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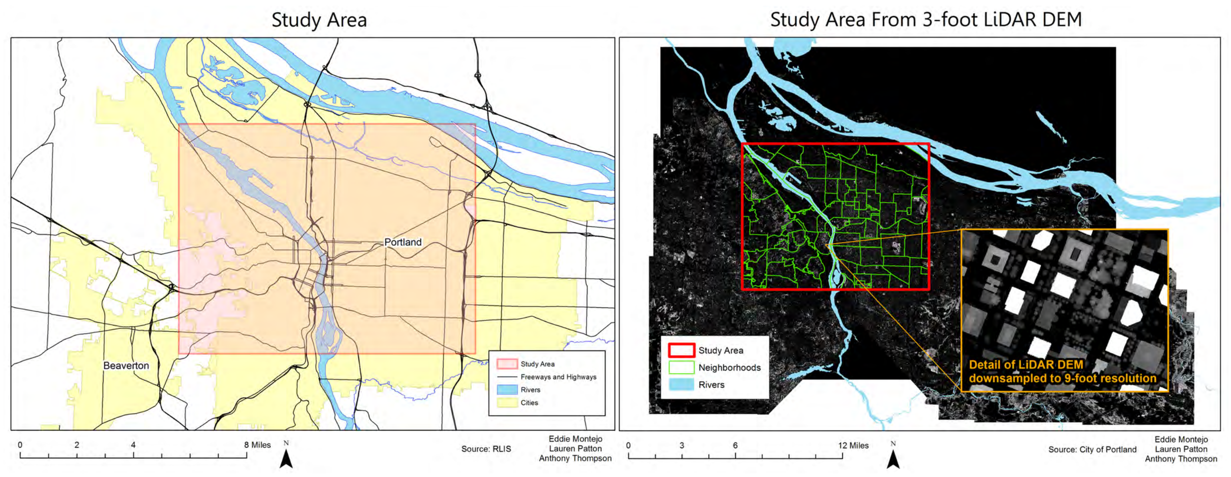
# SOLAR HOT SPOTS:

# Distributive Generation Mapping in Portland, OR

## STUDY AREA

Our study area is centered on downtown Portland and is served by Portland General Electric and Pacific Power. It extends roughly 5 miles in every direction from downtown Portland, and includes a small portion of Beaverton.

This study area was chosen to allow for comparisons across a wide range of Portland neighborhoods, but we didn't have the processing capabilities to analyze the entire 3-foot LiDAR DEM. For this reason, the study area was extracted from the regional DEM to include neighborhoods surrounding the central city, and was down-sampled to a resolution of 9 feet from 3 feet.




## BACKGROUND

There are currently a number of incentives available to Oregon residents and commercial tenants that drastically reduce the cost of installing solar arrays. The Energy Trust of Oregon offers upfront cash incentives per watt of solar installed, up to $10,000 per home. There are also state and federal tax credits, as well as renewable energy grants available from the Oregon Department of Energy that can cover up to 35% of project costs for new solar installations. Summatively, Oregon residents can offset as much as 80% of the initial investment for residential solar installations. Once installed, residents can expect drastically lower energy bills through a net metering agreement with their utility company.

Siting analyses for rooftop solar installations typically account for orographic and environmental factors; factors such as direct solar irradiance (DSI), diffuse solar radiation (DSR), slope, aspect, and elevation are well-established indicators for solar potential in urban areas. However, many of the factors that make urban spaces distinctly urban, such as high population densities, the presence of buildings, and socioeconomic considerations, are regularly omitted from solar optimization analyses. Furthermore, market conditions that dictate trends in residential and commercial installations are ostensibly less-influenced by physical factors than by matters of public policy. The endorsement of distributive-scale solar generation projects by municipal governments can lower utility bills for the poorest portions of the population, propagate community resiliency practices, and offer neighborhood-scale solutions to impending climate change. **The policy implications for broad-based urban distributive solar generation touch on matters of housing policy, equity, and sustainable urban planning.** This analysis attempts to incorporate these planning considerations into the otherwise geography-dominated practice of solar optimization studies.

## RESEARCH QUESTION:

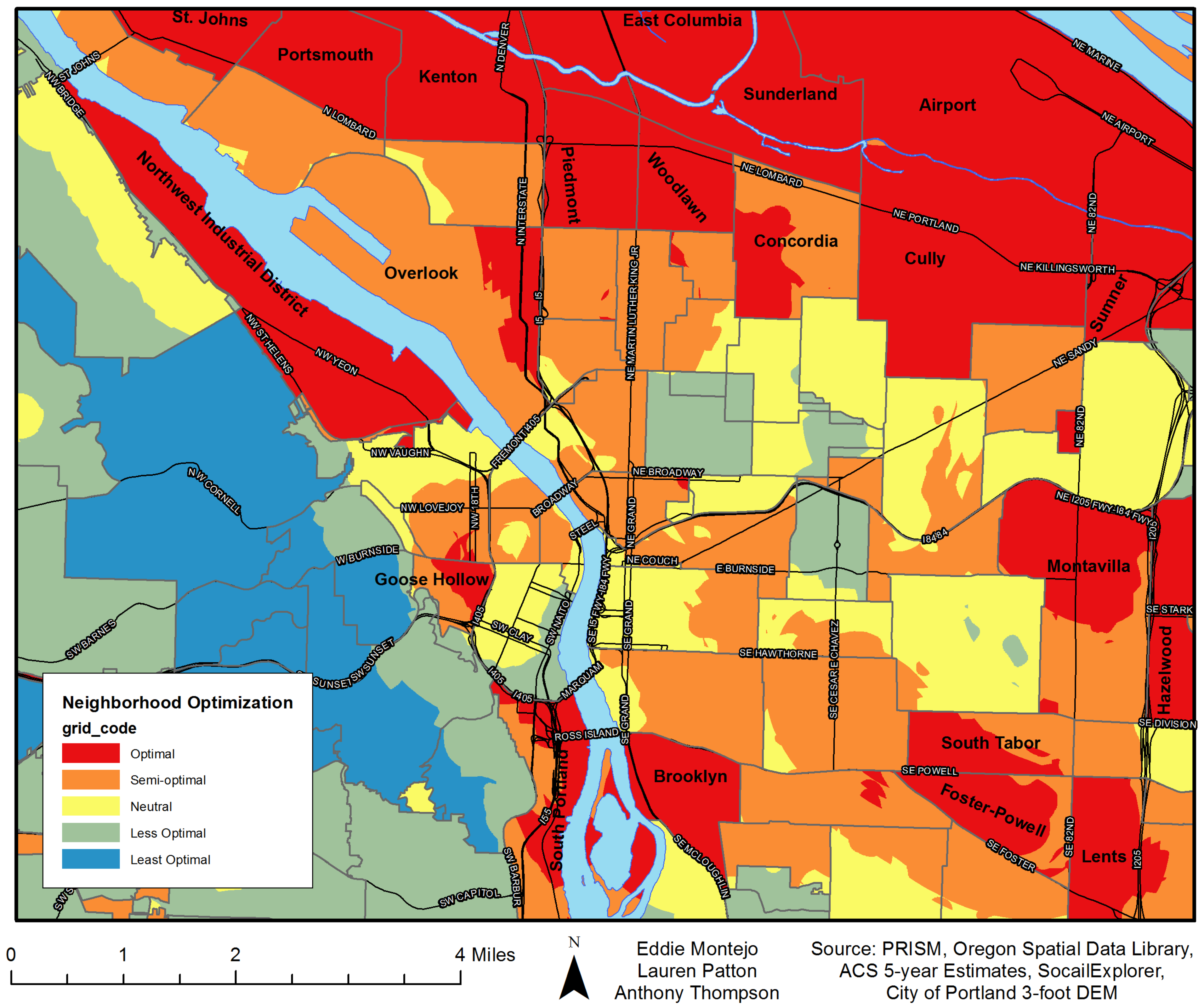
**Which Portland neighborhoods are in the best position to recieve solar installation incentives from public agencies?**

Our analysis attempted to identify neighborhoods in Portland that ought to be targeted by both public and private entities as key areas for solar proliferation. Based on physical as well as socioeconomic factors, we reason that the resulting neighborhoods have a high pay-back potential, and are likely to see heightened rates of socioeconomic benefits as a consequence of distributive solar generation in their neighborhoods. As socioeconomic 'proxies', population density and the percentage of households with public assistance were chosen as demographic indicators. Neighborhoods with higher percentages of households receiving public assistance are expected to benefit most from solar installations through reduced electricity bills. There was no distinction made between owner-occupied or unoccupied homes -- based on the assumption that renters and owners alike could benefit from reduced rent rates, and/or higher rents based on sustainable features. Population density was used a as a proxy for transmission costs and consumer-impact, reasoning that areas with higher density will use more energy. We had hoped to use proximity to substations as a way to account for transmission costs, but we could not locate a free source of substation data.

These socioeconomic factors were to be balanced through the incorporation of 'traditional' physical solar viability factors. We used the *Solar Radiation* toolset in *Arc Spatial Analyst,* which takes various orographic and environmental factors into consideration, such as orientation (slope and aspect), elevation, and shadows cast by the surrounding topography and structures. Solar radiation was modelled twice, using both overcast and 'clear sky' models that were then combined based on the percentage of *average annual overcast daylight hours* in Portland (46.6% cloudy, 53.4% sunny, http://www.portland.climatemps.com/sunlight.php). We added temperature data as another environmental factor based on our review of the literature (Carrion et al., 2008). Our weighted overlay analysis was **70% orographic/environmental** factors and **30% socioeconomic**.

| Table 1: Socially-Adjusted Solar Optimization Index | |
|---|---|
| **Factor** | **Weight (%)** |
| Diffuse (Overcast) Radiation | 25.63% |
| Direct (Clear Skies) Radiation | 29.37% |
| Temperature | 15% |
| Population Density | 10% |
| % Households w/Public Assistance | 20% |
| **Total** | **100%** |

Weighted Overlay of Neighborhood Solar Radiation, Temperature, Population Density, and Percent of Households Receiving Public Assistance




## RESULTS & CONCLUSIONS

The final output for this analysis was classified into five 'levels' of solar optimization (from most to least): 'optimal', 'semi-optimal', 'neutral', 'less optimal', and 'least optimal'. Each of these classes display a measure of clustering, and each class indicates data clusters with the least amount of variance. A very high degree of variability (nearly an order of magnitude) was found for the mean annual solar radiation within each neighborhood. Average neighborhood insolation ranged from 139.3 kWh/m2 to 1,049.7 kWh/m2; neighborhood-scale variations in topography, tree cover, and the height and size of structures likely played a significant role in this wide range of values. These findings supported our assumption that not all neighborhoods have equal opportunities to take advantage of solar radiation. When temperature (important for solar panel efficiency) and sociodemographic variables were accounted for, even more variability was found. Future studies might focus on extracting site- and building-specific statistics to find optimal structures for solar installations.

**Cully,** the **Columbia Slough industrial area**, the **Northwest Industrial District, Goose Hollow,** and the **South Waterfront** -- to name a few -- stood out as optimal areas for solar installations according to this methodology. Areas in East Portland also stood out as a significant hotspots, indicating that further studies linking equity to renewable energy could be focused in study areas east of I-205.

## METHODOLOGY

1. Downsampled the 3-foot DEM (including structures, not just topography) to a 9 foot resolution using the Nearest Neighbor tool to improve processing time.

2. Used the split raster tool and divided by number of tiles (rather than size of tile) to create 90 tiles for faster processing. We only used 12 of the 90 tiles that were centered around downtown Portland. The split rasters included a 50 cell overlap (450 feet) to facilitate mosaicing the solar radiation output rasters.

3. Used Area Solar Radiation tool and ran it twice on the 12 tiles. First, using the UNIFORM_SKY and the second time with STANDARD_OVERCAST_SKY.

4. Overcast solar radiation tiles were mosaiced into a new raster dataset, and the same was done for sunny conditions. Overlapping cells were averaged.

5. Used Raster Calculator to combine the 2 rasters at 46.6% (Overcast) and 53.4% (Uniform) into a single raster with values of kWh/m2 per year.

6. Converted raster to points using the Raster to Point tool, and then used the Erase tool to erase the points in river and parks shapefiles from RLIS. Converted the non-excluded points back into a raster of solar radiation excluding major bodies of water and parks. The NODATA cells were ignored in the following calculation, resulting in a more realistic output.

7. Used zonal statistics using neighborhood boundaries clipped to the study area to calculate mean solar radiation for each neighborhood.

8. Converted block groups to centroids for 2010 population data and poverty data. Joined with Social Explorer tables - Percent of Households Receiving Public Assistance.

9. Created kernel density maps for population and poverty data. Ran the Nearest Neighbor tool in order to find a search radius - 4,318 feet, and used a cell size of 9 feet to match the solar radiation raster.

10. The annual temperature data was national data at 800 meter resolution. Converted Raster to Point and then ran Kriging with the output cell size matching solar raster (9 foot cells).

12. Reclassify all four variable rasters into common discrete scale, Natural Breaks with 20 classes.

13. Applied weights to each dataset using the Weighted Overlay Tool (weights shown in table 1) and performed Weighted Overlay Analysis.

14. Converted Weighted Overlay output to polygon for classification and display.

## DATASETS USED/LITERATURE CITED


- PRISM Climate Group, Oregon Spatial Data Library. Annual Temperature Data
- City Data from City of Portland Data Catalog. Neighborhoods, Buildings
- Metro/City Data from RLIS. Parks, Rivers shapefile
- DEM from PSU Geography ArcGIS Server. DEM + Building Heights
- 2010 U.S. Census and 2008-2012 American Community Survey. Block Group socioeconomic data
- Carrion, J.A. et al., (2008). Environmental decision-support systems for evaluating the carrying capacity of land areas: Op timal site selection for grid-connected photovoltaic power plants. Renewable and Sustainable Energy Reviews, 12 (2358–2380).
- Energy Trust of Oregon (2014). Solar Electric for Homes. Retrieved from http://energytrust.org/residential/incentives/solar-electric/SolarElectric/


10% 20% 55% 15%