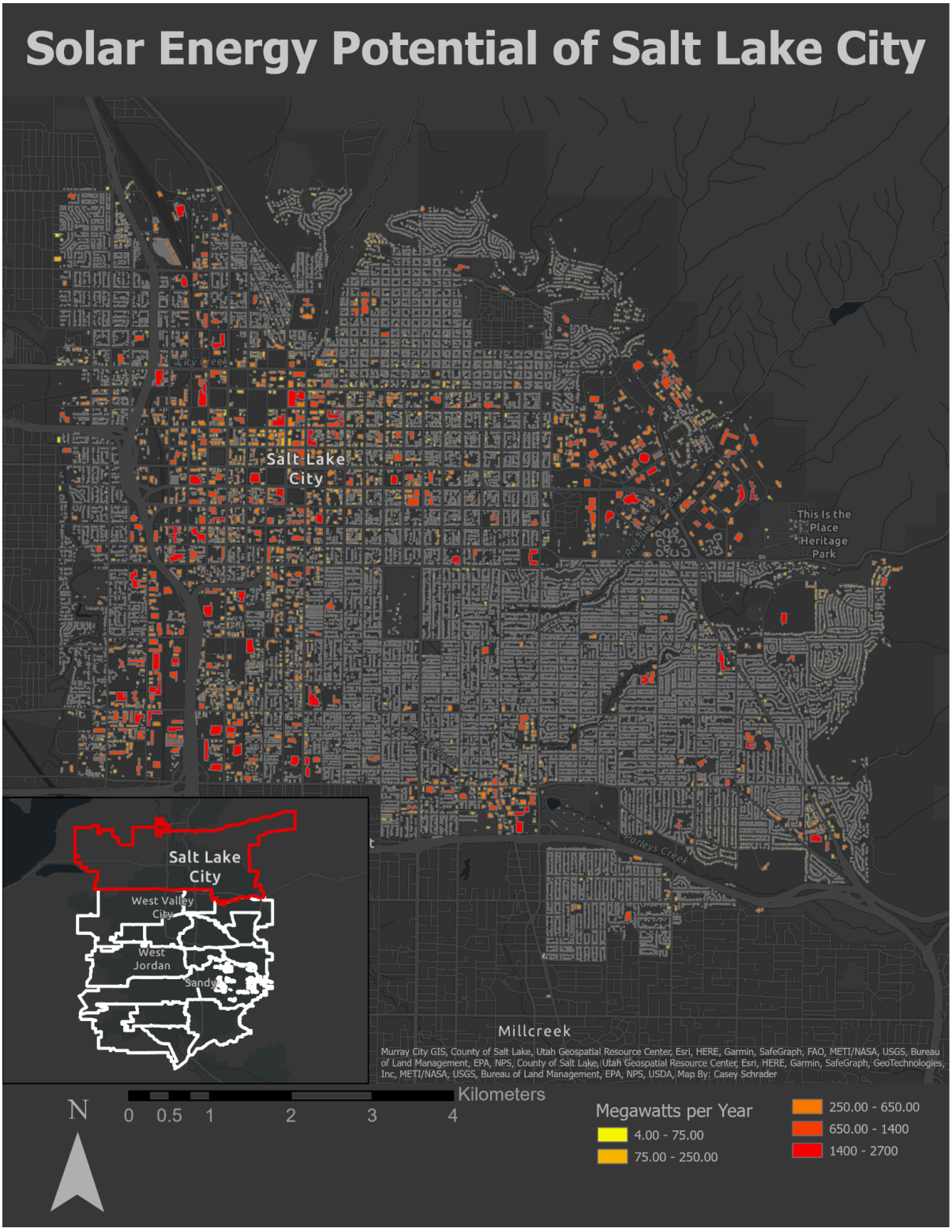
Our largest potential producers in the city of Salt Lake City are the Salt Palace Convention Center, Delta Center, and a handful of buildings on the University of Utah campus. Thankfully, it seems like the solar energy potential of the Salt Palace Convention Center and the Delta Center has already been taken advantage of as they have a considerable amount of solar panels. Unfortunately, the same can't be said for our campus. I only managed to find two buildings with a total of 6 sets of solar panels.

With our largest producers being located so close to our state power infrastructure, the means of transporting this energy all around the city can already be established.

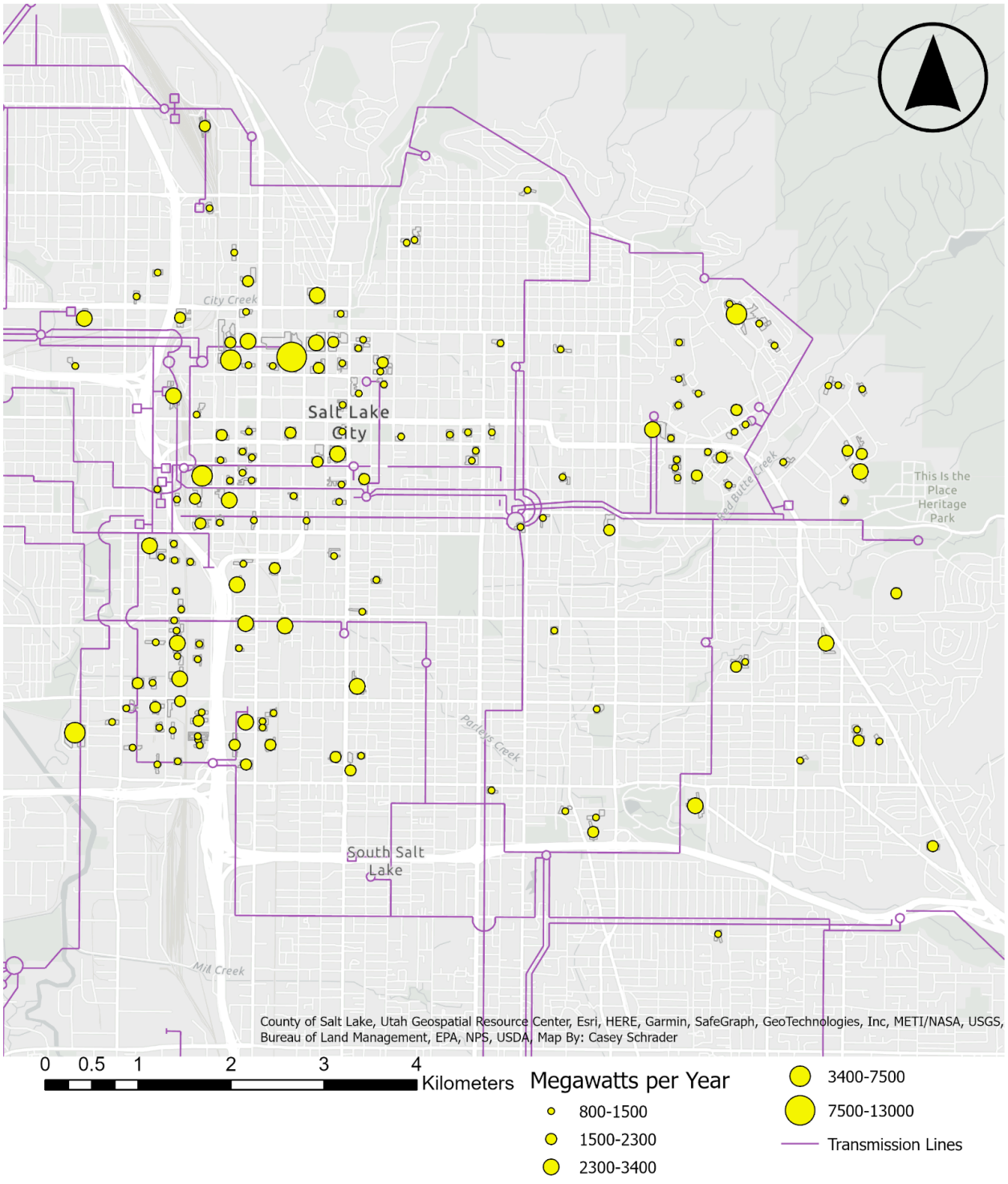
5. Conclusions

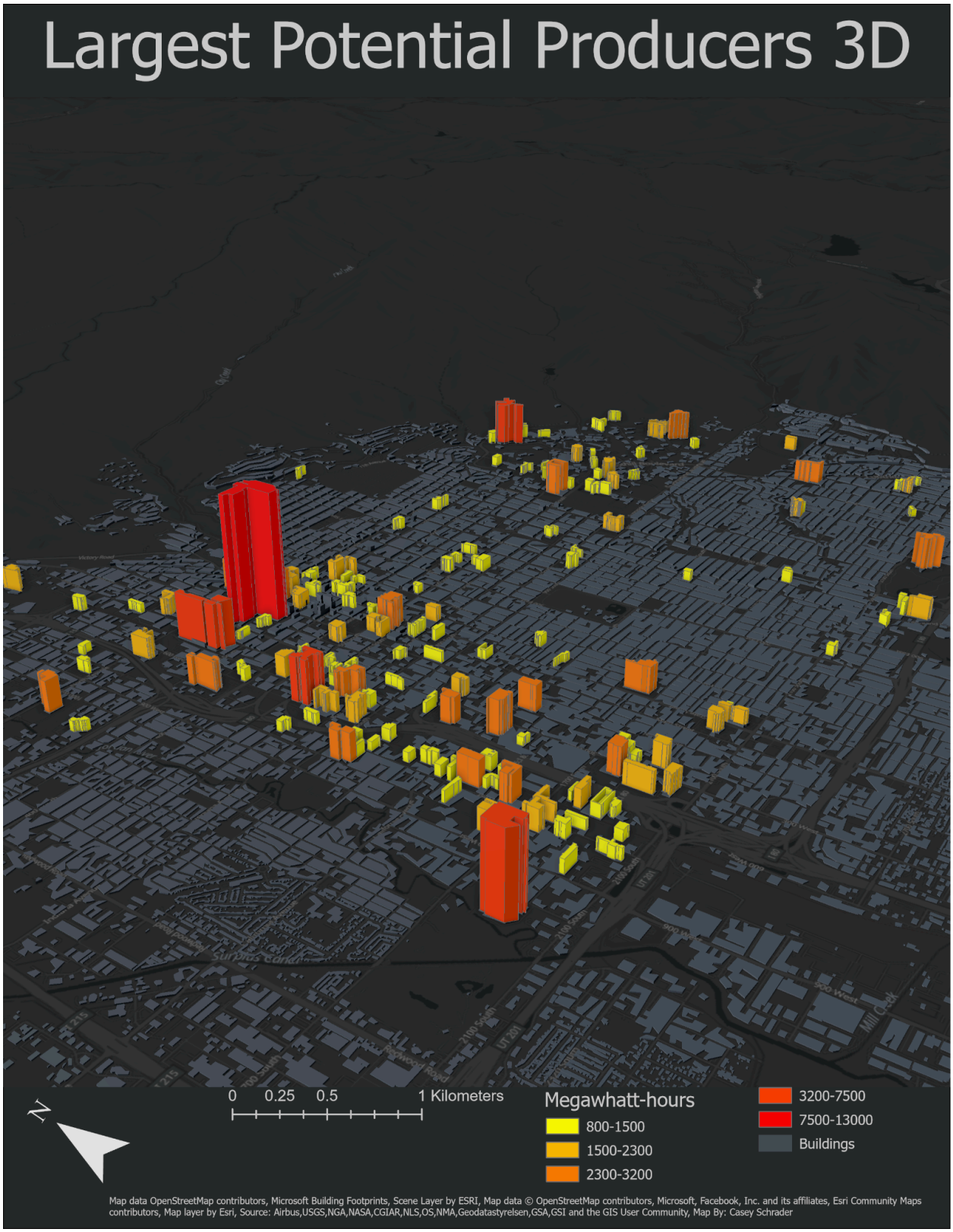
In conclusion, the production of clean renewable energy is not only vital for our planet during the current climate crisis, it is also extremely viable. With the right technology and the right priorities, cities all across the world can help offset their energy consumption and produce cleaner energy for a better future.

Solar Energy Potential of Salt Lake City

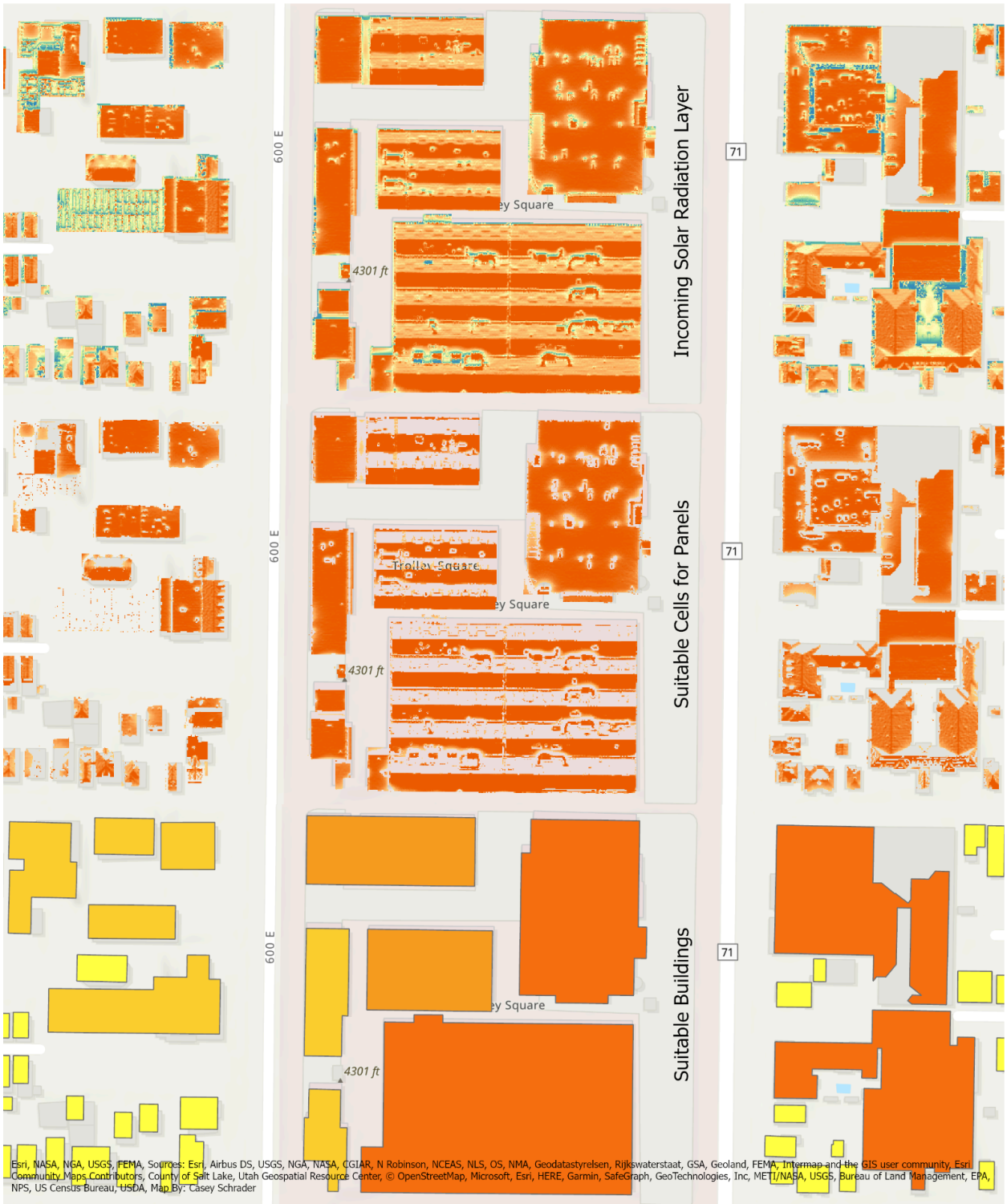


Largest Potential Producers




Largest Potential Producers 3D
0 0.25 0.5 1 Kilometers
N
Megawhatt-hours
800-1500
1500-2300
2300-3200
3200-7500
7500-13000
Buildings
Map data OpenStreetMap contributors, Microsoft Building Footprints, Scene Layer by ESRI, Map data © OpenStreetMap contributors, Microsoft, Facebook, Inc. and its affiliates, Esri Community Maps contributors, Map layer by Esri, Source: Airbus,USGS,NGA,NASA,CGIAR,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community, Map By: Casey Schrader

Layer Transformations to Find Suitable Buildings



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