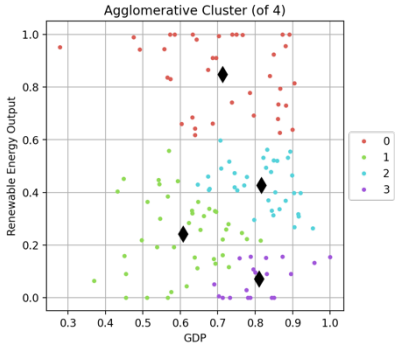
Renewable Energy and GDP

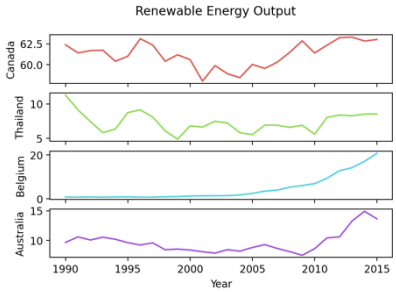
As the doomsday clock remains only 100 seconds from midnight, it emphasises the severity of climate change (even though the doomsday clock considers multiple threats to humanity). Becoming more aware of the impact we are having on our plant, many countries are making an effort to transition from fossil fuels to renewable energy sources – Although these investments aren't cheap, which is one of the many limiting factors which is having an impact to the transition.

How is a country's renewable output compared to their GDP?

By using clustering – an unsupervised machine learning algorithm, we are able to identify and group similar points. Using GDP per capita data and the amount of Renewable energy output from 2015 we can find significant clusters to observe countries performance based on their label given by the clustering algorithm. Applying both k-means clustering and Agglomerative clustering we can observe variations of clusters and decide the one best fit for our data. In this instance, using agglomerative clustering has given the most interesting output.



If we look at the Renewable energy output plotted against GDP, we already see some interesting clusters, label 0 shows countries which have relatively high GDP and are using large amounts of renewable energy. Labels 1 and 2 somewhat split the data into countries with low and high GDP with some use of renewable energy whereas in label 3 we see countries with a high GDP and very low renewable energy output. Picking a country from each cluster we can further evaluate their history with renewable energy.

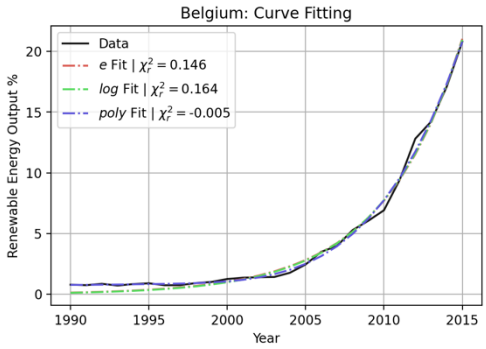


In the time series graphs above there is a country from each label of the cluster of 0 to 3 from top to bottom respectively. For Canada (label 0) we can see that they have maintained their renewable energy output for years now with only a very small increase in the past few years. Thailand (label 1) has a small negative trend in their output, potentially because they were outputting more energy that wasn't renewable over the years. For Belgium (label 2) we begin to see a clear positive trend over time as they have increased their renewable energy output and the same applies to Australia (label 3) as well. For labels 2 & 3 we see a positive trend towards more renewable sources whereas labels 0 & 1 don't have large improvements at all over time. This might possibly be due to the way the data is calculated as a percentage of total energy output but regardless of that, there is still no increase in renewable energy output as a percentage.

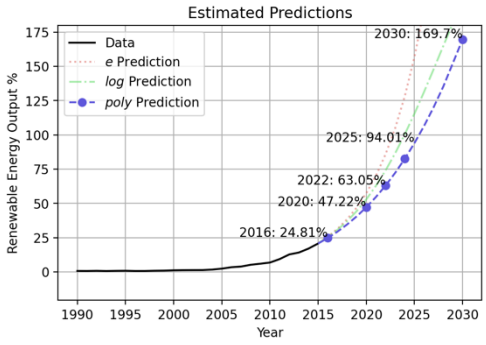
What does our future look like?

Obviously, the future is unpredictable but using curve fitting we can create estimated values that will give us an idea of what it may look like. There are several types of curve fitting that are best used in different applications, to measure the fit of the curve we can use the Chi Squared goodness of fit, which measures the quadratic deviation from the mean given by:

$$\chi^2 = \sum_{i=1}^{N} \left(\frac{y_i - f(x_i)}{\sigma_i} \right)^2.$$



From this clearly, we see that the polynomial fitting method proven to be the best with a χ^2 = -0.005. Using the polynomial function we can predict the value of renewable energy output in a certain amount years' time. If we apply this to Belgium, we can see that the trend continues upwards.



Due to the nature of poly fitting, we cannot extrapolate too far as clearly seen at the 2030 data point, considering the data is a percentage of the total energy output it is impossible to have over 100%. Although, we see this remain an issue for both the logistic and exponential predictions as well. Ideally for periodic data, the best fit would be a fast Fourier transform which can adapt to changes in data that we may encounter similar to Canada. However, that being said we can see that poly fitting has made reasonable predictions for 2016 of 24.81% till around 2022 so the less we extrapolate the better our predictions will be. Clearly, however, we can see a positive trend towards renewable energy, Obviously these models can be applied to any other countries as well.