AN INTERACTIVE VISUAL APPLICATION TO EXPLORE ELECTRICITY CONSUMPTION PATTERNS ACROSS SINGAPORE

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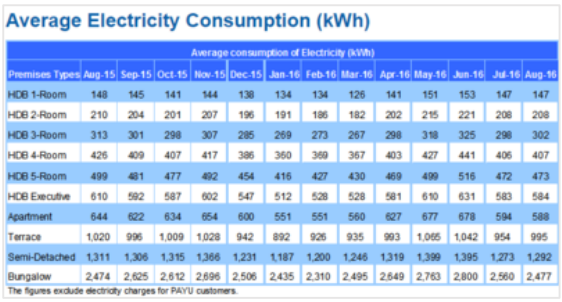
Abstract **-** Singapore experienced modernization at a tremendous speed over the years. This rapid modernisation is however, powered by a massive energy consumption by the industries and households. As a nation with no natural resources, this massive increase in energy consumption is a great concern. To address this pressing issue, the Singapore government introduced various combat measures. One of which is through initiatives that help increase public's awareness on electricity consumption and wastage. Hence, to play a part in increasing the public's awareness on this issue, our team designed an interactive visual application using d3.js, which enables user to interact and explore household electricity consumption patterns across the island. Through this data visualisation application, our team hopes to increase the public's knowledge of the rising levels of household electricity consumption.

I. Introduction

As a little red dot with no natural resources, the government aims encourage Singaporeans to reduce their energy consumption and wastage. For instance, in January 2008, the NEA introduced Mandatory Energy Labelling for registrable goods under the Energy Conservation Act (Cap. 92C). This act requires all electrical goods to be affixed with an energy label sticker depicting how much electricity they consume when used. Recently in August 2016, Singapore Powers introduced a utilities bill redesign in a bid to help fellow Singaporeans track and reduce their energy and water consumption. According to the energy statistics report published by the Energy Market Authority of Singapore, average monthly consumption of electricity by Households increased 0.5% from 466kWh in 2014 to 468 kWh in 2015. The average monthly consumption by public housing dwellings registered a 1.2% increase from 2014, to reach 376 kWh in 2015. Whereas, on the flip side for private housing units fell by 2.1% to 732 kWh in 2015. Hence, more can be done to further reduce electricity consumption and wastage in Singapore.

II. Motivation

A way to encourage a reduction of electricity consumption amongst fellow Singaporeans is through public education. By allowing fellow Singaporeans to visualise the amount of electricity consumed by at a national level as well as by their residential planning zones and sub zones will allow for a better understand of how much electricity they are consuming in comparison to the other households. Through our primary observations, some of the energy consumption data and statistic is provided via the Energy Market Authority's website lacks user friendliness and interactivity. This in turns serves as a barrier towards achieving an increased level of public awareness since not many Singaporeans will be innately interested in exploring these dull data sets. With reference to the interactive servlet available on Singapore Powers website [1] the data is displayed in a tabular format with numerical values is hard to digest.



Average Electricity Consumption (kWh)

Average consumption of Electricity (kWh)

Premises Types	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16	Mar-16	Apr-16	May-16	Jun-16	Jul-16	Aug-16
HDB 1-Room	148	145	141	144	138	134	134	126	141	151	153	147	147
HDB 2-Room	210	204	201	207	196	191	186	182	202	215	221	208	208
HDB 3-Room	313	301	298	307	285	269	273	267	298	318	325	298	302
HDB 4-Room	426	409	407	417	386	360	369	367	403	427	441	406	407
HDB 5-Room	499	481	477	492	454	416	427	430	469	499	516	472	473
HDB Executive	610	592	587	602	547	512	528	528	581	610	631	583	584
Apartment	644	622	634	654	600	551	551	560	627	677	678	594	588
Terrace	1,020	996	1,009	1,028	942	892	926	935	993	1,065	1,042	954	995
Semi-Detached	1,311	1,306	1,315	1,366	1,231	1,187	1,200	1,246	1,319	1,399	1,395	1,273	1,292
Bungalow	2,474	2,625	2,612	2,696	2,506	2,435	2,310	2,495	2,649	2,763	2,800	2,560	2,477

The figures exclude electricity charges for PAYU customers.

Fig 1: Interactive servlet showing Electricity Consumption Data, Singapore Power's Website

The EMA also releases a Singapore Energy Statistic Report [2] annually. Referencing to the 2016 report, our team felt that the report provides a good overview to end users, however lacks interactivity as it is displayed in a static report format.

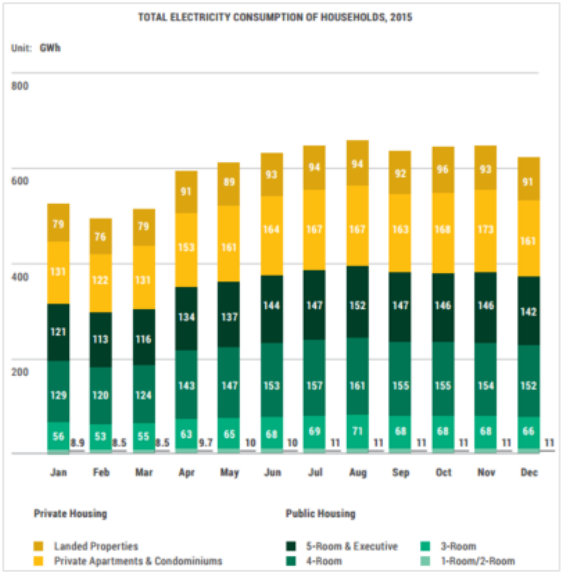


Fig 2: Total electricity consumption of households 2015, Singapore Energy Statistic Report 2016

To enable the public to interaction with the energy consumption data, the EMA made use of Tableau Public [3] to publish an interactive dashboard. The dashboard comprises of many insightful charts that allows users to interact and better understand energy consumption patterns.

Fig 3: Household Consumption by Dwelling Type 2014, Energy Market Authority Tableau Public

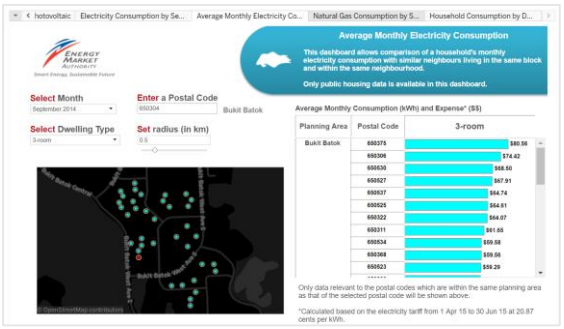


Figure 4: Average Monthly Electricity Household Consumption by Postal Code 2014, Energy Market Authority Tableau Public

Within the dashboard, they also included a function whereby users could enter their postal code and find out more about the electricity consumption patterns at their residential area. Overall, our team finds that this Tableau dashboard is interactive and does aid users to data exploration. However, we feel that user interactivity can be further enhanced through the use of other data visualisation methods.

Furthermore, demographic data can also be included in the data visualisation to provide users with more insights. Factors such as the population demographics could be incorporated to provide some interesting insights on the usage patterns.

III. Objective

The key visualization question our team wished to achieve using our visual application is to help end-users explore: *"How does factors identified affect the energy consumption pattern across Singapore? Are there any significant patterns or changes of concern?* The key objective of the visual application is that it has to be (1) Interactive; (2) Friendly towards layman.

IV. Data Preparation

As the data provided by Energy Market Authority is in a raw form, a series of data processing and cleaning was performed to prepare the data in an ideal fashion required in the later phases of our project.

Cleaning & Consolidation: Public and private household electricity consumption data from 2015 used. Using JMP Pro, a series of data processing techniques such as stacking, concatenating, and elimination of missing rows of data was performed. By the end of this phase of data cleaning, the final consolidated data consist of 241,766 rows of data. Furthermore, demographics data such as Age group and Ethnicity by Planning zone was cleaned up.

Geocoding: The consolidated data table was imported into Tableau, where the respective geographic coordinates (latitude and longitude) of the postal codes were generated. However, Tableau failed to recognise 561 postal codes from the data set. Hence, manual geocoding was performed using the Google Maps API for developer.

V. The Application

After much consideration, our team decided to make use of Data-Driven Document (D3.js) to build our visual application. D3.js is a JavaScript library for manipulating documents based on data. We decided on D3.js because it allows for our team to build the data visualisation we desire, without forsaking the key need for user interactivity and usability. Furthermore, the rich library also allows for our team to tab on some of the great works created by other users.

VI. Data Visualisation

Our team created our data visualisations such as interactive line charts, double bar chart, tree maps, and bubble graph using D3.js. Using the interactive line charts users can explore the electricity consumption per housing type. Looking at the average monthly consumption by housing type, it seems that (1) The bigger the housing type, the higher the electrical consumption. E.g. a 5-room/executive type will consume more electricity than that of a 3-room type. (2) Peak electrical consumption appears to be the highest in the month of August across all housing types. (3) Electrical consumption is at its lowest in February and March.

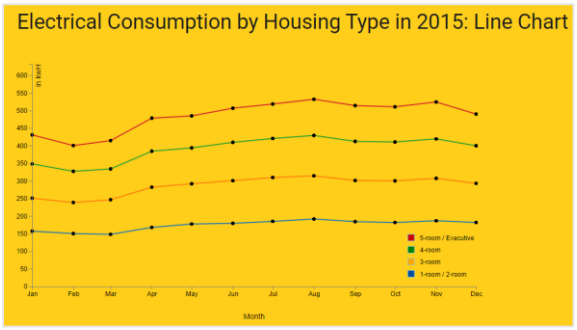


Fig 5: Line chart showing electrical consumption by housing type, 2015

Fig 6: Line chart showing electrical consumption per room by housing type, 2015

However, comparing the average room consumption for each housing type it was observed that 4-room public housing tend

to have a higher electrical consumption that it is consistently higher across the year as compared to 5-room/executive housing. This could indicate that electricity consumption is not solely affected by size of apartment but rather by user behaviour.

A double bar chart was also used to compare the composition of housing types in 2015, against electrical consumption for the year. We observed that the majority of housing in 2015 belonged to 4-room and 5-room / Executive types. While 4-room housing is the most common type of public housing in Singapore, the 5-room and executive housing actually have a higher total annual electrical consumption. In addition, while 1-room / 2-room flats are the minority housing type, electrical consumption from this category is disproportionate to its size.

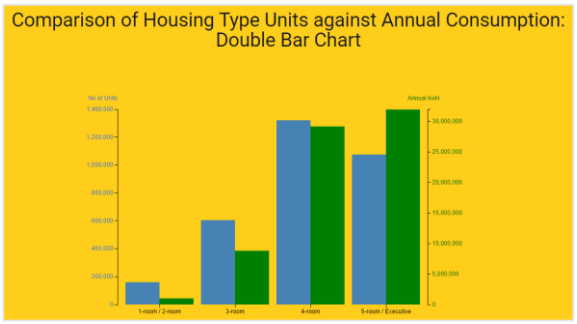


Fig 7: Double bar chart showing comparison of housing type units against annual electrical consumption, 2015

To visualise two dimensions of data: one, the annual electricity consumption visualized in the scale of its circular bubbles, and the subzones each bubble represents a bubble graph is used.

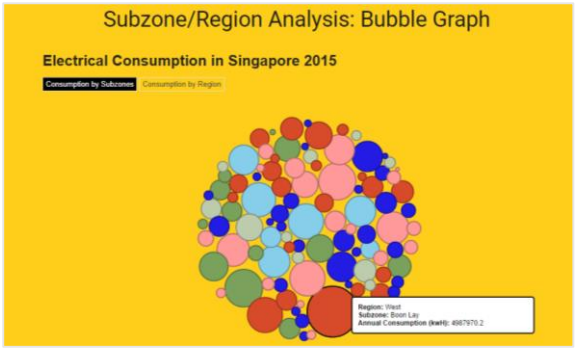


Fig 8: Bubble graph showing annual electrical consumption by subzones, 2015

Using the bubble chart, we are able to observe if there are any particular regions or subzones with high electrical consumption. It is observed that Boon Lay has the highest electrical consumption amongst all the subzones, with Changi Village being the least.

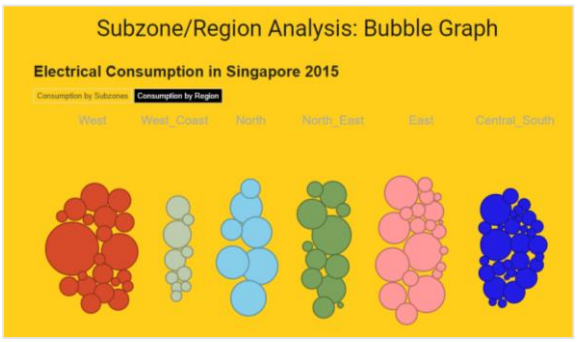


Fig 9: Bubble chart showing electrical consumption by region, 2015

By rearranging the bubbles into their respective regions, we can also see that West Coast has the lowest electrical consumption amongst all other regions, while West and East use up more electricity than the rest.

Lastly, treemaps are used to visualize the electrical data by regions. Treemaps were selected out of the various other data visualisation methods due to its compatibility with the hierarchical data we want to visualize. Tree maps allows for users to visualize the correlation between colour and size in the tree structure, and through which see patterns that would be difficult to spot in other ways.

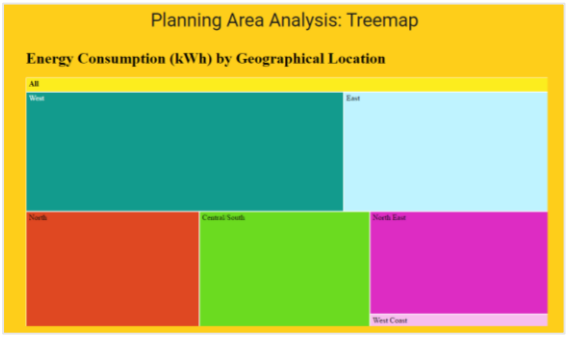


Fig 10: Treemaps showing annual electrical consumption by planning area, 2015

At a glance, we observe the West has the highest consumption and Jurong planning

area accounts for approximately half of the energy consumption in this area.

Taking a step further, we attempted to see if demographics (age group) plays a part in the energy consumption, where we had a conjecture that the higher the number of working population in an area, the more the energy consumed. Once again a tree map is used, and the size of the tree map represents the energy consumption while the colour intensity represents the percentage of active working people. It seems that going by region and the percentage of active working people, we can see a relationship where the West region with the highest consumption has the higher proportion of the active working population, and West Coast (consuming least energy) has the least proportion of active working people.

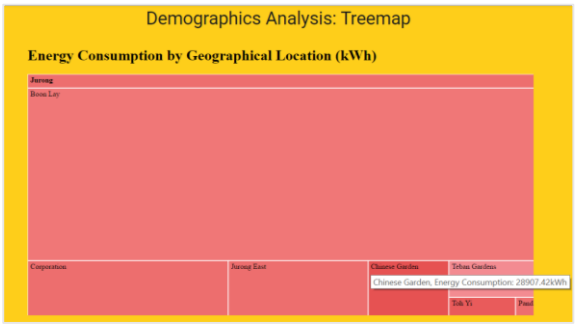


Fig 11: Treemaps showing age demographic and annual electrical consumption by geographic location, 2015

However, once we go deeper into the various planning area and subzones, there does not seem to be much of a correlation between the colour intensity and size of the tree map. Hence, there should instead be other factors influencing the energy consumption in Singapore.

VII. Conclusion

Through our data visualisation, it allows for users that are not equipped with data analysis knowledge to interact with the data set. Through which, end users were able to identify some of the interesting electricity consumption patterns across the island and compare some of the figures to the household electricity consumption levels at their own household. Furthermore, our application allowed users to observe how factors such as housing types, gender, age group at the respective geographical planning zones affect household electricity consumption levels.

VIII. Future Work

There are certainly many areas where our data visualisation application can be further improved on. Interested parties might want to explore incorporative geospatial data visualisation techniques into the application to allow for users to visualise how the consumption patterns vary geospatially. More demographic factors that may potentially affect consumption patterns such as household income, no. of people per household could also be explored.

References

[1] *Singapore Powers*. Retrieved from http://www.singaporepower.com.sg/irj/servlet/prt/portal/prtroot/docs/guid/d06e53be-040d-2f10-81a5-beb38060addd?spstab=Our%20Services

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