A REMOTE SENSING (RS) AND GEOGRAPHIC INFORMATION SYSTEM (GIS) APPROACH TO ESTIMATING ELECTRIC POWER CONSUMPTION: A CASE OF SOKOTO METROPOLIS, SOKOTO STATE, NIGERIA

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Abstract

Electricity consumption forecast for any city in Nigeria is an inexact estimate, as electricity workers are not aware of the size and rate of city expansion. This study therefore forecast electricity consumption of residential land use for Sokoto metropolis for 2020 using RS and GIS. 1986 and 2005 land use maps, 1986 Landsat TM and 2005 ETM+, 2003 Quickbird image, electricity consumption and building area coverage data from snowball-sampled 49 residential homes were combined within ArcGIS and Idrisi Andes environments. Each electric meter was observed for 30 minutes, then consumption and GPS location of each building were recorded, after which building areas were digitized from the Quickbird image. Area coverage was correlated with consumption. Also, the landsat data were classified into wetland, built up, bare-surface and green area at 91% and 87% accuracies, producing. The land cover of 2020 was projected with Marcov Chain Analysis. The built up was extracted from each land cover map and was masked by non-residential land uses within the built up. Growth rate of non-residential land uses within the built up was estimated. Results showed a high positive correlation of 0.63 between building size and electricity consumption which is statistically significant at 99% confidence level. Residential land use expanded by 122% between 1986 and 2005 at an annual

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rate of 1.9 Km^2. Non-residential land uses within the built up expanded by 50.4% at 0.33Km^2 annual rate. Between 2005 and 2020, residential land use would have expanded by 31% and non-residential land uses within the built up by 27%. The 2020 electricity consumption for residential land use was estimated as 3,412,000Kwh. With the current scenario signaling jeopardy for the realization of vision 2020, more funding of the sector by the government and adoption of improved method of management such as the application of RS and GIS by the Power Holding Company of Nigeria (PHCN) are recommended.

Key words: Sokoto, Electricity Consumption, Building size, RS and GIS

1. INTRODUCTION

Urban growth according to Potter (1992) is the absolute increase in the physical size and total population of urban areas. It is the sum of three processes: net urban migration (in-migration minus out migration), urban natural increase (birth minus death) and geographical extension that transform the formerly rural zones located in the periphery (or peri-urban parts) of large cities into urban areas (Jacguemin, 1999; Brocker, 2000). Between 1960 and 1990, 60% of urban growth in developing countries was attributed to natural increase and 40% to migration from rural areas and expansion of the boundaries (Brocker, 2000). In the next two decades, most urban growth will result from urban natural increase of population and the structural transformation of peri –urban areas.

The world is increasingly becoming urbanized and the rate at which city populations grow and countries urbanized are indicative of the pace of social and economic change (Donk, 2006). In 1976, one-thirds of the world population lived in cities, and in 2006, half of the entire humankind lived in cities (Tibajuka, 2006). By the target year for the Millennium Development Goals (MDGs), cities in the world are estimated to grow to 6 billion people.

Sokoto is the administrative, socio-cultural, spiritual, political and economic hub of Sokoto state of Nigeria. Its spatial growth in the last decade, according to Eniolorunda and Dankani (2010) has become bolstered to an extent that the master plan of the city is suspected to have grossly been altered. The rapidity of the city growth has posed a serious challenge for the Power Holding Company of Nigeria (PHCN) as electric power supply is both epileptic and grossly below demand, resulting in power rationing, making supply to be epileptic. Besides the high growth rate, worse still, the regime of high daily temperature of about 40^0C on the average necessitates further demand for electricity for powering air conditioners at homes as a coping strategy against the heat.

Electricity is an aspect of the utility sector that is very essential to the development of a society. It is the pivot of the economy, promoting the well being of individuals. Therefore the efficient functioning of this utility is of paramount importance for the realization of growth and development of any nation. The efficiency of power supply partly depends on efficient planning for future industrial and domestic needs. RS and GIS have proved competent and effective for such planning. Elsewhere, they have been used for assessing site suitability for hydro and thermal plants, distribution network, facility management, consumer service data base management, transmission lines and stations.

Ayeni *et al* (2003) noted that Geospatial Information (GI) is very essential to economic planning and national development. This is further buttressed by Alamu and Ejiboh (2002), when they concluded that a well maintained utility information infrastructure gives up-to-date information on what is where, the state of it, and how it can be harnessed for optimum use of the people and economy. It is in the light of this that this study aimed at projecting the residential land use and electric consumption of Sokoto metropolis for the year 2020 using RS and GIS. The following objectives were captured: sampling of residential homes for electric meter reading and coordinate taking, mapping of area coverage of each sample house, correlating the sampled residential buildings and electricity consumptions, classification of the study area into land cover classes for 1986 and 2005, isolation of residential areas for 1986 and 2005, estimation of the annual growth rate of the study area between 1986 and 2005, projection of the growth of the metropolis for the year 2020 and quantification of the average power need by the residential land use for the year 2020.

2. Study Area

Sokoto is the capital of Sokoto State. It is located between longitudes 5.14^0E and 5.30^0E and latitudes 12.96^0N and 13.08^0N. Sokoto State is one of the 36 States that make up the Federal

Republic of Nigeria (Figure 1). Sokoto is characterized by sandy savannah and wet and dry seasons. The wet season begins toward the end of May and ends in October during which showers are almost a daily occurrence. The dry season begins with the onset of tropical continental air mass commonly referred to as harmattan which blows Sahara dust over the land. It dims the sun light thereby lowering temperature significantly and also leading to the inconvenience of dust everywhere. This wind is usually predominant between November and February. Temperature is as high as 43^{0}C around March/April (middle of the dry season) and as low as 23^{0}C in December/January (middle of the cold season). The surrounding vegetation is that of Sudan Savanna with plenty of short grasses and scanty trees.

The study area is in the floodplains of Sokoto-Rima River system, which is covered with rich alluvial soil that supports the growth of crops like groundnut, maize, millet and guinea corn.

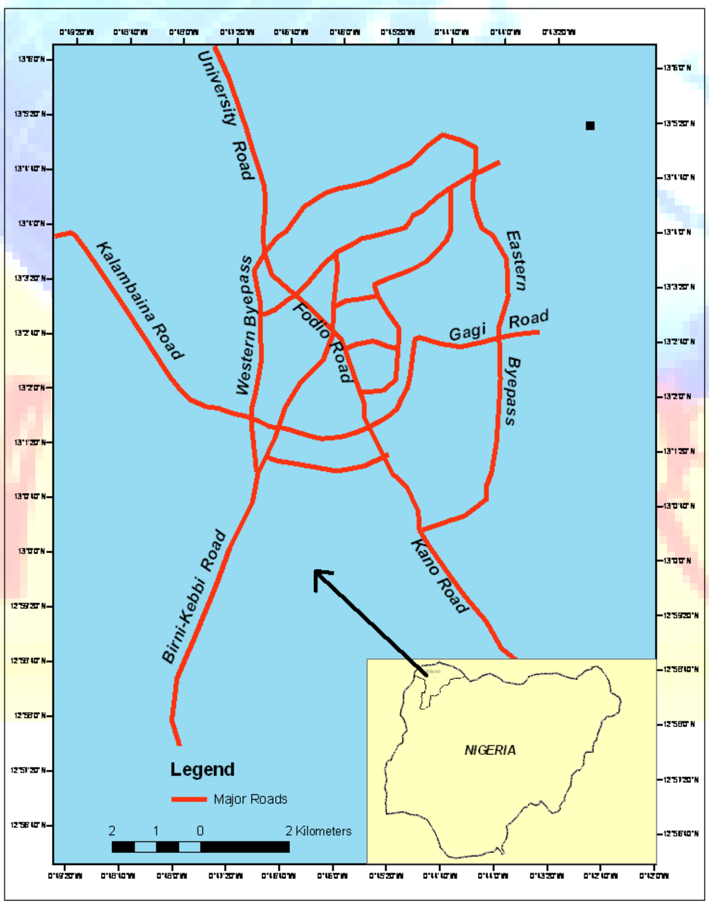

Figure 1: Study Area

The valley has an average altitude of 240 metres above sea level representing the lowest level in the study area. The highest part of the study area has an altitude of about 334 metres above sea level (Eniolorunda, 2010). Local craft such as blacksmithing, weaving, carving and leather works also play an important role in the economic life of the people in the study area.

3. Materials and Methods

Five data were used for this study: land use maps of 1986 and 2005 (Figures 2 and 3) for land use classification, Landsat TM of 21st October 1986 (Figure 4) and Landsat ETM+ of 15th September 2005 (Figure 5) for land cover classification, Quick-bird image of 2003 (Figure 6) for map georeferencing and feature identification, electricity consumption data for each sampled housing unit and area coverage of each sampled housing unit (Table 1).

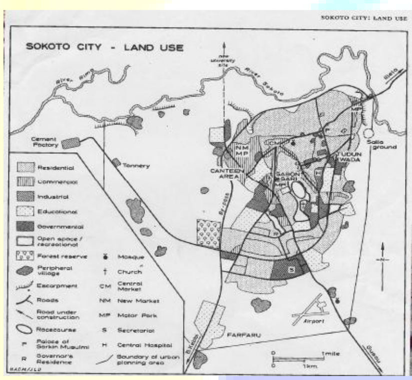

Figure 2: Land use Map of Sokoto Metropolis 1986

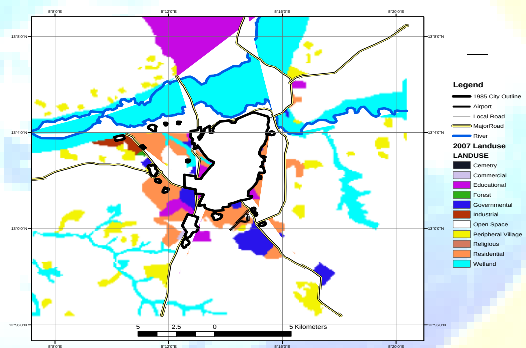

Figure 3: Land use Map of Sokoto Metropolis 2005

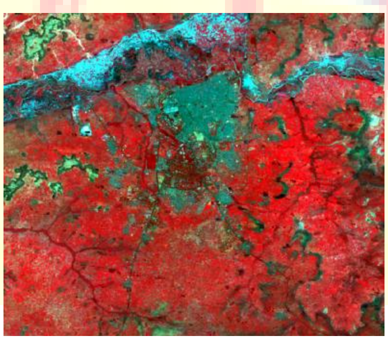

Figure 4: Landsat TM of 1986 (in false colour)

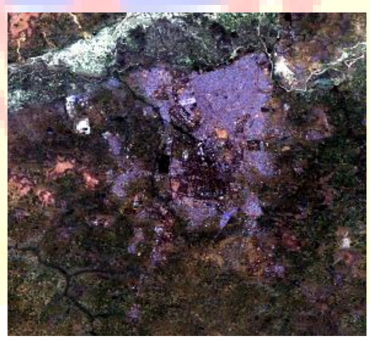

Figure 5: Landsat ETM+ of 2005 (in true colour)

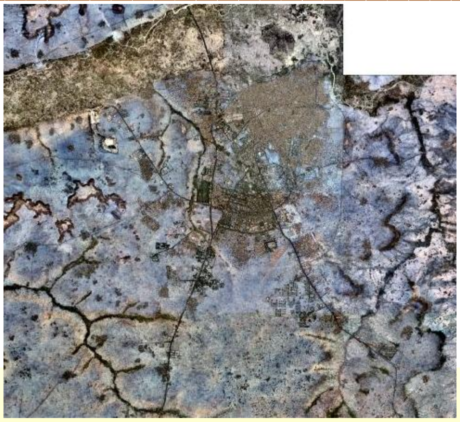

Figure 6: Quickbird Image of 2003

Table 1: Building Area versus Electricity Consumption

No	B/A (m^2)	C (Kwh)	No	B/A (m^2)	C (Kwh)	No	B/A (m^2)	C (Kwh)	No	B/A (m^2)	C (Kwh)	No	B/A (m^2)	C (Kwh)	No	B/A (m^2)	C (Kwh)
1	990	22	9	870	13	17	650	9	25	240	5	33	240	5	41	140	3
2	730	10	10	400	6	18	810	10	26	400	6	34	160	6	42	140	3
3	240	5	11	480	7	19	320	5	27	860	12	35	240	4	43	140	3
4	160	4	12	480	8	20	320	6	28	870	13	36	730	10	44	140	4
5	730	7	13	320	5	21	890	14	29	650	9	37	240	5	45	160	6
6	480	6	14	80	3	22	240	5	30	560	7	38	140	3	46	140	3
7	160	3	15	730	10	23	140	3	31	400	6	39	650	6	47	140	3
8	650	3	16	320	5	24	160	6	32	160	6	40	140	3	48	160	4
Total B/Area =19,250 (m^2)									Total C=317 (Kwh)								

Source: Generated from Author's Ground-thruting

Where No = Serial Number, B/A=Building Area C = Electricity Consumption

Projecting electricity consumption from residential land use premises on the fact that a positive relationship is presumed between housing size and amount of electricity consumed. Hence this relationship was tested with Spearman Rank correlation at 99% confidence level. As a prelude, snowball sampling technique was used for sampling houses with electric meters in view of the fact that the researcher had no knowledge of the houses with installed electric meters. The electric meter of each sampled house was observed for 30 minutes and wattage consumed was recorded (Table 1). The GPS readings of the sampled houses were captured and the coordinates overlaid on the Quickbird image for identification and digitizing of the areas covered by the sampled houses.

The land use maps were captured into the ArcGIS 9.3 environment and geo-referenced using the satellite data which were in UTM 31N. The Landsat data were also re-projected to the same resolution. Land uses were extracted from the land use maps of both dates by digitizing. The Landsat data of 1986 and 2005 were subjected to land cover classification using the maximum likelihood classifier and the built up area eventually extracted. For the purpose of land cover classification, the training areas for land cover classes namely wetland, built up, bare surface, and green area were identified from the Quickbird image of 2003 covering the area and the classes were then digitized. The Quickbird with the resolution of 0.6m offered the advantage of seeing clearly the ground features.

In order to extract the residential land use from the built up, non residential land uses such as educational, commercial, industrial and governmental were extracted from the land use maps of 1986 and 2005 and masked out of the built up area of 1986 and 2005 land cover maps (Figures 7 and 8). The land cover maps were submitted for Markov Chain Analysis to predict the land cover for the built up area for 2020. Markov Chain Analysis is a convenient tool for modeling land use change when changes and processes in the landscape are difficult to describe (Eastman, 2006).

The area coverage for the residential land use was estimated for each of 1986 and 2005 (Table 2). To estimate the annual rate of growth for residential land use, the difference between the areas of residential landuse for 1986 and 2005 was divided by the number of years (19) in between i.e. Growth Rate = (Area 2005-Area 1986)/19). In order to estimate the power need for residential land use of the study area, the formula: C=A*D was applied, where C=Total Consumption for the study area, A=Total area covered by residential land use and D=Total electricity consumed by sampled houses/Total area of sampled houses.

4. Results and Analysis

The Spearman Rank Correlation statistic run on building size and consumption in Table 1 reveals that a high positive correlation of 0.63 exists between the building size and electricity consumption in the study area, and this relationship is statistically significant at 99% confidence level. This therefore validates the adoption of this method for electricity forecast for the study area.

Four land cover classes were derived from the study area for each year namely wetland, built up, bare surface, and green area (Figures 7 and 8) at 91% classification accuracy for 1986 and 87% for 2005. The built up area was later extracted from the land cover map of each year as presented in Figures 9 and 10. It is evident from these figures that the built up area was twice its size in 1986 by 2005. Figures 11 and 12 present the masking of non-residential land uses within the built up area of 1986 and 2005 respectively.

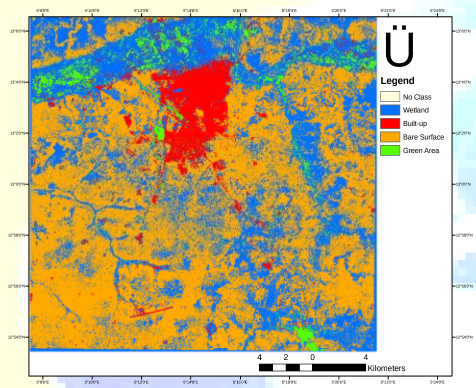

Figure 7: land Cover Classes for 1986

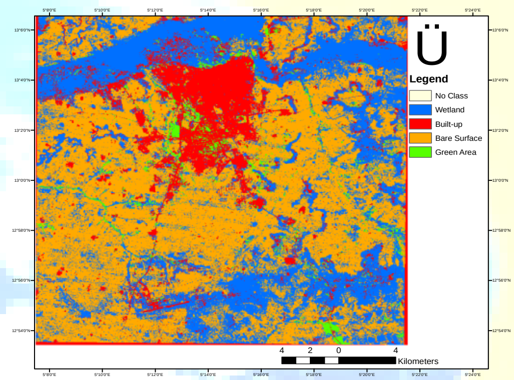

Figure 8: Land Cover Classes for 2005

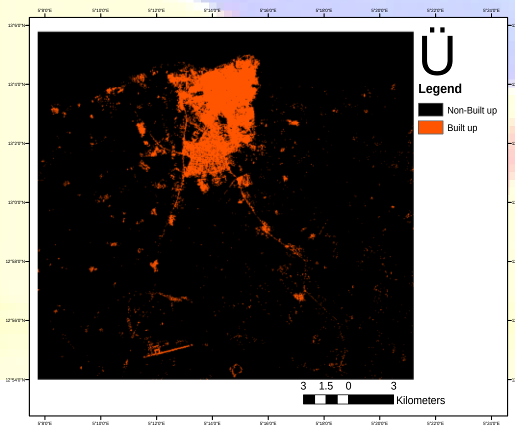

Figure 9: Built up Area for 1986

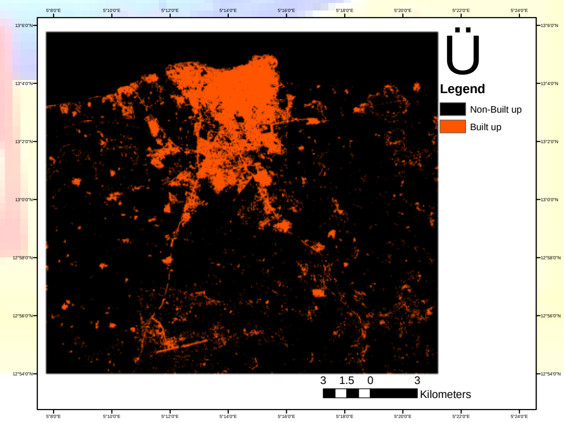

Figure 10: Built up Area for 2005

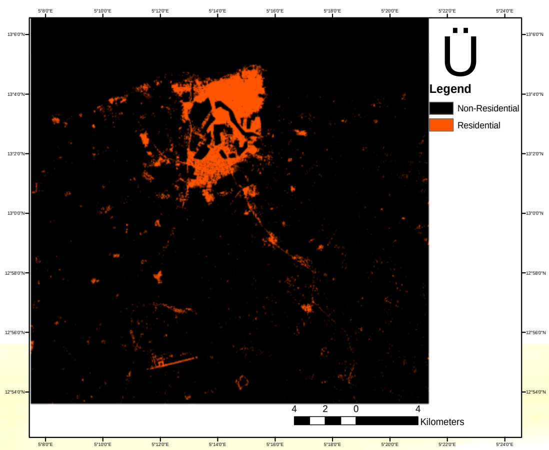

Figure 11: Residential Land use for 1986

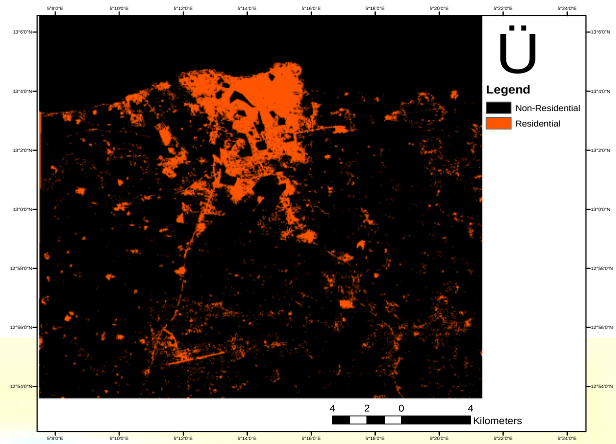

Figure 12: Residential Land use for 2005

The areas covered by residential land use and non-residential land uses within the built up area for 1986 and 2005 are presented in Table 2.

Table 2: Area Coverage for the built up area for 1986 and 2005

Year	Residential (Km^2)	Other Uses within the Built up area (Km^2)	Total Built up (Km^2)
1986	29.4	12.33	41.7
2005	65.3	18.5	83.8

Source: Derived from Figures 9, 10, 11 and 12.

From Table 2, residential land use in 1986 was 29.4 Km^2 while it was 65.3 Km^2 in 2005, giving a difference of 35.9 Km^2 and amounting to 122% increase. Also it was discovered that the annual residential growth rate from 1986 to 2005 was 1.9 Km^2. Table 2 also presents the area of land uses other than residential in the built up area as 12.3 Km^2 and 18.5 Km^2 for 1986 and 2005 respectively. This gives a growth of 6.2 Km^2, amounting to 0.33 annual growth rate.

The projected built up area for the year 2020 (Figure 13) covered 108.8 Km^2. Because it was hard to model what non-residential land uses within the built up area of the metropolis would be by 2020, the annual growth rate for other land uses in the built up area was multiplied by the number of years between 2005 and 2020 (15 years), giving a growth of 5 Km^2. Therefore, the total size of non-residential land uses within the built up area will be the addition of this growth and the size of the non-residential within the built up area in 2005. This value amounts to

23.5 Km^2 (5 Km^2 + 18.5 Km^2). Therefore, the total projected residential land use for the year 2020 is 85.3 Km^2 (108.8 Km^2 - 23.5 Km^2).

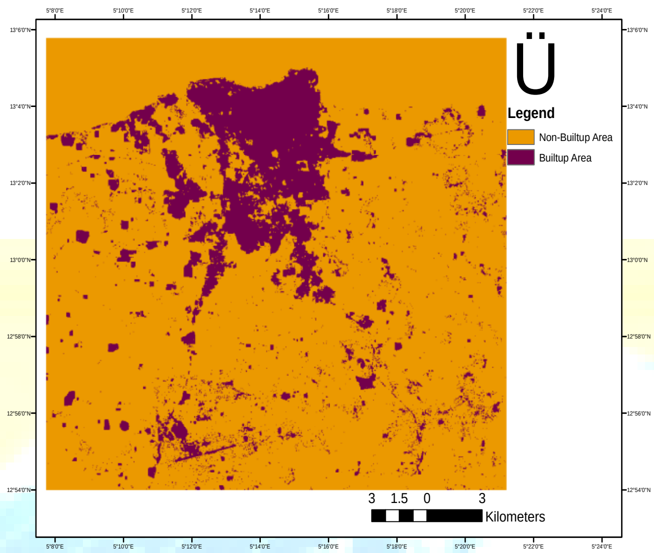

Figure 13: Projected Built Up Area map for 2020

To project the electricity consumption for the year 2020, the formula: C=A*D was adopted, where C=Total Consumption by the residential land use, A=Total area coverage of the residential land use and D=Total consumption by the sampled houses/Total area of sampled houses. Using the data from Table 1, D = 317/19,250 = 0.02 Kwh/m^2 representing the consumption per m^2 for 30 minutes. There are 1,000,000m^2 in 1km^2, therefore for 1km^2, 20,000Kwh (1000, 000*0.02) of electricity is consumed in 30 minutes. This amounts to 40,000Kwh per hour. To estimate hourly electricity consumption for the year 2020, the formula C=A*D applies, where A=85.3km^2 and D=40,000Kwh. Therefore C = 85.3*40,000Kwh = 3,412,000Kwh.

5. Conclusion

The method used in this study has demonstrated that the city has expanded in size and pattern and that further expansion is envisaged by the year 2020. Electricity supply will surely be a very critically challenging problem as it is already evident in the epileptic nature of the electricity supplied to the study area, necessitating power rationing among consumers on a six-hour basis.

Year 2020 is the target year for the achievement of the millennium goal for Nigeria when among other things uninterrupted electricity supply is expected. As the trend of expansion continues without corresponding electricity supply, this goal is in jeopardy as worse situation is envisaged by the year 2020. Therefore, there is a need for the government to evolve a budgetary plan towards at least equating supply with the demand of electricity. Also, it is recommended that the Power Holding Company (PHCN) should adopt this method for projecting future electricity consumption based on settlement growth. Further studies should incorporate the power need by other land uses such as commercial and industrial as this will be consider a holistic approach to estimate power need for all classes of land use.

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