Alternate energy resources in Hong Kong: An analysis of solar and wind energy

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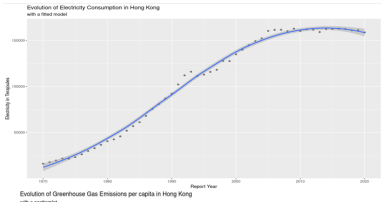
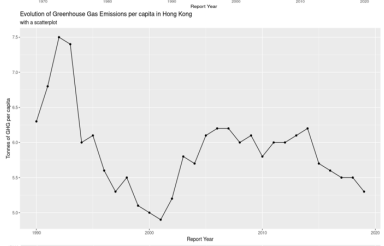
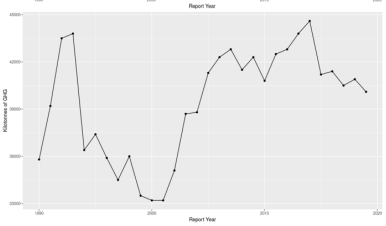
Introduction: Hong Kong Energy Statistics





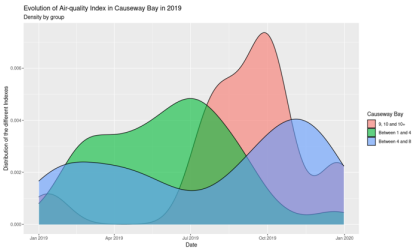


Graph 1:
According to the first graph, the aggregate energy consumption in Hong Kong from 16023 Terajoules in 1970 to 160363 Terajoules in 2005. This exponential growth than stabilize at around 160000 Terajoules a year and reached 158751Terajoules in 2020. This stabilization in energy consumption is positive as the population of the city rose from 6.813 to 7.482 million during the same period. Yet, many climate experts stress the importance of reducing our global energy consumption to reach the 1.5-degree target set at the COP21 of Paris.

Graph 2 & 3:
According to the second graph, the total Greenhouse Gaz (GHG) emissions in Hong Kong rapidly rose after 1990 and reached 43800 KTonnes in 1993, before a rapid decrease of emissions to reach 33200 KTonnes in 2001. Then GHG emissions rose again and reached 44600 KTonnes in 2014, to stabilize at around 40100 KTonnes in 2019. The emissions per capita followed similar evolution yet with a but with a less severe increase between 2001 and 2014, and reached 5.3 KTonnes per capita in 2019

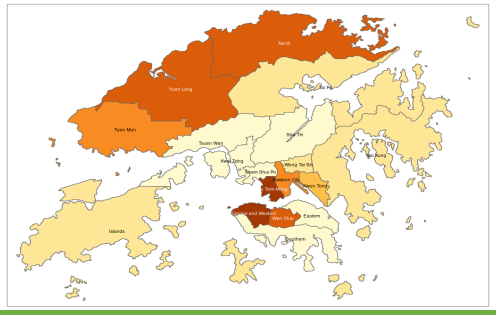
Graph 4 & Map:
Before looking at the consequences of these emissions and energy consumption in Hong Kong on the air Index in the city, we want to emphasizes the striking difference in electricity consumption and pollution between different quarters in Hong Kong, Indeed, graph 4 shows that since 1992, the production of electricity in Hong Kong is on average much higher in the third quarter, with a mean at almost 40000 Terajoules since 1992 compared to 30400 (Q1), 34500 (Q2) and 27800 (Q4) during the same period.

Hence, our poster will focus on the third quarter as the pollution and electricity production is more relevant during this quarter. Indeed, looking at graph 5 we can see that the distribution of high pollution Air Index (9, 10 and 10+) is in majority present during Q3 (July, August and September).



Besides, the map with average Air Quality Index shows that the most densely populated districts (Central/Western, Wan Chai, Yau Tsim Mong) and and the border districts with Mainland (North, Yuen Long) are the most poluted in Hong Kong. Besides, all districts have an average Air Quality Index between 4.5 and 5.1 in 2019, more than for instance Paris (3.8), New York (4.4) or Singapore (3.5) during the same period. Hence, pollution must be reduced in Hong Kong, and this involves the development of renewable energies

Average Air Quality Index in 2019 by District



Objectives and Methods:

Objective:
In this poster, we will review current technological trends and analyze two forms of renewable energies, namely 1) wind energy and 2) solar energy. Using data from Hong Kong government, we suggest alternate energy sources to reduce green house gas emissions and improve air quality in the city. Our objective is to assess the potential for the installation of small wind turbines and solar panels in Hong Kong, the effects on electricity production and consumption in Hong Kong, and discuss the benefits and challenges such policies will have on the population.

Wind energy:
We gathered data from Hong Kong observatory on mean wind speed for different observatories and manually categorized them into the 18 districts. Our initial research showed us the great wind energy potential in Hong Kong which was not being utilized: It was less than 1% in 2013. This is despite the fact that it can contribute to 32% of Hong Kong's electricity consumption if utilized properly.

Solar energy:
The gathering of data on solar exposition in Hong Kong by district proved to be irrelevant for our poster, as the exposition is rather homogeneous on the island. We have used general data on average radiation in Hong Kong during the year and compared it with other cities in the world that have already implemented a solar energy development policy. In addition, we used government data on population concentration to determine which districts can

Methods used:
We used geocomputation and spatial analysis using R for the maps, data wrangling in R for cleaning and merging different sets of data, and exploratory data analysis using R. We used text mining to find key-words related to our specific interests such as mean wind speed, Hong Kong district wind speed etc. The majority of our raw datasets come from Hong Kong government's data and Hong Kong Observatory.

Results:

Solar energy:
Solar energy resource in Hong Kong is usually regarded mildly rich. Hong Kong has an "annual average global horizontal solar irradiance" of 1,290 kWh/m2. According to a study conducted by Dr. K.M. Leung, the potential of solar energy in Hong Kong was 5,944 GWh/year in 2010. Another study from University of Hong Kong's department of Architecture showed that the average percentage of bright sunshine in Hong Kong is 44%. This represents an estimation of a "mean daily global solar radiation (GSR) of 14.46 MegaJoules per square meter".

To put this into perspective, London have a mean GSR of 9 MegaJoules per square meter. Besides, the average GSR during the third quarter in Hong Kong reaches 17.75 MJ/m2, compared to 11,19 during the first quarter. Hence, Solar panel installation in Hong Kong is economically viable. The efficiency of these future installations will be most important in the third quarter, which is the period when electricity consumption on the Island is highest.

Besides, several building-integrated photovoltaics (BIPV) installations are already under constructions, but are not yet widely accepted by the population, especially because of the noise and the space they take up. The map on population density shows that the installation of solar panels that are non-BIPV is not possible on Hong Kong Island and Kowloon. Yet, several districts like North and Yuen Long are less densely populated and have little topographical relief. Hence, the development of solar installations there is possible and necessary.

Wind energy:
In Hong Kong, it was proved that there is great wind power potential with suitable geographical conditions for wind energy development. Potentially, there is 14,499 GWh wind potential in offshore projects itself which is 32.30% of electricity consumption. At the stage of project planning, the location selection is important for the power generation of the project. Windy locations with long-term wind resources observation are essential (Gao, et al. 2019).

We analyzed and mapped out the windiest locations according to district. We also utilized government data to compare the wind power density to the average wind speed required for wind turbines. A minimum wind speed of 3 m/s is needed to drive a wind turbine, and a 10% increase in speed leads a 30% increase in power output according to HK electric. Most areas mapped out have average windspeeds superseding this amount.

Wind resources in HK can be divided into two categories in Hong Kong: 1) on land 2) offshore. Data analysis shows the potential of Lamma offshore with wind speeds measured up to 7.03 m/s and the government has also installed a large wind turbine project in Tai Ling, Lamma.

Population Density in 2016 by District

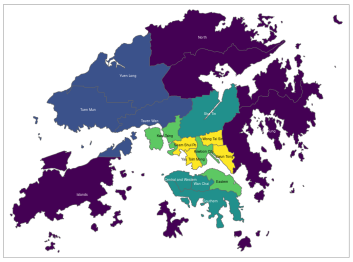
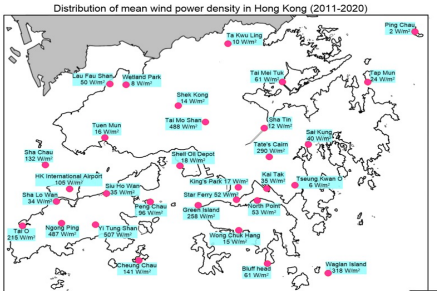


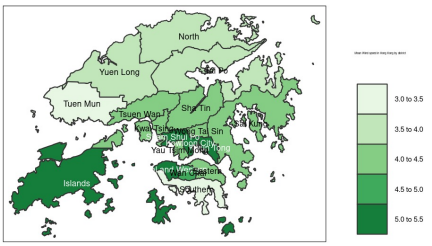
Table 2. Optimization results of the selected wind farm and Hong Kong offshore wind power potential assessment.

Area (km^2)	Number of WTs	Total Power ($\times 10^8$ kWh)	COE (HKD/kWh)	Potential Offshore Area (km^2)	Total (GWh)	% of Electricity Consumption in 2017
16.86	25	5.78	1.55	421.48	14449	32.02

Distribution of mean wind power density in Hong Kong (2011-2020)



Wind speed in Hong Kong by district in m/s



Moreover, small turbines can also be installed on the top of buildings, and studies showed theoretically the installation of individual turbines on top of local high-rise buildings is feasible. We also mapped out urban density to see the potential for these individual turbines. There are approximately 30,000 such buildings which gives a total resource of 20–30 × 108 kWh/yr. Asides from local and offshore projects, individual turbines should be installed on local high-rise buildings above 60m.

Limitations

Solar:
Several limitations remains to the development of solar installations in Hong Kong. There are only a few places that can accommodate large non-BIPV installations due to the population density and topography of the island. The price of a KWh produced from solar energy is today 2.2HKD against 0.4HKD if the same KWh is produced with fossil energies. The noise and space they occupy make them unpopular with the population. Thus, the spreading of information about the benefits of this energy, and the development of cheaper and more efficient technologies are necessary before a massive public investment in this energy on the island.

Wind:
There is a lack of government support and incentives which pose challenges to development of wind energy. Despite "First Sustainable Development Strategy for Hong Kong" in 2005, this target was not satisfied and is low compared to other countries. There is a lack of legislation and strategies, and both the government and big companies look down upon the long-time payback, high-risk and low return energy projects.

Conclusion

Solar:
The local conditions in terms of sunshine and radiation are quite good in Hong Kong, and push for the development of solar installations. The efficiency of such projects will be important especially in the third quarter, which coincide with the highest electricity consumption in the Island. Several projects were already undertaken by the city, like the EMSD Headquarters at Kai Tak and the Hong Kong Disneyland Resort solar installations. Yet, solar energy represents still less than 0.1% of electricity consumption in Hong Kong. The government should hence undertake massive public investment to create new installations, notably in the North and Yuen Long districts. If BIPV projects are also a possible development path, consultation with the local population must be extended to explain the benefits of these projects and improve their acceptance.

Wind:
The government has already installed some projects in Tai Ling, Lamma for example but government and private investment in wind energy must be increased to rely less on fossil fuel imports. Projects must be installed offshore such as Lamma and Cheung Chau, locally on high-rise buildings and especially in Islands district and Central and Western.

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- Greenhouse Gas Emissions and Carbon Intensity in Hong Kong