Plugging in Beyond the Grid in Tanzania

Gauging suitability for off-grid electrification

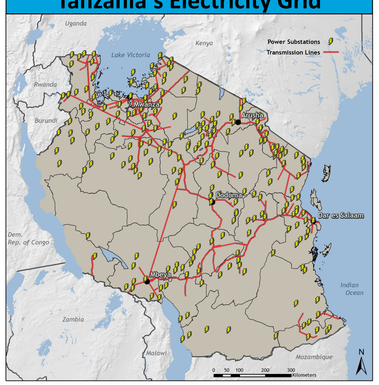
Electricity Access in Tanzania

Nearly one billion people lack consistent electricity access, mostly among rural communities around the world. These rural populations often remain out of reach of electricity access because of limited grid infrastructure. In Tanzania, the power grid links together urban centers in the country but remains largely undeveloped in rural areas. As of March, 2018, only 32.8% of the Tanzanian population had access to electricity. Given Tanzania's high rate of economic growth and dearth of electricity infrastructure for most of its population, there is heightened potential for off-grid solutions. This opportunity is particularly prominent with micro-hydro, wind, and PV solar technologies. The goal of this project is to determine optimal areas for off-grid electricity potential in Tanzania.

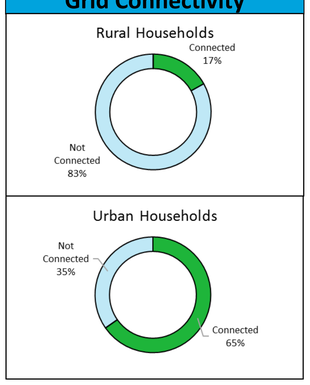
Spatial Questions Considered

- Where is grid-connected electricity available in Tanzania and where is it not?
- What is the population density across Tanzania that resides outside of grid connectivity?
- Among off-grid zones, what factors increase potential for off-grid solutions and where is this potential the highest?

Tanzania's Electricity Grid

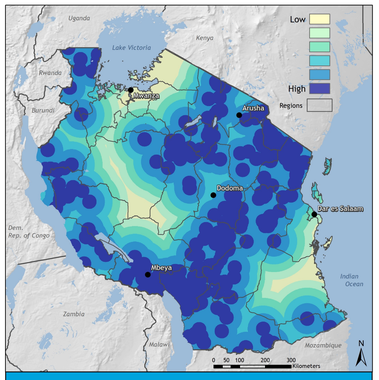


Grid Connectivity



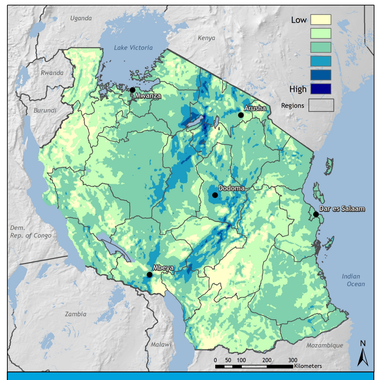
Methodology

This project involved analyzing four categories of data: 1) Hydro Potential, 2) Wind Potential, 3) Solar Potential, and 4) Proximity of population to power substations (the farther away, the less likely a household will be connected to the grid). This data was then aggregated into composite scores to determine overall suitability. Tanzania's administrative levels from biggest to smallest are Regions, Districts, and Wards. While these maps feature regional boundaries for reference, all data collected was analyzed at the Ward level using the Zonal Statistics tool. There are 3,574 Wards in Tanzania, providing a granular level of population and power potential detail for this project.



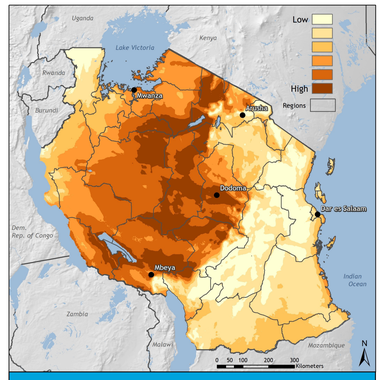
Hydro Potential by Ward

Hydro potential was calculated by mapping the point locations of promising micro-hydro sites identified by a January 2018 World Bank survey. The Euclidean Distance tool was then used to map the distance between each hydro site and the mean population density (pop. / square km) of each ward. The resulting distance then received a score of 1 (far away) through 6 (close).



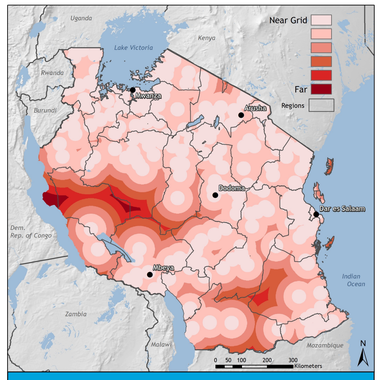
Wind Potential by Ward

Wind data within the following ranges was isolated from a July 2015 World Bank wind survey: 0 to 100 feet above ground level (AGL); and 3 to 12 meters per second (m/s). Most energy developers classify these ranges as ideal for small to medium-sized wind turbines. A score of 1 through 6 was then used to classify average wind speed (m/s).



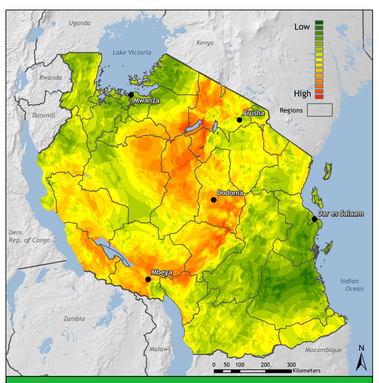
Solar Potential by Ward

Solar irradiance data was derived from a 2016 World Bank survey, which provided rasterized data on Photovoltaic (PV) potential (kilowatt per hour (kwh) / kilowatt peak (kwp), ranging from 1,000 to 1,900 kwh. A score of 1 (1,000 kwh) through 6 (1,900 kwh) was then used to classify lowest to highest PV output.



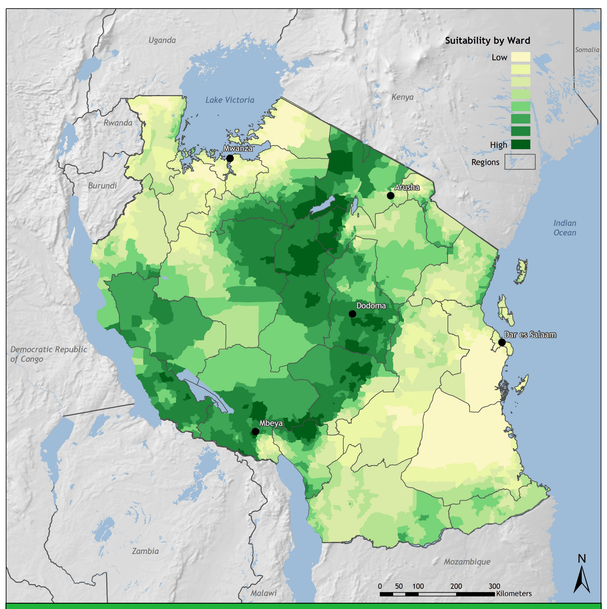
Substation Proximity by Ward

Using TANESCO's (Tanzania's power provider) point data on power substation locations, the Euclidean Distance tool was then used to map the mean distance between each substation and the population density (pop./square km) of each ward. The scoring rubric was 1 (close) through 6 (far away).



Combined Potential by Ward

Using the Field Calculator, scores for hydro (1-6), wind (1-6), and solar (1-6), were aggregated into composite scores for combined power potential. This resulted in scores that ranged from 4 to 18, with 18 representing the highest power potential (6 hydro + 6 wind + solar 6).



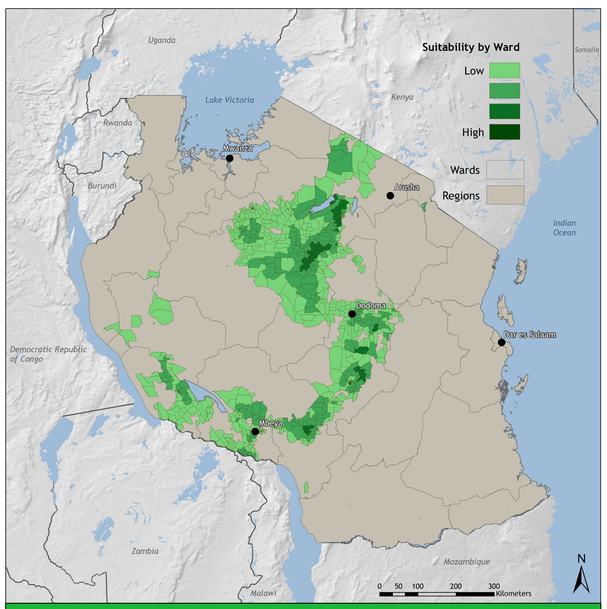
Off-Grid Suitability Score by Ward

The combined power potential score was added with the scores rendered from population proximity to the grid. Areas with populations that reside far away from the grid but also exhibit high power potential for micro-hydro, small to medium-size wind turbines, and PV solar, thus received the highest scores. Scores ranged from 6.3 to 20.

Results, Analysis, and Limitations

This analysis suggests ample opportunity to close that gap with suitability for off-grid development being particularly prominent in the north-central area of the country. Incidentally, most of the highest scoring wards overlap with gridded areas of the country, suggesting that the power potential for hydro, wind, and solar, far outmatched the population's relative distance to substations. This may be in part due to Tanzania's already heavy use of hydro for on-grid generation (42% of total generation), which means that grid development would track with where the hydro hotspots are in the country. Additionally, the west and northeast regions represent notably high scoring clusters with little to no grid infrastructure.

Limitations: TANESCO's annual situation report indicates that most unconnected households have high enough incomes to afford being connected, but upfront capital costs associated with off-grid development were not within this scope. This study also assumed all substations to be equal capacity and while the Euclidean Distance technique was one means of accounting for that uncertainty, more detailed analysis is needed to gauge the physical range limits of the grid. Finally, this project had originally accounted for national parks and protected areas as assumed areas of low population and grid connection. Over 40% of Tanzania's land area is designated as natural wildlife reserves. National Census data unexpectedly revealed that most park land is on par with other rural land (e.g. farm land) in population density, however. These populations may be in part comprised of tribal and indigenous peoples, many of whom are allowed to live on national lands and serve as caretakers. This dimension should be further investigated.



Highest 25% of Suitable Wards

The highest scoring 25% of suitable wards had suitability scores between 14 and 20. These wards should represent the first frontier of new off-grid development projects, based on their larger proportions of people who remain unconnected to the grid but also live in areas with high hydro, wind, and solar potential. Approximately 8.8 million of Tanzania's total population of 55.5 million live within these wards.

Cartographer: Matthew Arnold

Projection: WGS 1984, UTM Zone 37S

Sources: TANESCO, Tanzania National Bureau of Statistics, World Bank Group, Global Atlas, ESRI, DIVA-GIS, USAID Power Africa

The Fletcher School of Law and Diplomacy
Tufts University

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