ROOFTOP SOLAR POTENTIAL OPTIMIZATION FOR SUSTAINABLE ENERGY IN NAIROBI

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BUSINESS OVERVIEW

SunOptimize Technologies is a pioneering company dedicated to revolutionizing the energy landscape through solar innovation. SunOPtimize Technologies is committed to sustainability and efficiency by aiming to empower individuals, businesses, and communities to embrace solar energy solutions. Through the utilization of state-of-the-art technology and specialized knowledge, the company focuses on optimizing rooftop solar installations to achieve maximum energy potential while simultaneously reducing total power consumption costs. SunOptimize Technologize is dedicated to fostering a greener and more sustainable future by making solar energy accessible to all, driving positive transformations and advocating for environmental stewardship through each installation endeavor.

The business values include optimized solar installations where property owners can optimize rooftop solar installations, maximizing energy potential and minimizing costs. It also helps increase solar adoption by encouraging widespread adoption of solar energy in Nairobi, contributing to sustainable and renewable energy goals. Lastly, it contributes economic savings where property owners benefit from potential cost savings and a reliable renewable energy source, contributing to long-term economic benefits.

Based on the business values, the stakeholders include property owners and managers who seek insights into the solar potential of their buildings and guidance on optimizing rooftop installations. They can use the system for sustainable energy planning and cost-effective solar projects. Another stakeholder would be solar installation companies who are interested in identifying and prioritizing buildings with high solar potential for targeted marketing. They can use the system to streamline sales efforts and optimize project planning. The third stakeholders are the Energy Regulatory Authorities whose aim is to promote sustainable energy practices in the city. They can leverage the insights for policy formulation and incentive programs to encourage rooftop solar adoption.

PROBLEM STATEMENT

There has been an increased disappointment in Nairobi residents and businesses for experiencing multiple unprojected power outages from the Kenya Power Lighting Company (KPLC). Most people have been interested in alternative energy sources, but are stuck with KPLC as it is a monopoly. SunOptimize Technologies noticed that people were open and interested in using solar power, but they did not know how to go about it as Nairobi lacks a systematic approach for harnessing the solar potential of individual buildings.

There are several issues with the implementation of solar power, the first being an absence of Precise Insights: It suggests that there is a lack of detailed information regarding suitable areas for solar installations, the capacity that can be installed, and the potential energy generation from these installations. Informed decision-making regarding solar energy projects requires accurate data on these aspects.

The second problem is leveraging a Vector Dataset: A vector dataset is a type of geographic data representation that uses points, lines, and polygons to represent geographic features. In this case, the dataset contains polygons representing building footprints in Nairobi. This dataset likely includes information about the shape, size, and location of buildings.

The primary goal and aim of the project is to develop a robust system for optimizing rooftop solar potential. Optimization here refers to maximizing the efficiency and effectiveness of rooftop solar installations. The focus is on individual building units within Nairobi.

There are several factors that the system aims to consider in optimizing rooftop solar potential:

- Building Type: Different types of buildings (residential, commercial, industrial, etc.) may have different rooftop characteristics and solar potential.
- Tilt: The tilt of the rooftop plays a significant role in determining the efficiency of solar panels in capturing sunlight.
- Capacity Factors: This likely refers to the maximum capacity of solar installations that can be feasibly installed on each rooftop, considering factors such as available space, structural integrity, and local regulations.

In summary, the project seeks to fill the knowledge gap regarding rooftop solar potential in Nairobi by analyzing building footprint data and developing a systematic approach to optimize solar installations at the individual building level. By considering factors such as building type, tilt, and capacity factors, the project aims to provide valuable insights for informed decision-making in solar energy investments and installations.

OBJECTIVES

Main Objective

1. <u>Rooftop Solar Potential Prediction:</u>

- Utilize machine learning techniques to predict suitable rooftop areas, installable capacity, and estimated yearly energy potential for each building unit.
- Incorporate features such as building type, estimated tilt, and building height in the predictive models.

Specific Objectives

2. <u>Optimization Strategies:</u>

- Implement optimization algorithms to identify the most efficient rooftop solar installations, considering factors like building type and capacity factor.

- Develop strategies for maximizing solar potential while respecting building characteristics. From this, we can go on to conduct a basic cost-benefit analysis considering unit installation prices to determine the economic viability of rooftop solar installations for different building types. This will provide insights into the return on investment for solar projects on individual buildings.

3. User-Friendly Interface:

- Develop a user-friendly interface for stakeholders to interact with the system.
- Enable users to input building characteristics and receive real-time recommendations for optimal rooftop solar installations.

THE DATA

The data is from NEO (https://www.neo.nl/home-int) which is a leading company in the Earth Observation (EO) business based in the Netherlands. The link to the dataset is:

https://energydata.info/dataset/nairobi-rooftop-solar-potential-mapping

Project Goals

- Build a machine learning model that can accurately predict suitable rooftop areas, installable capacity, and estimated yearly energy potential for each building unit.
- Establish evaluation metrics to assess the performance of the recommendation system.
- Deploy and Implement a real-time recommendation feature that can adapt to users' changing preferences and provide up-to-date suitable rooftop areas, installable capacity, and estimated yearly energy potential for each building unit.

Success Metric

Root Mean Squared Error (RMSE) and the Mean Squared Error (MSE)

Methods Used

- Descriptive Statistics
- Data Visualization
- Machine Learning

Data Understanding

- **Data Source:** We downloaded the dataset from NEO, a leading company in the Earth Observation (EO) business based in the Netherlands.
- **Data Type:** Most of the data is numerical data, apart from the “building type” column that has categorical data.
- **Data Description:** We identified and described the different columns that we were to use in the project to answer our different objectives.

Data Cleaning

- The first step was dropping the columns that we did not require which were ‘Comment’, ‘Unit Installation Prices’, and ‘City’.
- **Data Understanding:** the data type and the descriptive statistics for the Numeric columns are displayed.
- **Missing Values:** we checked for missing values where the Estimated_building_height had 30 missing values and Estimated_capacity_factors was found to have 3502 missing values.

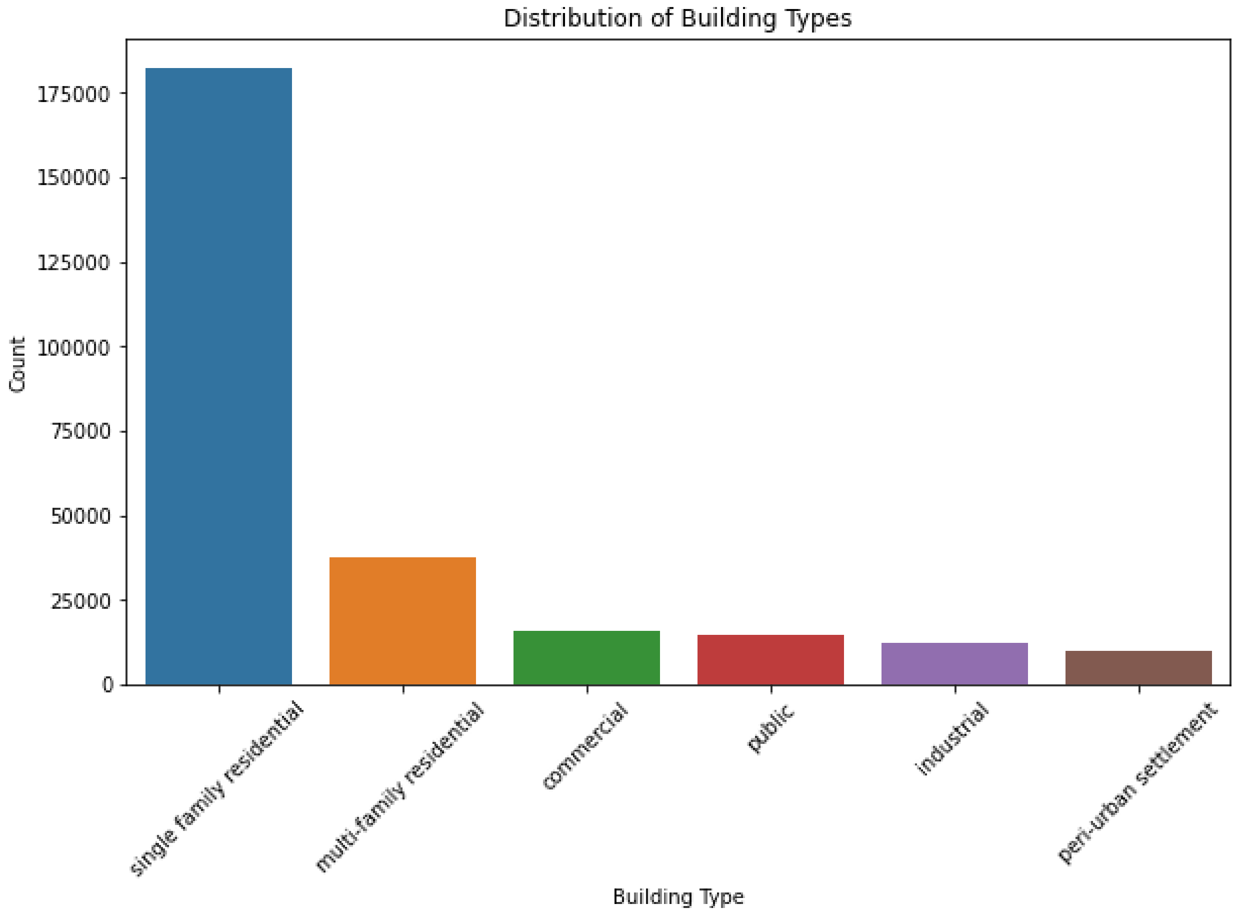
  To decide whether to impute the values in the Estimated_capacity_factor we check the distribution of this data using a histogram to decide whether to use mean or median where we found the use of the median to be more appropriate.

  We then dropped the rows with the missing values.
- **Duplicate Values:** there were no rows that contained missing values.
- **Outliers:** A boxplot will be generated for each numeric column in the dataset to visualize the spread of values and identify any data points that fall outside the expected range. Outliers will be identified based on their position outside the whiskers of the boxplot.

These data points may require further investigation and consideration in subsequent analyses.

EDA

- **Value counts**: we checked for the value counts of the assumed building types

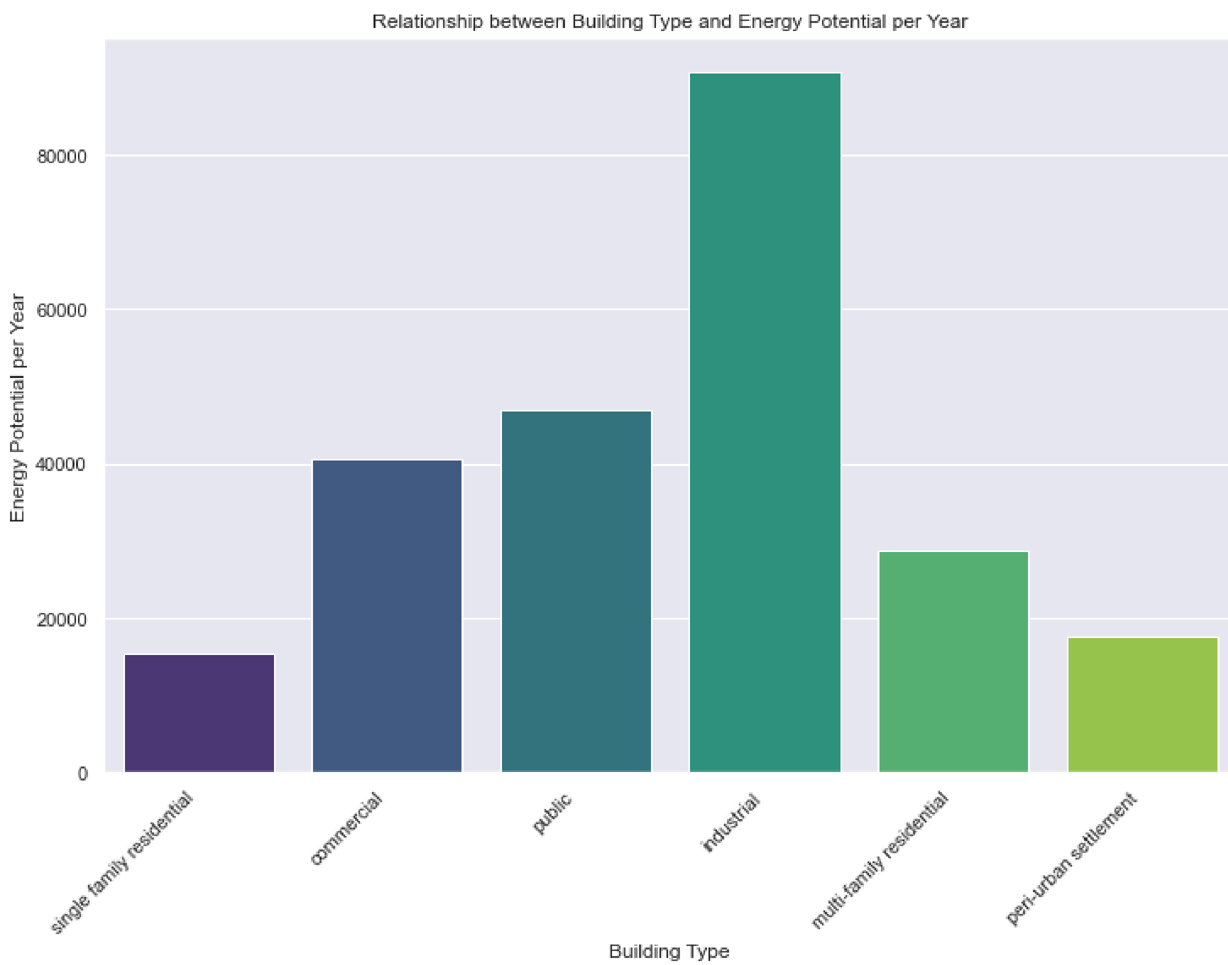


The above bar chart is interpreted as follows:

1. Single-family residential: here the majority of the buildings in the dataset, constituting approximately 66.77%, are characterized. This suggests a predominant representation of individual homes.
2. Multi-class Family Residential: Around 13.85% of the buildings fall under the multi-family residential category, indicating the presence of structures designed to accommodate multiple households.

3. Commercial: Approximately 5.87% are classified here suggesting a presence of business or retail establishments.
4. Public: represents 5.34%, public buildings such as government facilities, schools, or community centers are a notable category in the dataset.
5. Industrial: with a share of 4.61%, this represents the manufacturing or production facilities.
6. Peri-urban Settlement: this comprises if about 3.56% of the dataset suggesting a representation of buildings located on the outskirts of urban areas.

- **Bar plot:** to show the distribution of the different assumed building types



The provided bar graph visually represents the energy potential per year across various building types. Let's interpret the key insights derived from the plot:

- Industrial: Industrial buildings exhibit the highest energy potential, reaching close to 80,000 KWh per year.

- Public: Public buildings, such as libraries or museums, have the second-highest energy potential.

- Commercial: Commercial buildings used for business purposes rank third in terms of energy potential.

- Multi-family Residential: Buildings accommodating multiple families (e.g., apartments) show a lower energy potential compared to commercial structures.

- Single Family Residential: Standalone houses designed for one family demonstrate a lower energy potential than multi-family residential buildings.

- Peri-urban settlement: Buildings within specific areas dedicated to particular purposes or groups display the lowest energy potential.

- **Bar graph:** it gave a visual representation of the energy potential per year across the various building types

Data Preprocessing

- **Frequency Encoding**
- **Correlation Matrix:** shows the relationship between the selected columns.
- **Variance Inflation Factor Analysis (VIF):** we used this to show multicollinearity among predictor variables in a regression analysis
- **Squareroot Transformation:** we used this transformation to address the issue of high Variance Inflation Factor (VIF) values in certain predictor variables.

Model Selection and Training

- **Random Forest**
- **Extreme Gradient Boosting (XGBoost)**

We compared our values with Random Forest Regressor and Neural networks to check its performance in minimizing prediction errors.

To prevent the potential for overfitting, we tune the neural network.

- **Target Variable**: our target variable is Energy_potential_per_year

- **Evaluation Metrics**: We utilized metrics such as Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), and R-squared to evaluate the performance of our models
- **Optimization**
- **Cost-Benefit Analysis**

Conclusions

Growing Interest in Solar Energy:

There is a noticeable interest among Nairobi residents and businesses in adopting alternative energy sources, particularly solar power, driven by dissatisfaction with traditional power sources like Kenya Power Lighting Company (KPLC).

User-Friendly Interface:

A user-friendly interface is developed to enable stakeholders to interact with the system, input building characteristics, and receive real-time recommendations for optimal rooftop solar installations. This enhances accessibility and usability for decision-makers.

Cost-Benefit Analysis:

The project includes a basic cost-benefit analysis to determine the economic viability of rooftop solar installations for different building types. This analysis provides insights into the return on investment for solar projects on individual buildings.

Stakeholder Engagement:

The project engages various stakeholders, including property owners, solar installation companies, and energy regulatory authorities, to promote sustainable energy practices and facilitate informed decision-making regarding solar energy investments and installations.

Lack of Systematic Approach:

Despite the interest in solar energy, there is a lack of a systematic approach for harnessing the solar potential of individual buildings in Nairobi. This gap presents an opportunity for innovative solutions to optimize rooftop solar installations.

Recommendations

Diversification of Solar Installations:

There is an opportunity to diversify solar installations across different building types. Encouraging installations in commercial, public, and industrial buildings alongside residential units can lead to a more balanced distribution of solar energy generation.

Targeting Industrial Buildings:

Initiatives focused on incentivizing solar adoption in the industrial sector can significantly contribute to overall energy generation and sustainability efforts.

Optimizing Surface Area Utilization:

Implementing strategies to maximize available surface areas, such as utilizing rooftops, facades, and open spaces, can enhance energy generation efficiency.

Consideration of Square Root of Potential Installable Area:

Recognizing the strong positive correlation between the square root of the potential installable area and energy potential per year, it's important to consider the non-linear relationship between these variables. This insight underscores the need for careful planning and scaling of solar projects based on available space to maximize energy generation.

Focus on Predictive Models:

Given the significance of the target variable, Energy_potential_per_year, in evaluating the potential output of rooftop solar installations, investing in accurate predictive models is crucial. Developing robust predictive models that accurately estimate energy potential can provide valuable insights for decision-making processes, ensuring the economic viability and sustainability of solar energy projects.

Next Steps

Continued Stakeholder Engagement:

- Maintain active engagement with property owners, solar installation companies, and energy regulatory authorities.

- Foster collaboration and partnerships to address regulatory constraints and financing options.
- Gather feedback from stakeholders to inform decision-making and strategy development.

Evaluate and Iterate:

- Monitor the performance of implemented initiatives using key performance indicators (KPIs) and success metrics.
- Incorporate lessons learned from stakeholder feedback into future iterations of the project.
- Stay informed about emerging trends and technologies in the solar energy sector to guide decision-making.

Scale and Expand Initiatives:

- Explore opportunities to scale up successful initiatives and expand solar installations across the city.
- Identify new areas for potential solar projects and prioritize locations based on energy potential and feasibility.
- Seek funding and partnerships to support the expansion of solar adoption efforts.