

Energy Sector of India

Motivation:

Energy plays a vital role in our life and is an important parameter for the country growth and is a strong indicator for the country performance. India is the world's third largest producer and third largest consumer of electricity and continues to grow. It is of prime importance to see from where we are getting this energy, what are the sources, how much they contribute, how much the states are getting these resources and how the emissions from these have grown and also how much renewable is being used in India.

The goal of this project is to understand the Energy Sector of India and the various resources used in the generation of electricity and how the emissions of particularly electricity sector contributes the total emissions.

Objective:

Following are the questions I am looking forward to analyze

- 1.) How are the electricity distribution regions wise in India and also by the ownership among these regions?
- 2.) To make comparison among states by parameters of electricity generation and electrical capacity.
- 3.) Under the total electricity generated how much is renewable with their types.
- 4.) Comparison by the sector wise electricity generation, comparing non-renewable and renewable by their types.
- 5.) If we talk about the non-renewable sector then where are the most coal reserves in India, which are the most coal consuming states.
- 6.) Among the renewable energy, which states have the highest capacity, and also which source are the highest one by renewable.
- 7.) Which areas have the most Wind energy capacity and Solar energy capacity?
- 8.) How much is the gap among generation and capacity among the states in renewable sector?
- 9.) Which states has the highest per capita energy consumption?
- 10.) How among the highest consumption states the per capita energy consumption has risen over the years?
- 11.) States comparison by the Industrial and Residential electricity load.
- 12.) How the CO₂ emission have risen over the years in India.
- 13.) CO₂ emissions sector wise and different types of fuel sources.
- 14.) Trend of Greenhouse gas emission by the sector over the past years.
- 15.) Trend of Energy produced by renewable sources.

Data Resources:

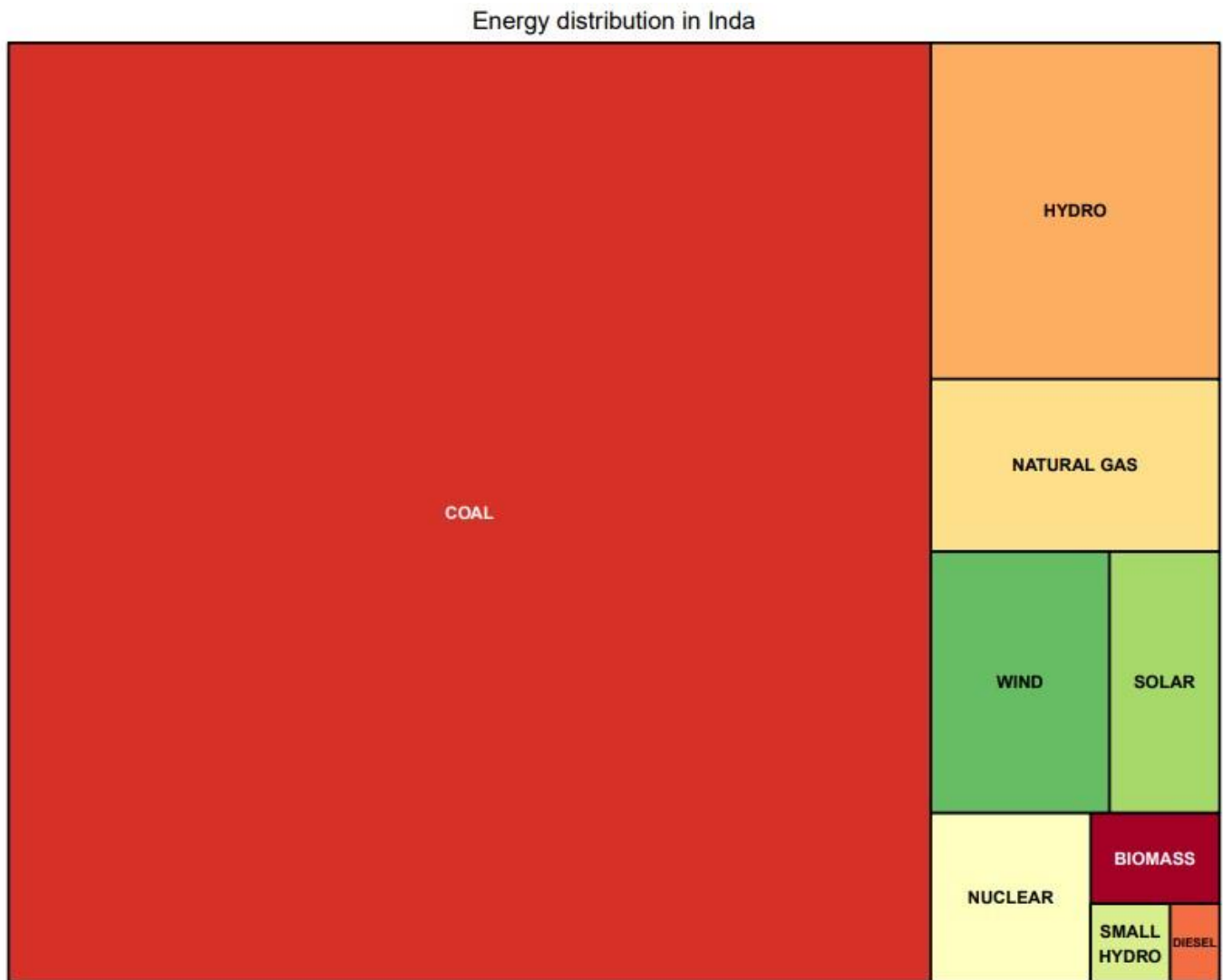
Following are the links of website from where I have taken the data and processed as required.

- 1.) <https://data.gov.in/>
- 2.) <https://ourworldindata.org/co2/country/india?country=~IND#per-capita-how-much-co2-does-the-average-person-emit>
- 3.) <https://edm.niti.gov.in/?dataKey=energyBalance>
- 4.) <https://www.kaggle.com/twinkle0705/state-wise-power-consumption-in-india>
- 5.) <https://www.iea.org/data-and-statistics/data-tables?country=INDIA&energy=Electricity&year=2019>

Total of 29 files and one .rmd file is in the compressed folder, these files are required for the code to run. Also one shape file is used in the code which is required for Map to be made and is in the compressed folder. Before running the code please see the readme file.

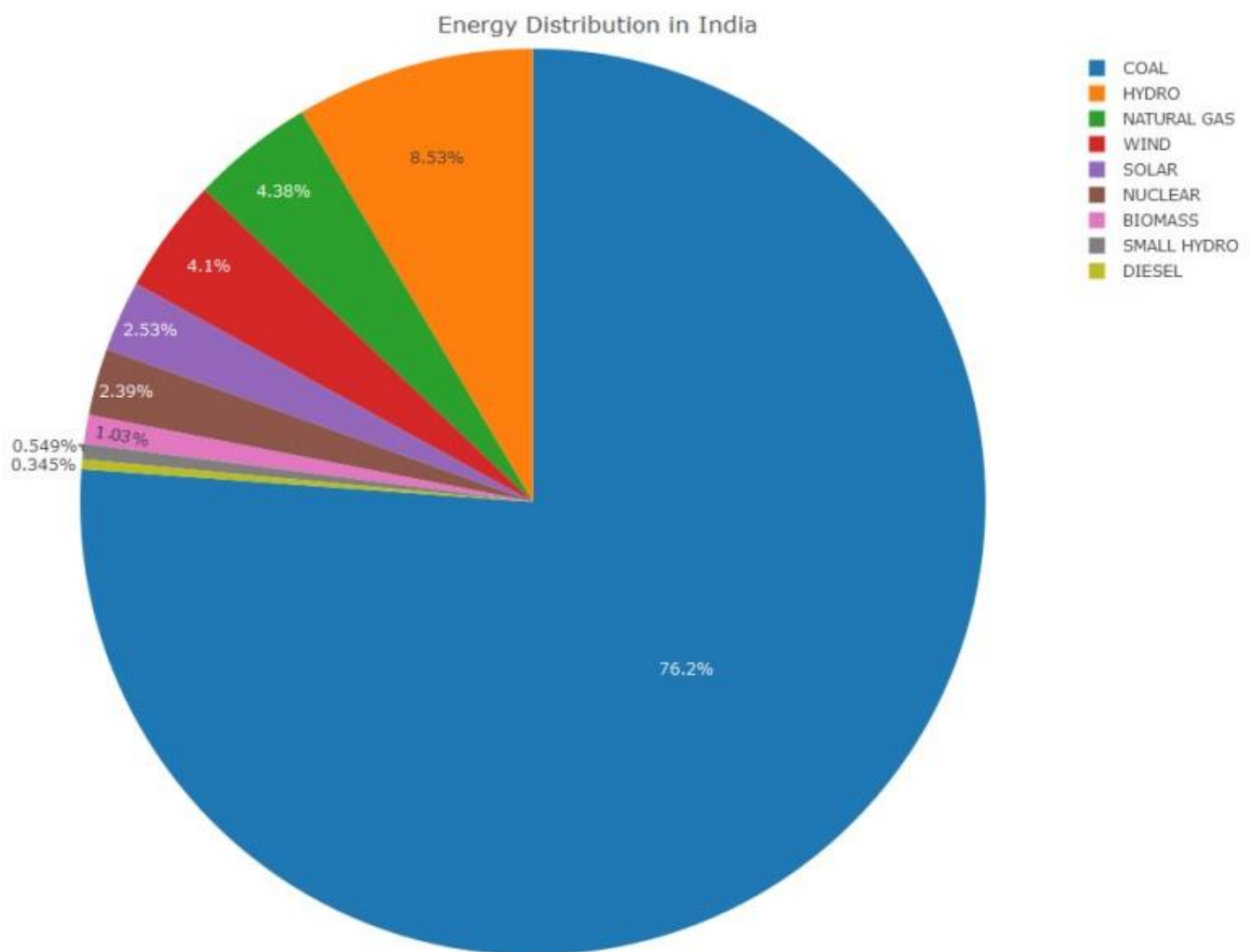
ENERGY DISTRIBUTION IN INDIA ON THE BASIS OF ELECTRICITY GENERATION:

First we try to see how is the energy distribution in India, for this first a Treemap is made in which the area of the map shows the capacity of energy available. This tells us the hierarchy of the energy easily.



But in the Treemap it is hard to understand the contribution of each source, so we make the pie chart for this and in which we show the percentage of each source of energy.

PIE CHART:

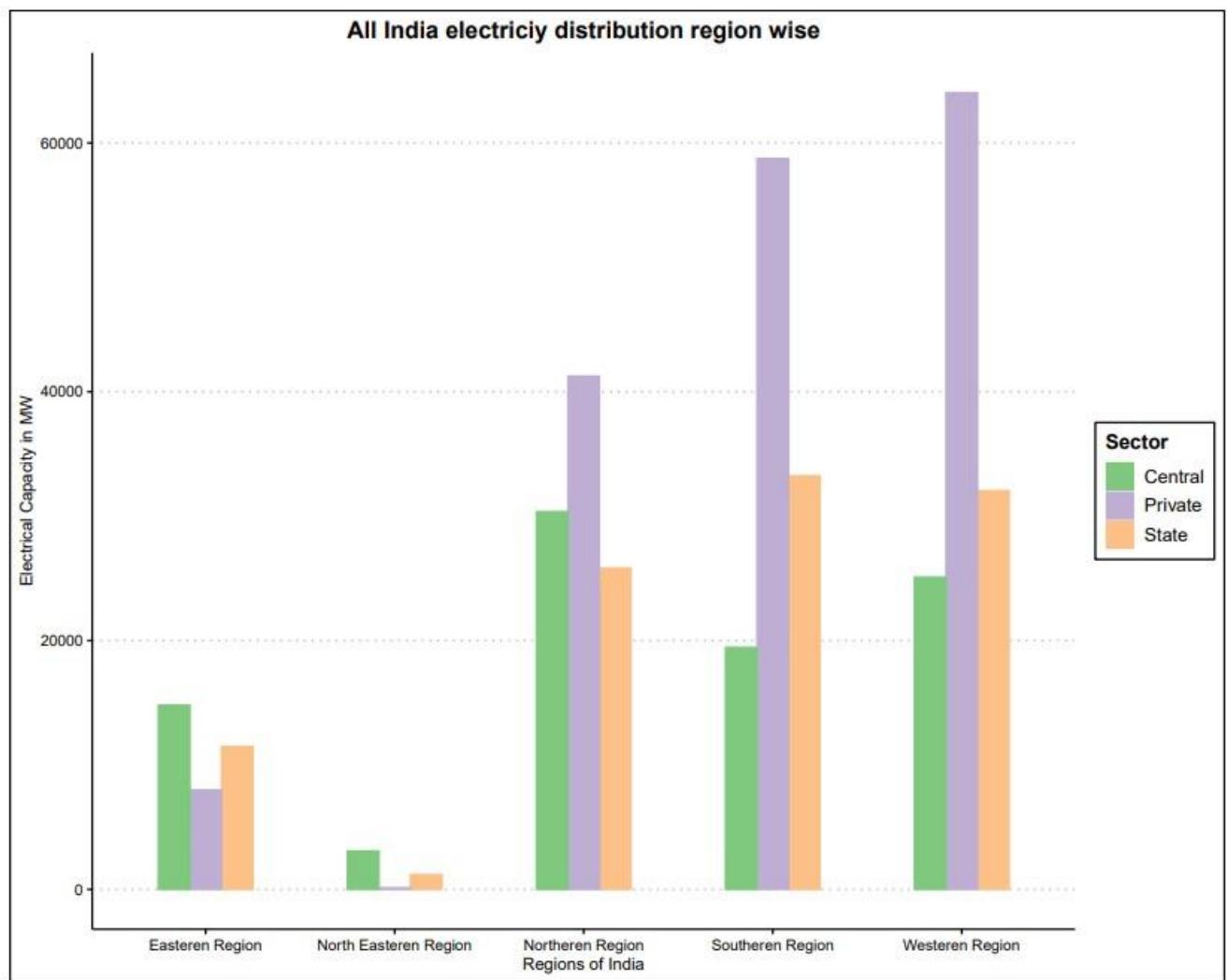


In the pie chart we can better analyze how much percentage of overall the sector contributes to and also the percentage is shown in each sector for better understanding.

We can observe that Coal is the most used source in the Energy production

Now after we have seen the hierarchy of the energy, let's see the categorical wise distribution. First let's analyze the energy distribution capacity wise among the regions of the India and also in this sector wise, which comprises the CENTRAL, STATE AND PRIVATE

ALL INDIA SECTOR WISE:

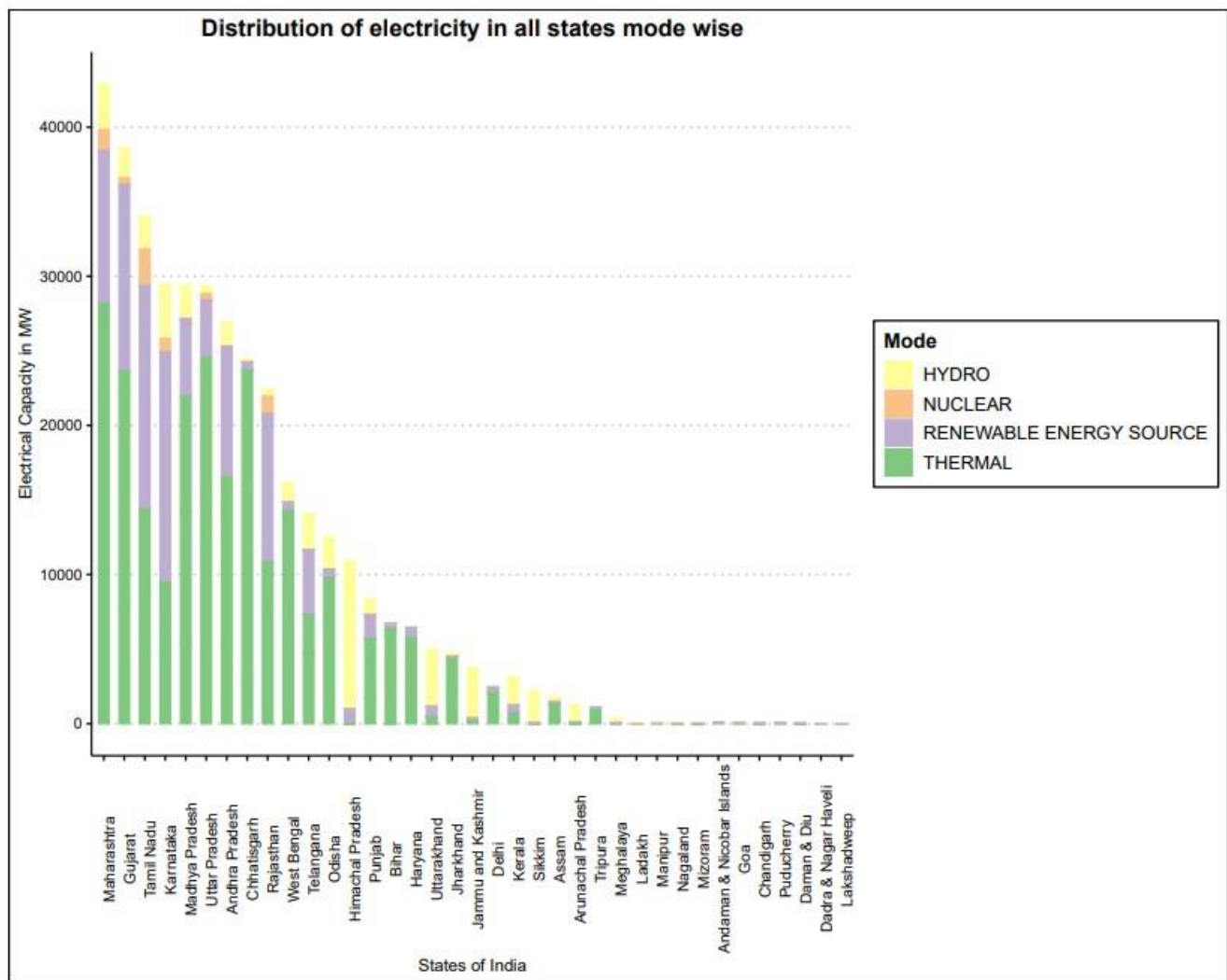


Bar plot is chosen because it gives the relative comparison among the regions, as it is a categorical chart

We can observe that Private sector is the most dominating one in North, South, Western region of the country whereas in Eastern and North Eastern regions the central sector is the highest one.

Now let's see the comparison among the states on the basis of Electrical Capacity, and in this also the different modes of electricity are shown on the same bar.

MODE WISE COMPARISON:

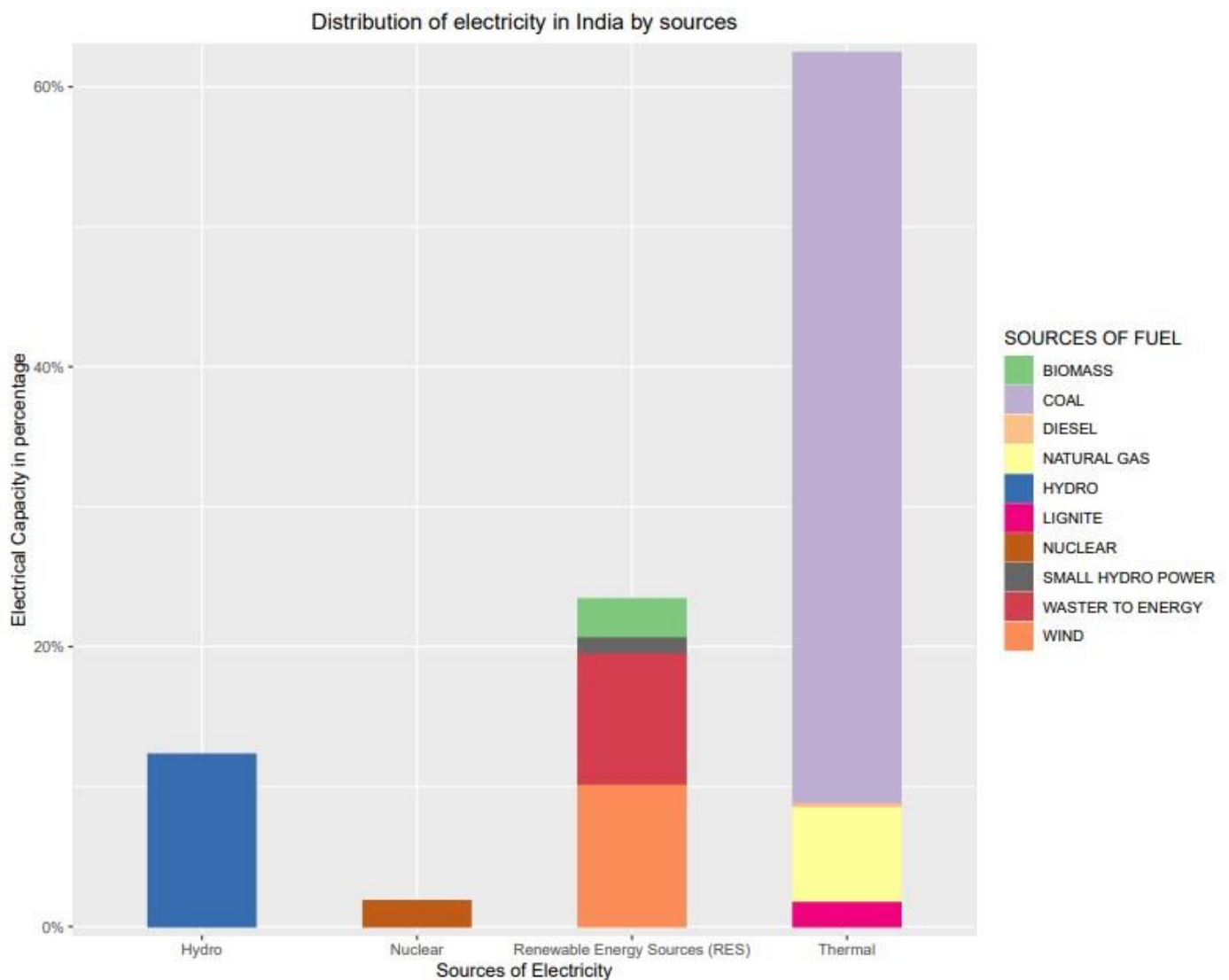


Bar plot is again chosen for this comparison as this can easily compare different states. Also, the different modes are on the bar so as which an overall picture of all the energy in all the states.

We can infer from above that Maharashtra has the highest capacity, Tamil Nadu seems to have the highest renewable energy share and although most of the states have the Thermal energy as their biggest supplier, Himachal Pradesh although has a very high capacity, but the share of thermal energy is very low and instead it has Hydro as the major share.

Now as we have compared the states, so now we will compare the different energy sources by their capacity which will gives us more insight about each source.

SOURCE WISE COMPARISON:



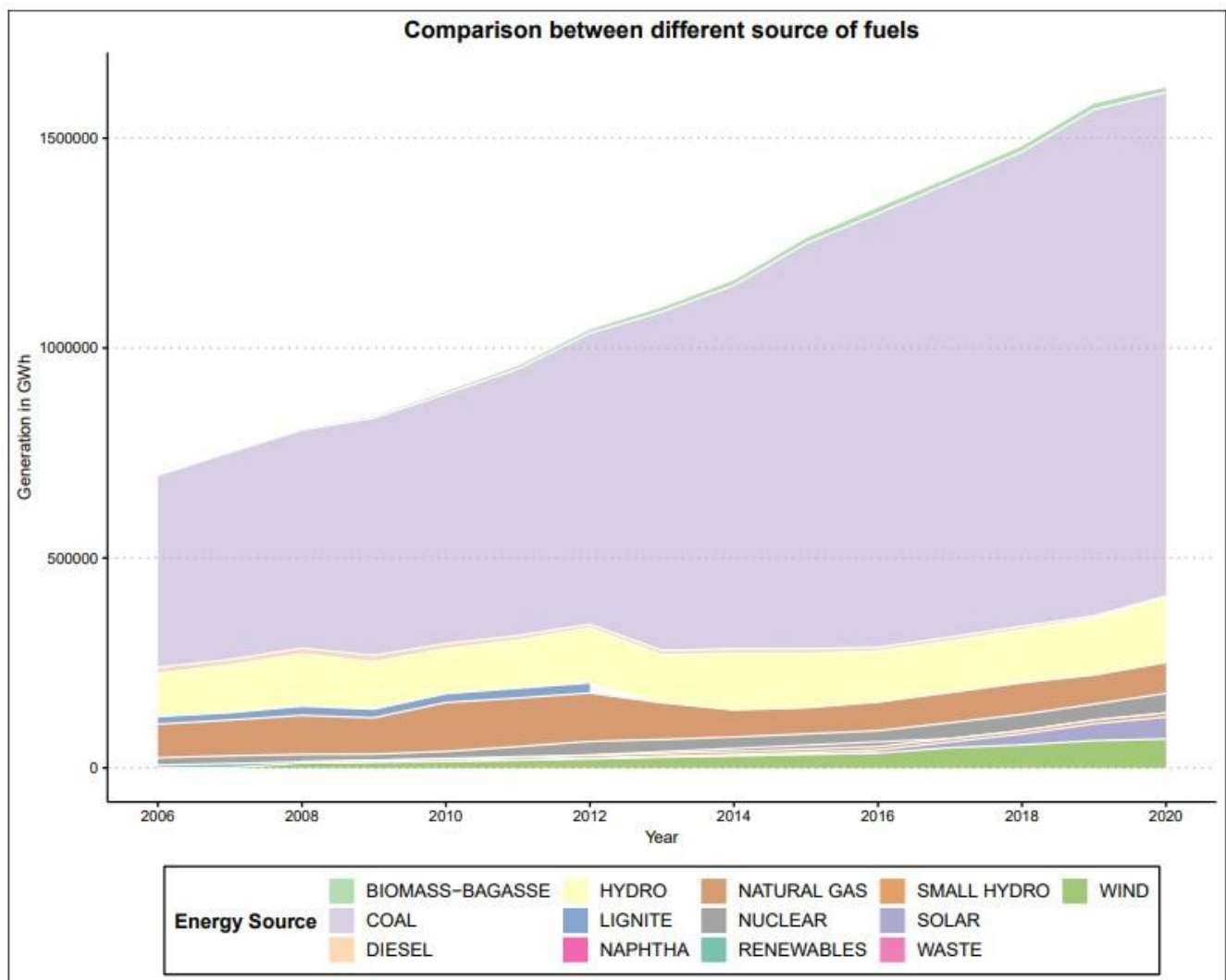
Bar plot is again chosen as it a very good indicator for relative comparison, but in this the Y axis is change to percentage basis, as that gives a natural comparison than unit such as MW.

We can observe that Thermal is the largest contributor, but among thermal also the major contributor is Coal, then Natural gas and then Lignite.

Nuclear which is a very promising sector, has the least share, Hydro has a significant more than 10 % share. In this data solar is missing and in renewable energy sources Wind has the highest share.

So now as we have looked the share of each energy resource, let's have a look at the trend over which these resources are being used and growing over the past years.

COMPARISON BETWEEN DIFFERENT TYPES OF FUEL SOURCE USED:



As the data is over the years and we want to see the trend, we used the Area graph which is a type of trend graph and the area under the line shows the percentage it acquired in that period.

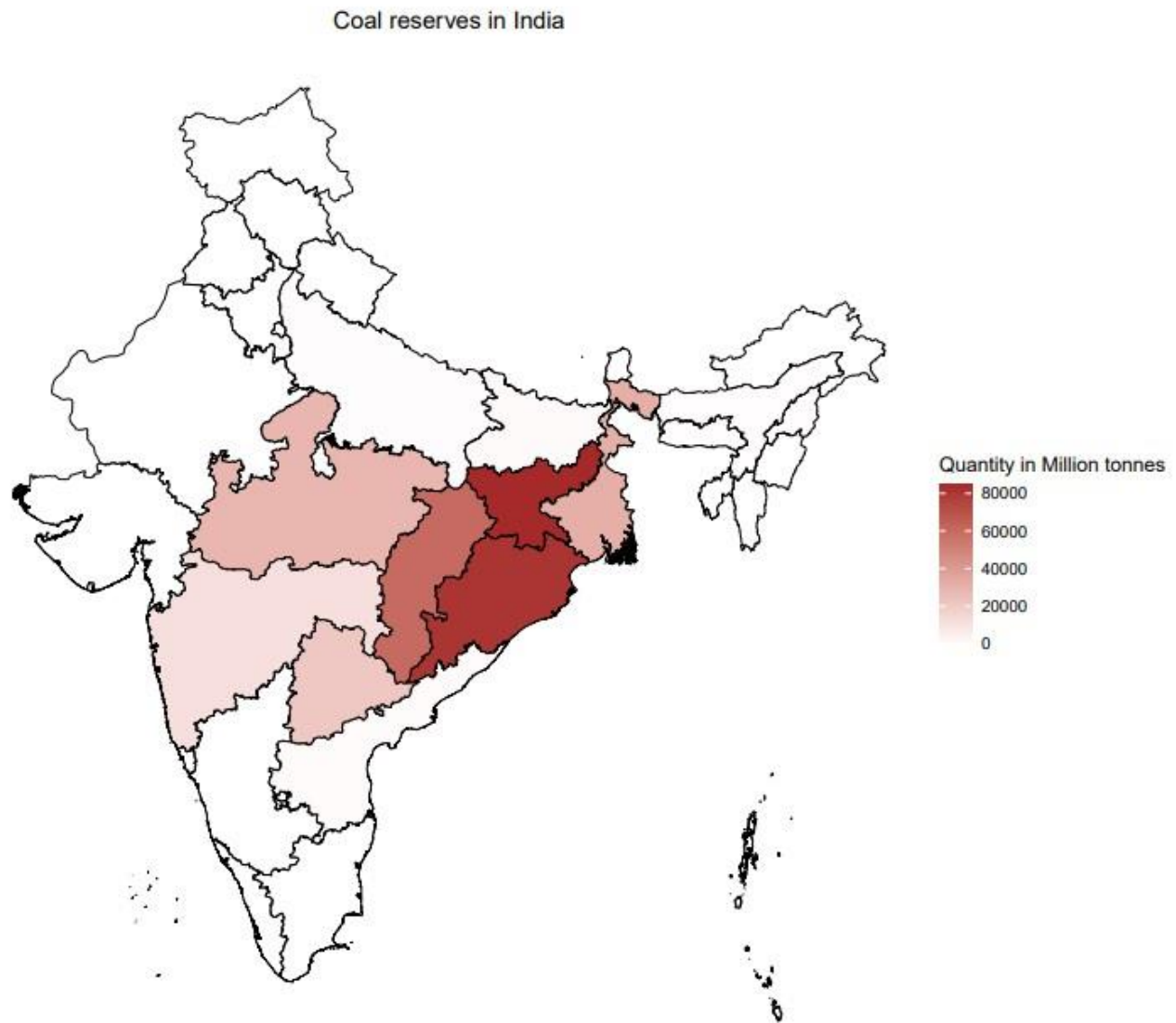
We can clearly see that Coal was the dominant source and its dominance has not decreased rather increased over the period of time.

Hydro is constant over the years, and in renewable energy, Wind and solar continue to dominate but the growth of Wind has been more, although most of us assume that solar is growing more rapidly.

Now as we have seen that Coal is the dominant in energy resources, let's take a dive into it and see what are the locations where it is present, which states are the most consumers of Coal, and how over the period of 2009 to 2019 the coal energy used has increased.

First, we will try to see the location where Coal reserves are and for this we plot it in the Map of India.

COAL RESERVES IN INDIA:



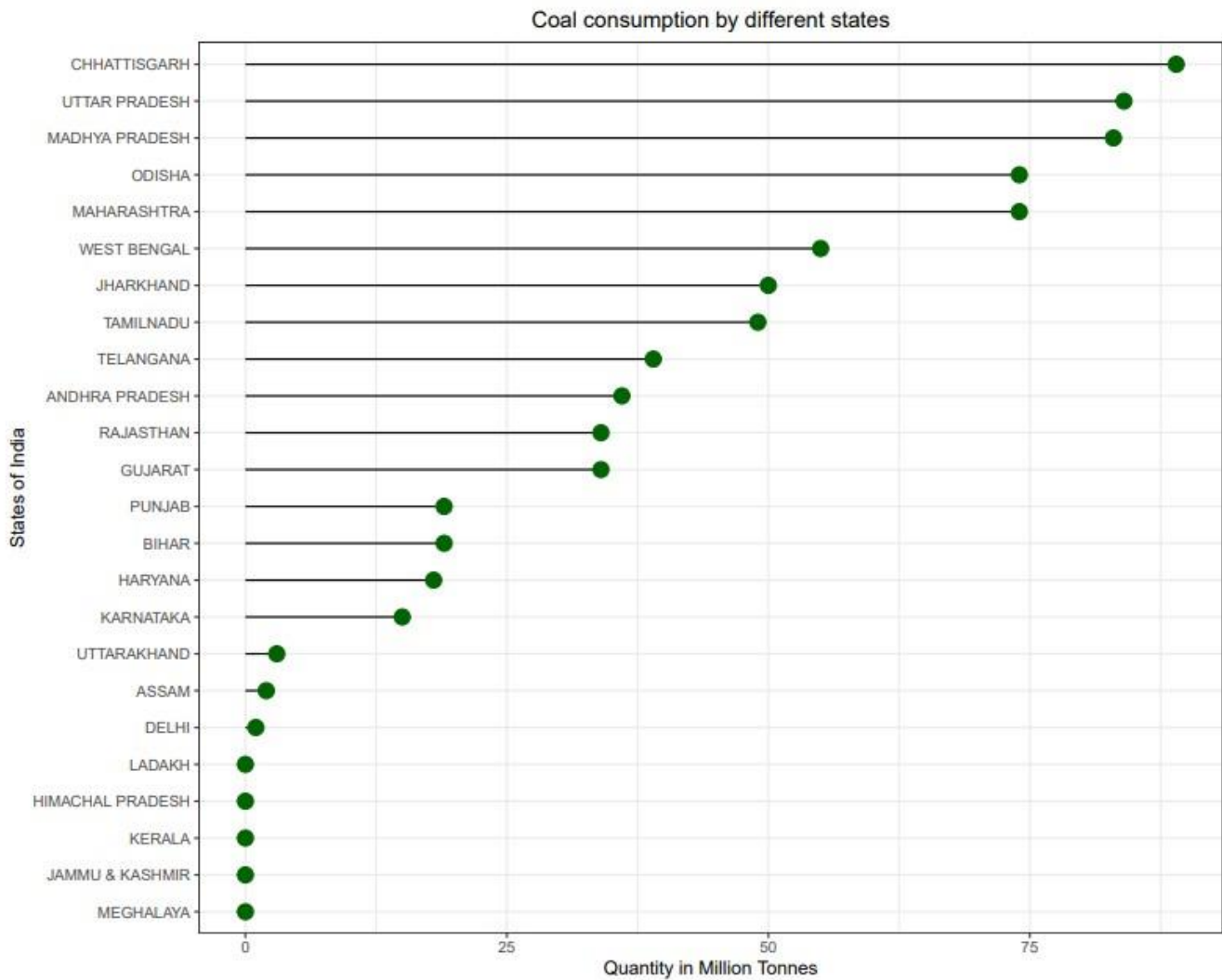
We choose a Choropleth graph, a spatial graph, which seems as the best fit to see the states which has the highest coal reserves.

Gradient fill is used to better understand the values changing.

We can see that Chhattisgarh and Jharkhand have the darkest region, meaning highest coal reserves. Also, most of the reserves are only in the central part of India. There is no reserve in the South, nor in the Northern East nor in the North.

So, now we will check who are the highest consumers of the Coal

COAL CONSUMPTION BY EACH STATE:



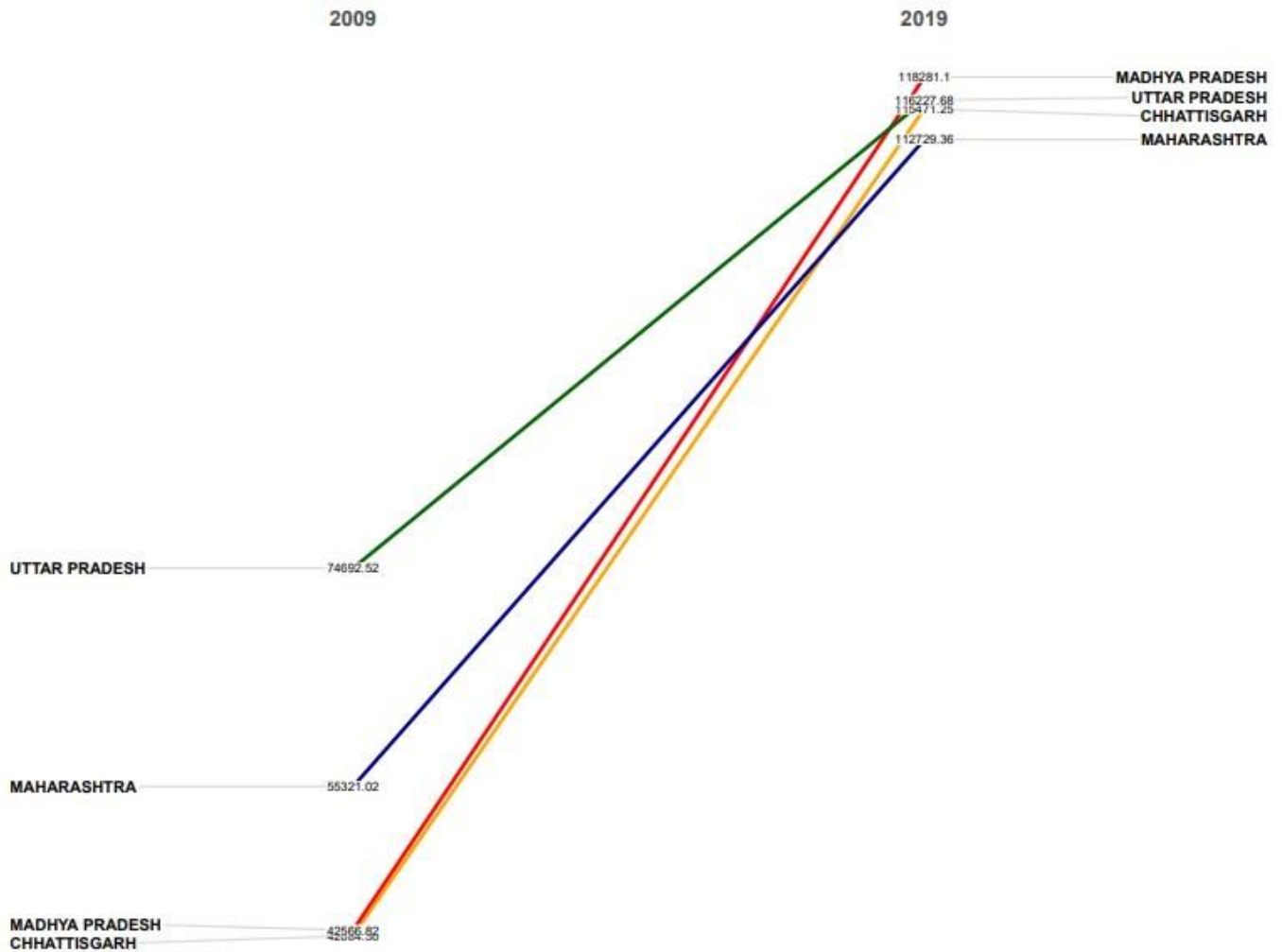
A categorical chart is preferred, but this time, since we have to compare only coal that is one variable among different states, so choosing lollipop chart for this.

We can clearly see the Chhattisgarh is the highest consumers of the coal, but interestingly Jharkhand is not even in top 5 consumers of the Coal.

In fact, Maharashtra and Uttar Pradesh are in top 5 consumers of Coal, and they have very little to no reserves, this can be attributed largely due to the population of these states.

SLOPE GRAPH:

Electricity from coal



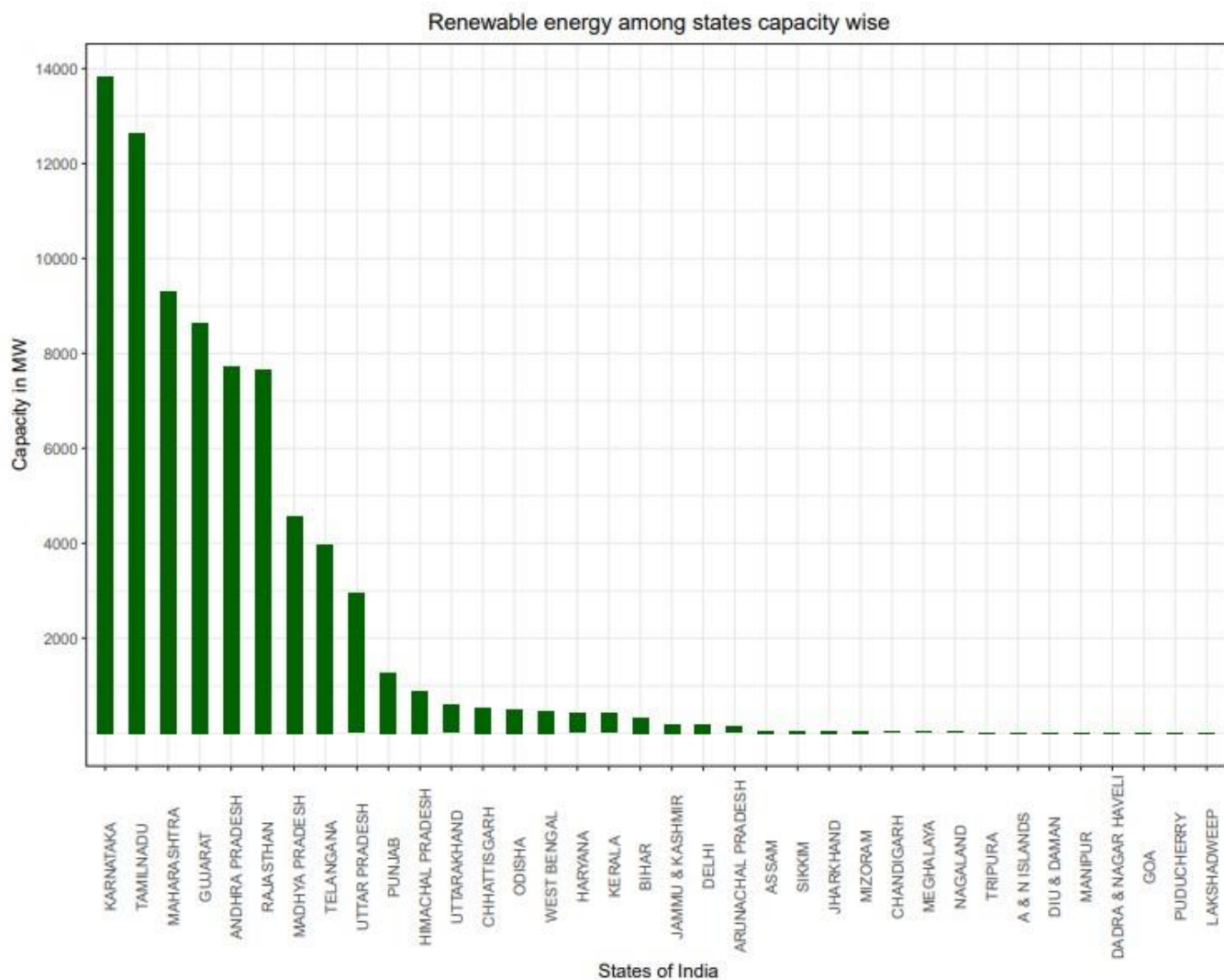
To understand the coal consumption, increase in the past 10 years, a slope graph is made, this fits a line in between the two end points and tells how they varied.

We can observe that in 2009 U.P was the highest coal consumer, for electricity generated from coal. But in 2019 all the 4 states are very near.

This tells about the increasing energy demand among all the states.

Now coming to the renewable energy, first we try to find the states having the highest capacity in the renewable energy.

RENEWABLE COMPARISON CAPACITY WISE:

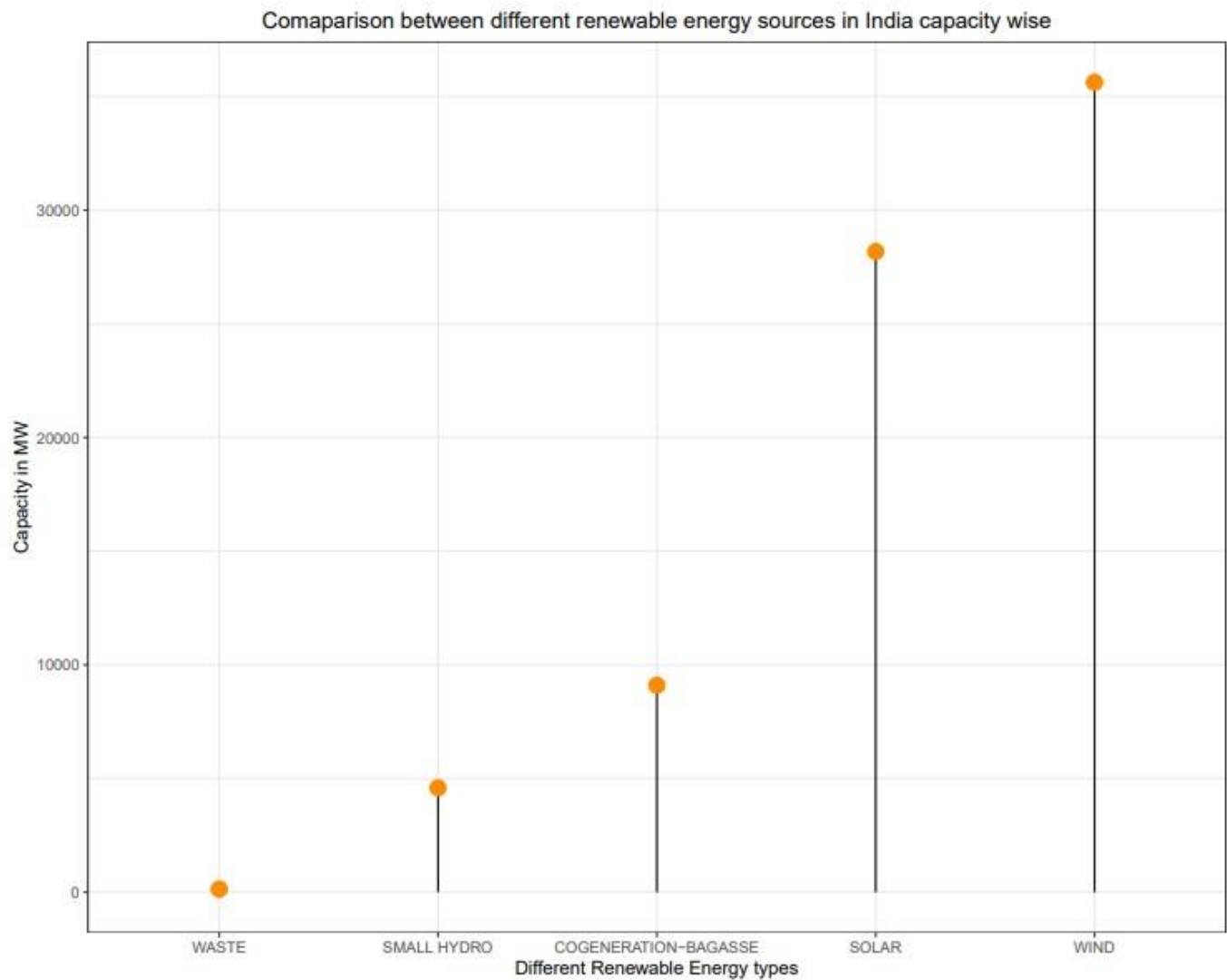


For this bar plot is made, that is a categorical chart is made. For this lollipop chart is not made as for similar small values it is slightly difficult to compare.

We observe that Karnataka and Tamil Nadu has the highest renewable energy capacity and that states like Chhattisgarh and Jharkhand have very low renewable energy capacity. This can be very well attribute to no reserves in southern regions so they better adapted to new policies, but these states could be very well geographically supported for renewable energy.

So now we try to first see the renewable energy comparison and see which renewable sources dominates.

RENEWABLE BY SOURCE:

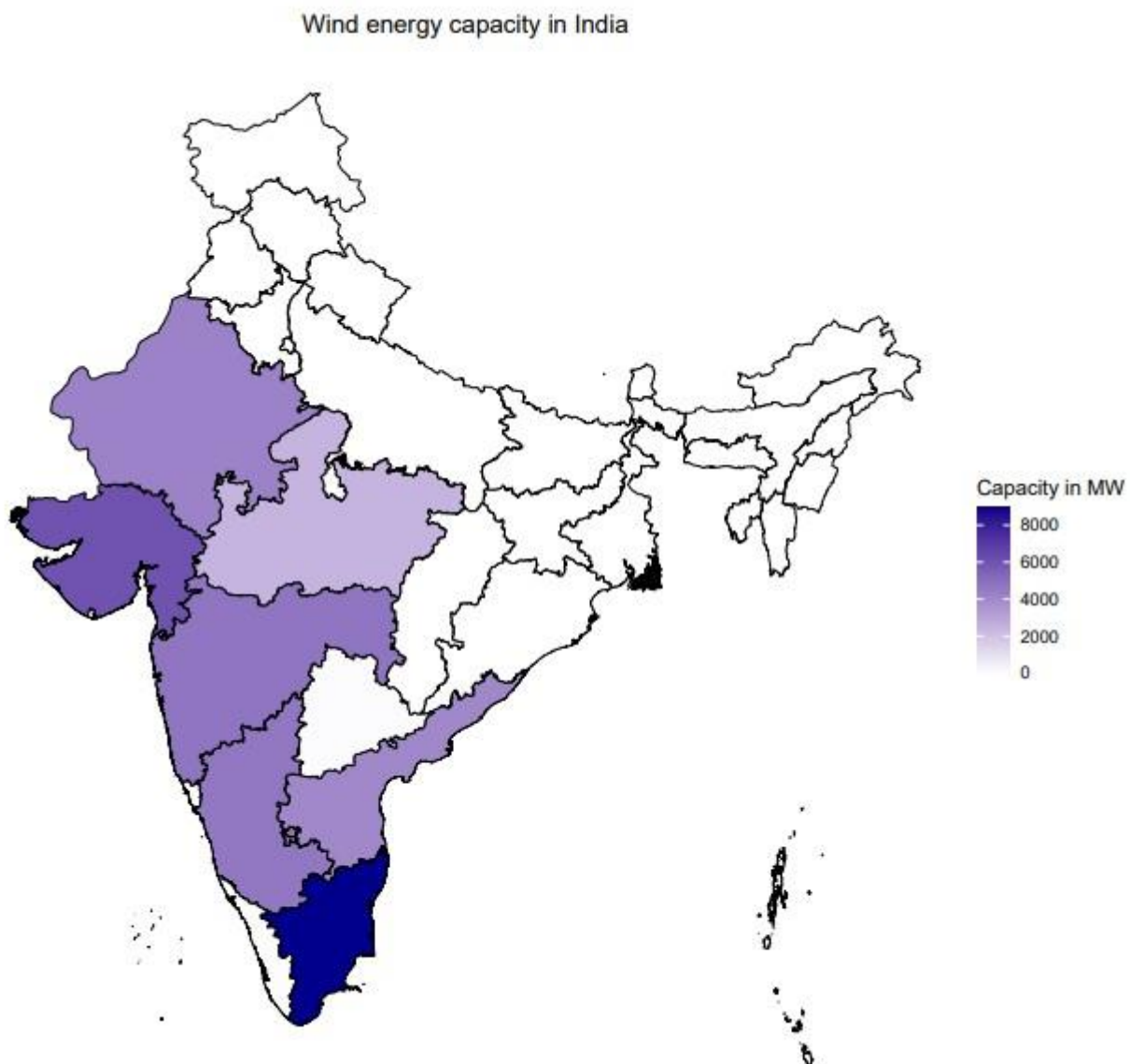


Lollipop chart is used here as for direct comparison where there are no very similar values it is a good comparison measure.

We can clearly see that Wind energy dominates all other and the next is Solar.

So now let's look at wind energy and see the states where it is dominant.

WIND ENERGY DISTRIBUTION ON MAP:



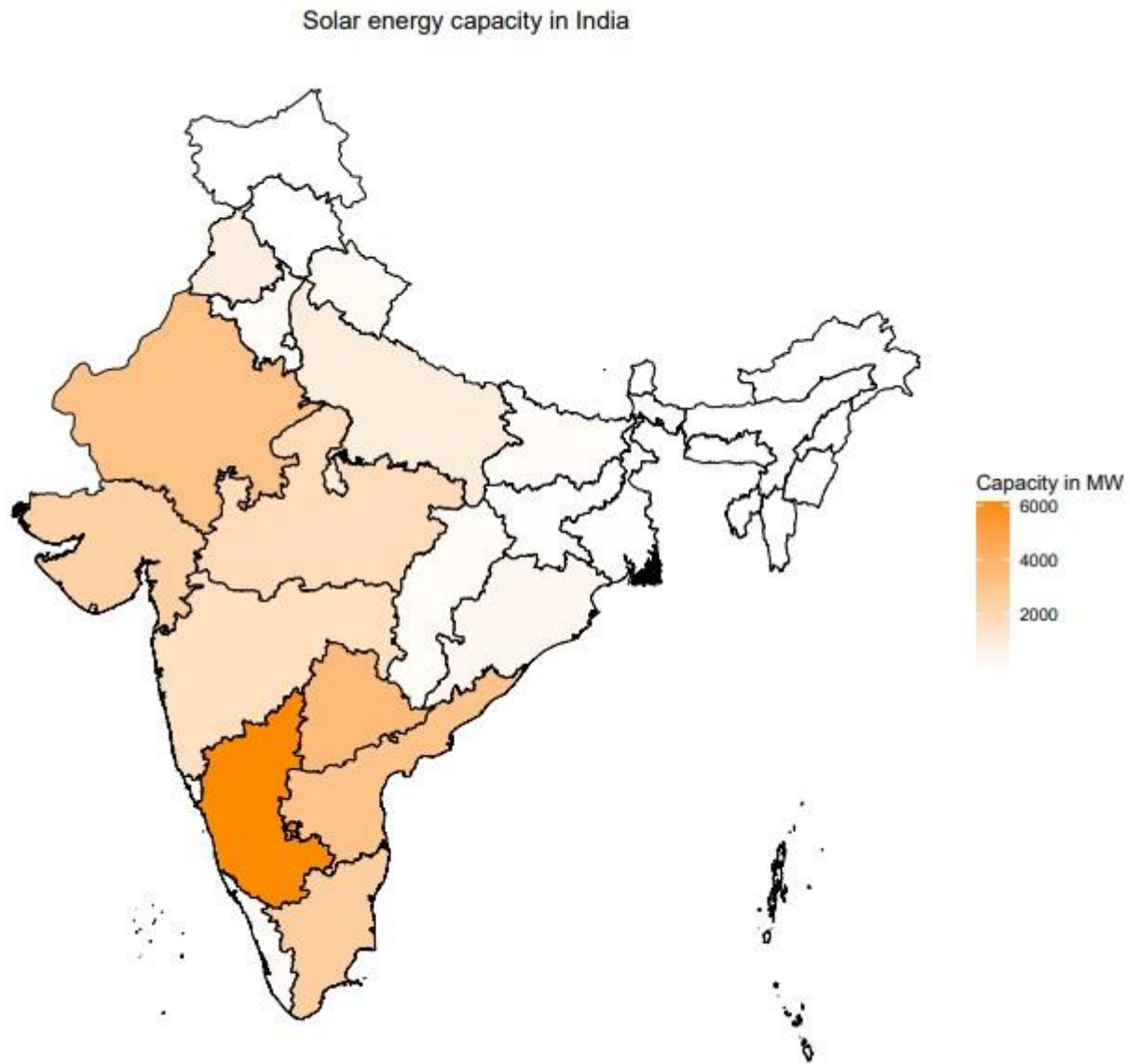
Spatial graph, choropleth is best for this comparison. Gradient fill tells about where the values are high.

We can see that indeed Tamil Nadu has the highest Wind energy.

Most of the North and North eastern part doesn't have wind energy. This is also correlated with the wind pattern that follows in country.

Now we do the same analysis for Solar Energy.

SOLAR ENERGY DISTRUBUTION ON MAP:



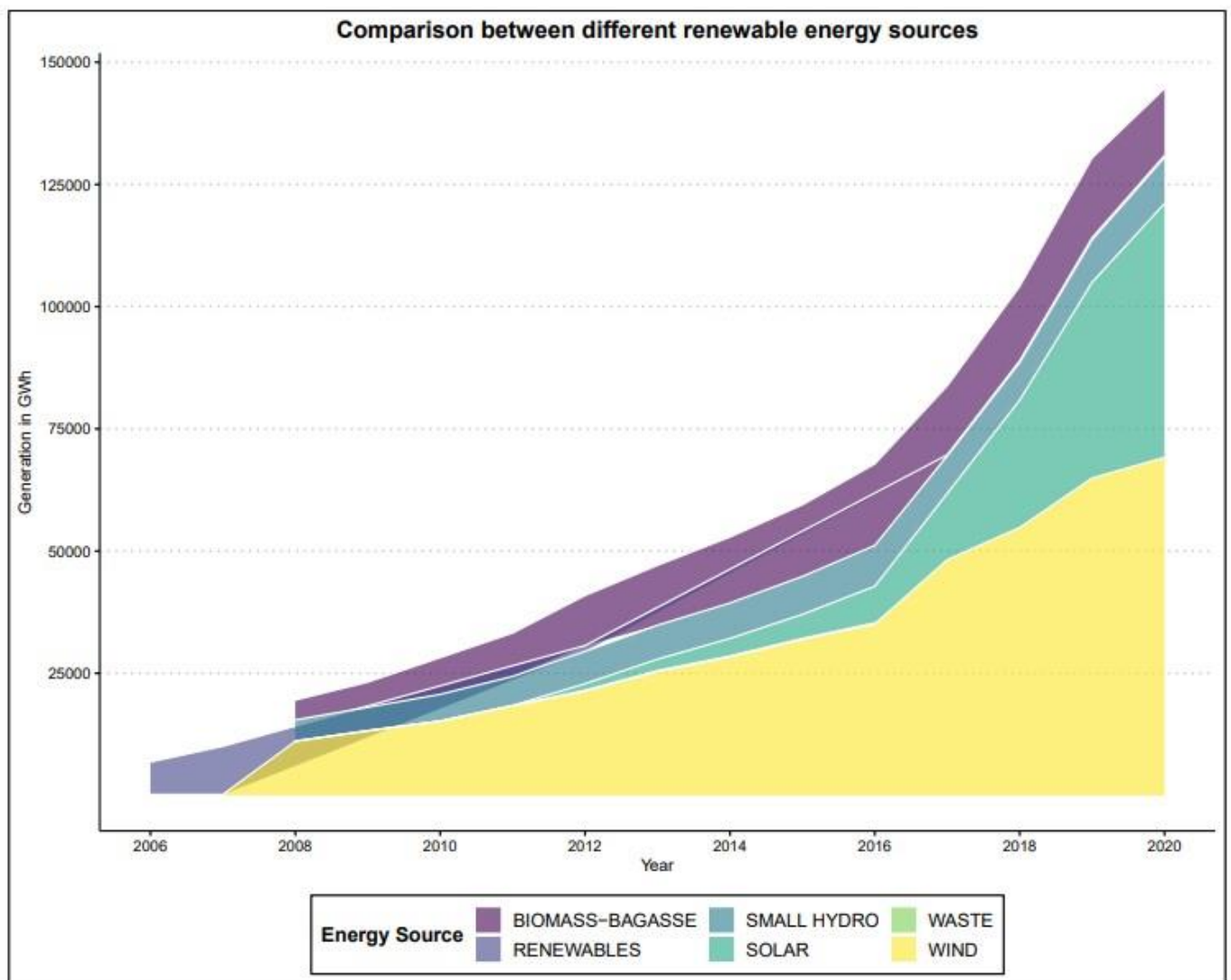
Choropleth map is chosen for the same reason of better comparison among all states with the view of geographical aspect also.

We can observe that Karnataka has the highest Solar Energy share.

It is interesting to note that U.P, Haryana and Punjab also have a share in Solar energy, which off course requires less space than wind. But still in the Northern East region, there is no Solar energy share.

Now let's look at the trend of these renewable energy resources and see how they have grown over the past years.

GENERATION TREND BY RENEWABLE SOURCE:



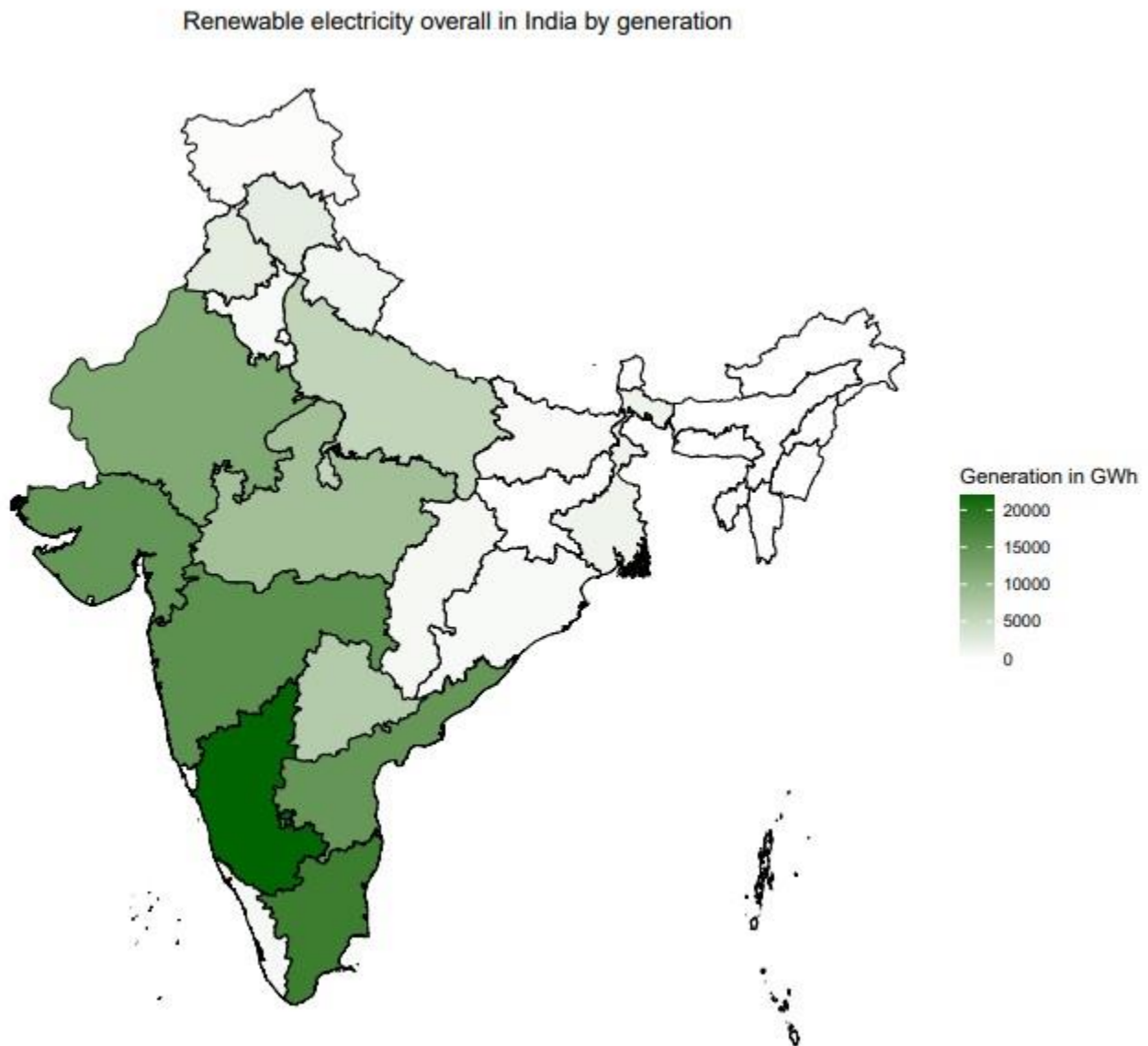
As we want to see the trend, Area graph is best suited for this, hence chosen.

We can observe that Wind although started a bit late, has been the dominator from the first and continues to dominate.

Interesting to note that Solar was quite small till 2017, but after that it has seen tremendous growth.

Now for the last comparison we want to compare all the renewable in all the states. Again, for this we will make choropleth map.

GENERATION OF RENEWABLE SHOWN ON MAP:



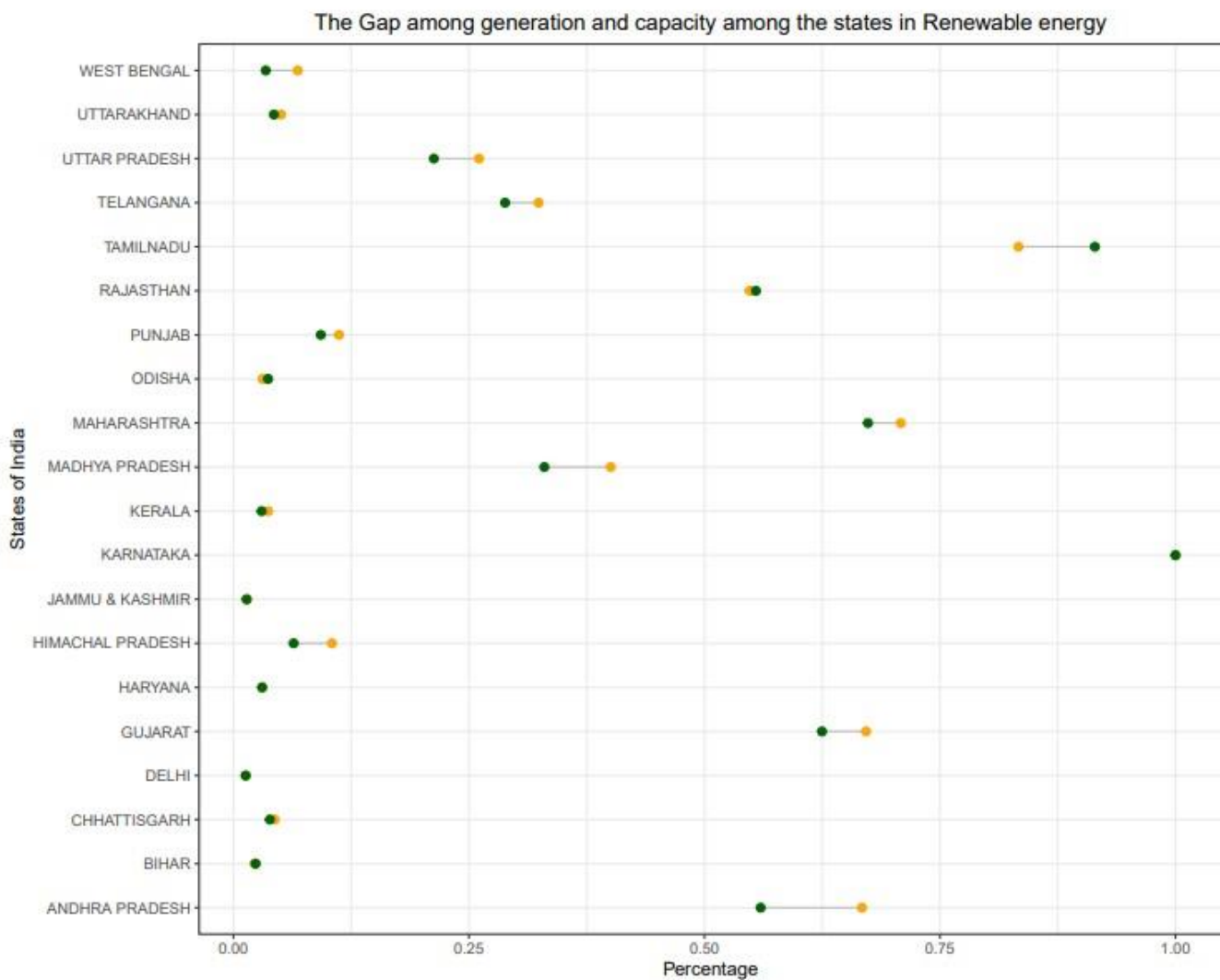
Choropleth map is again chosen for this type of comparison.

We notice that Southern and the North Western region of India is the most dominant in the renewable energy and the North eastern part the least, and then the North part.

Till now we have seen direct Capacity and Generation comparison, but now we want to know the gap between generation and capacity, and want to know the states, which have the highest gap.

For this we are comparing all the states relative to Karnataka which has the highest generation and capacity both.

RENEWABLE COMPARSION GENERATION AND CAPACITY:



The goal here is to understand the gap, not the generation or capacity. The bigger the length between the two dots the bigger the gap.

Dumbbell charts are perfect for this type of comparison as for all the categories they can be shown easily.

All the comparisons are made with respect to Karnataka

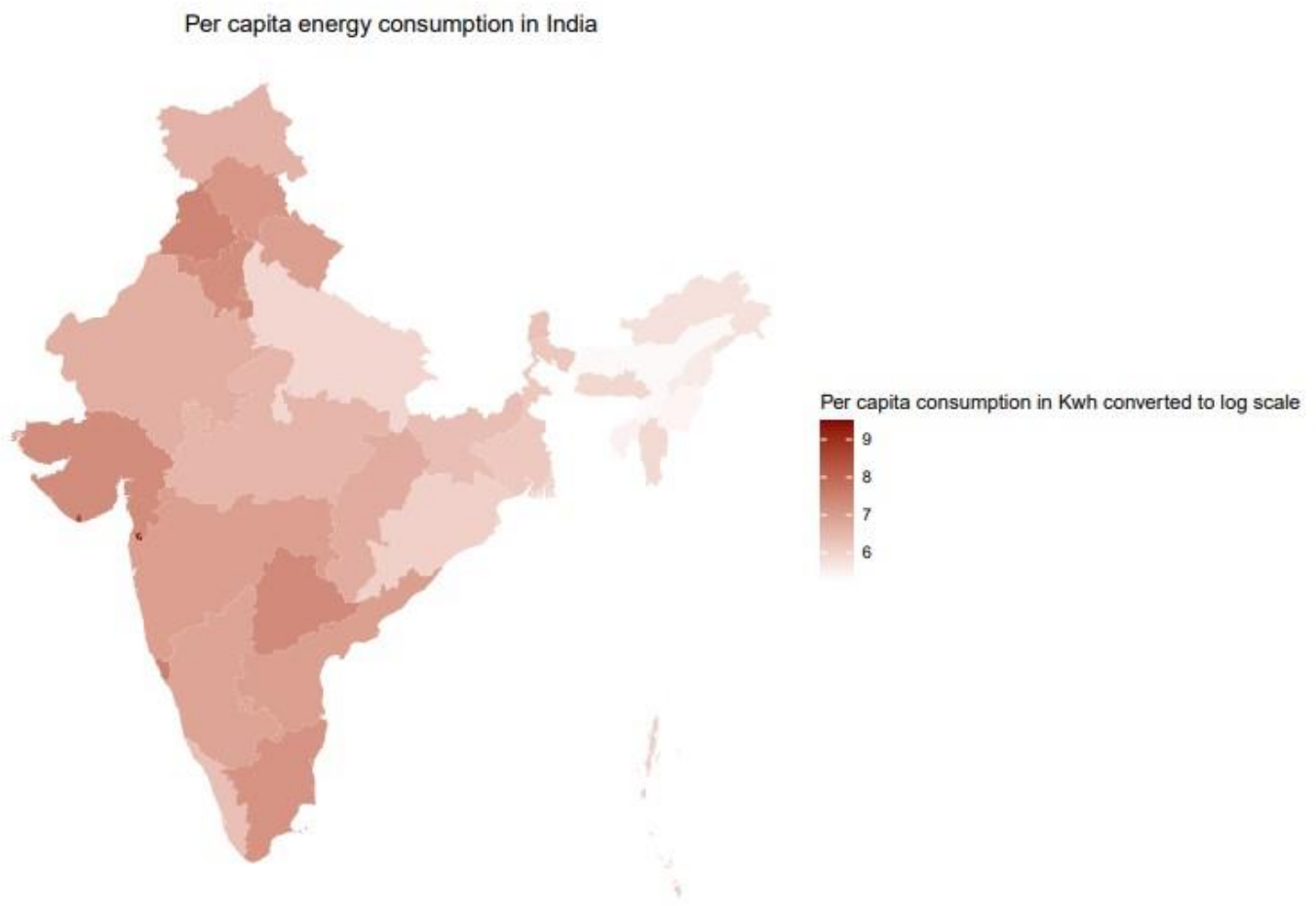
We can see that Andhra Pradesh and Tamil Nadu have the highest gap.

The green dot represents Capacity and the orange one the Generation.

We can see that comparatively Tamil Nadu is lagging behind its capacity, but at the same time, Andhra Pradesh is doing better.

Now let's move to another attribute, which is the Per Capita State Wise comparison.

PER CAPITA SHOWN ON THE MAP:

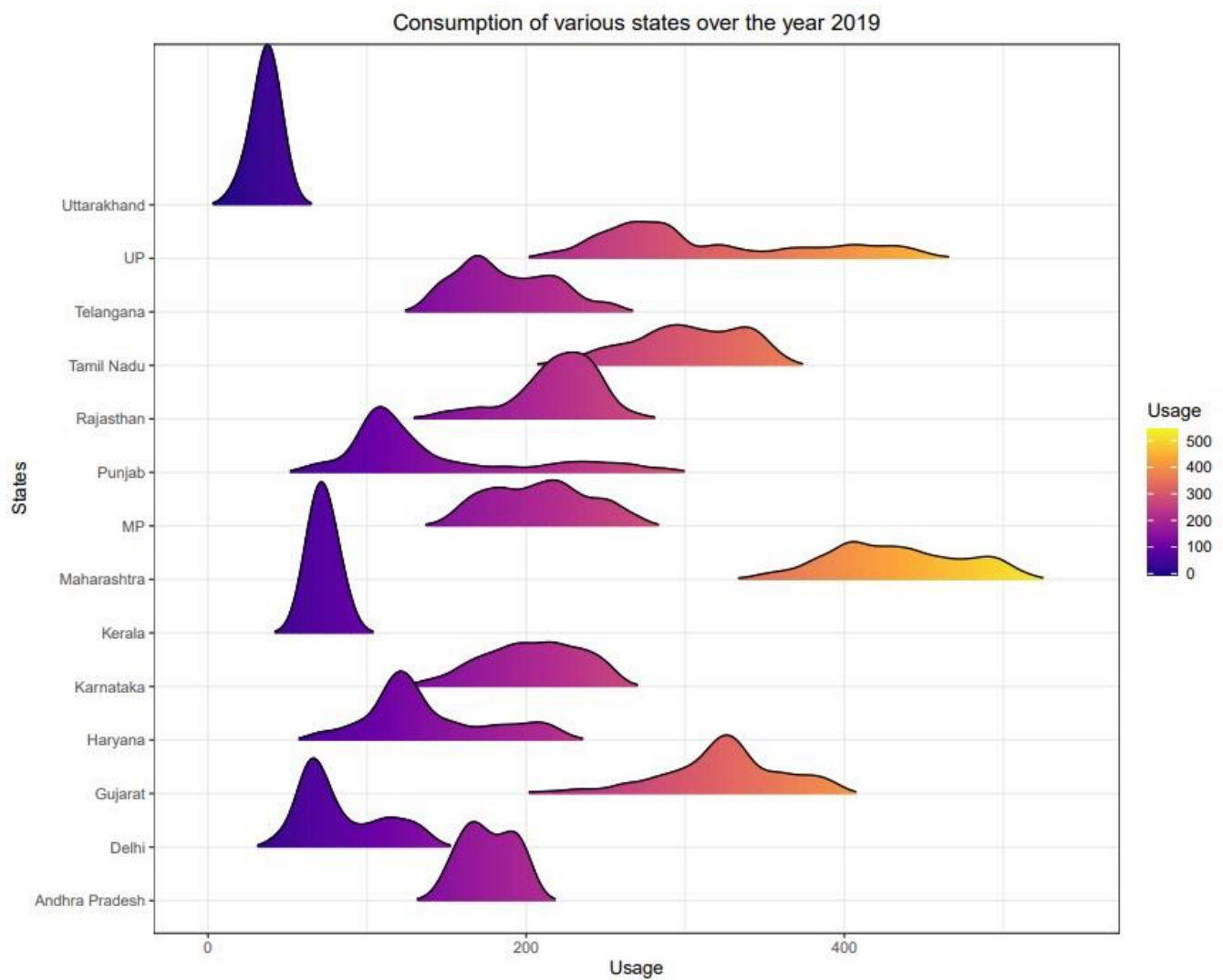


For this type of comparison choropleth map is best suited along with no boundaries and gradient fill. Boundaries removed because some regions are too small to be noticed if boundaries are there.

We can see that Dadar and Nagar Haveli and Daman and Diu have the highest per capita electricity consumption.

Now for a particular year which is 2019, for each particular day throughout the year data was collected and for this we try to understand among the states which has the highest variation, which has the most abrupt variation, which has the least variation and the minimum, maximum, mean consumption of each states.

VARIATION OF CONSUMPTION IN 2019:



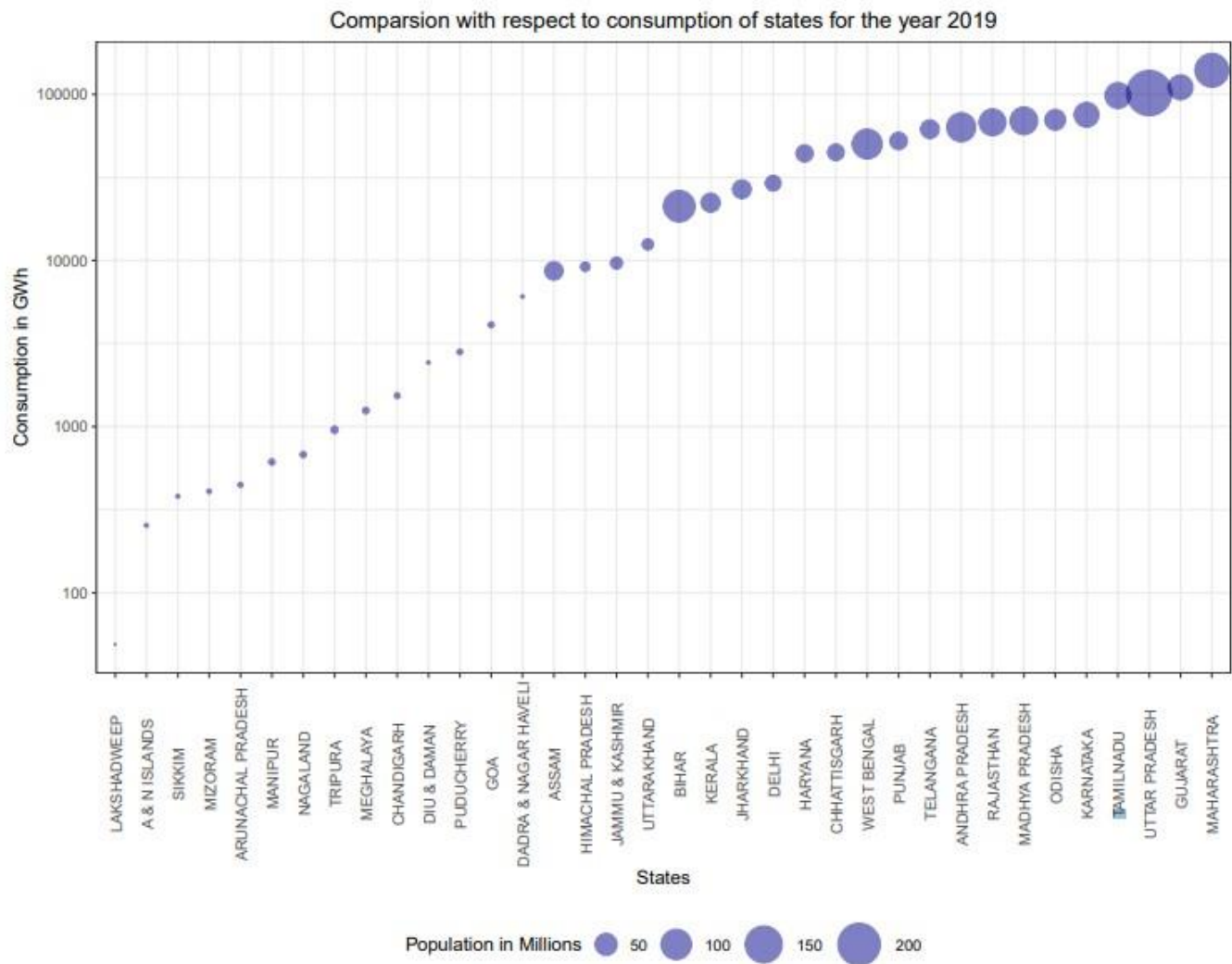
As the data was for the whole year and carried a continuous variable which is consumption, Ridge regression is best choice for this type of data.

This tells use which states have how much minimum, maximum consumption.

From the above we get to know that Uttar Pradesh has the highest spread, but highest consumption is in Maharashtra. The least variation is observed in Uttarakhand.

Now comparing all the states with respect to their consumption of electricity,

CONSUMPTION OF STATES FOR THE YEAR 2019:



In this plot we wanted to show the consumption among the states and also include the population parameter by which we can analyse that does the highest consuming states have higher population.

So, for this Bubble plot was the choice as this gives the ability to add another dimension of circle size as population.

We can observe that although higher population states do have higher consumption. But this is not a perfect rule, for example Bihar has higher population but its consumption is lower than even Delhi which has 4 times less population than Bihar.

Same is the case with U.P which has about 240 Million population has lower consumption than Gujarat which has population of about 60 Million.

Now seeing the Per capita electricity consumption among the top 4 states having highest consumption.

PER CAPITA INCREASE FOR THE TOP 4 HIGHEST CONSUMING STATES:



Trend is shown and since we need to make a comparison, we plot a line graph, showing the variation over the years.

We can see that Per capita consumption hasn't change much, and the trend remains the same. Although after the year 2016 Gujarat has seen a dip in Per capita consumption.

Now if we compare the electricity generation by states over the years.

ELECTRICITY GENERATION BY STATES OVER THE YEARS:



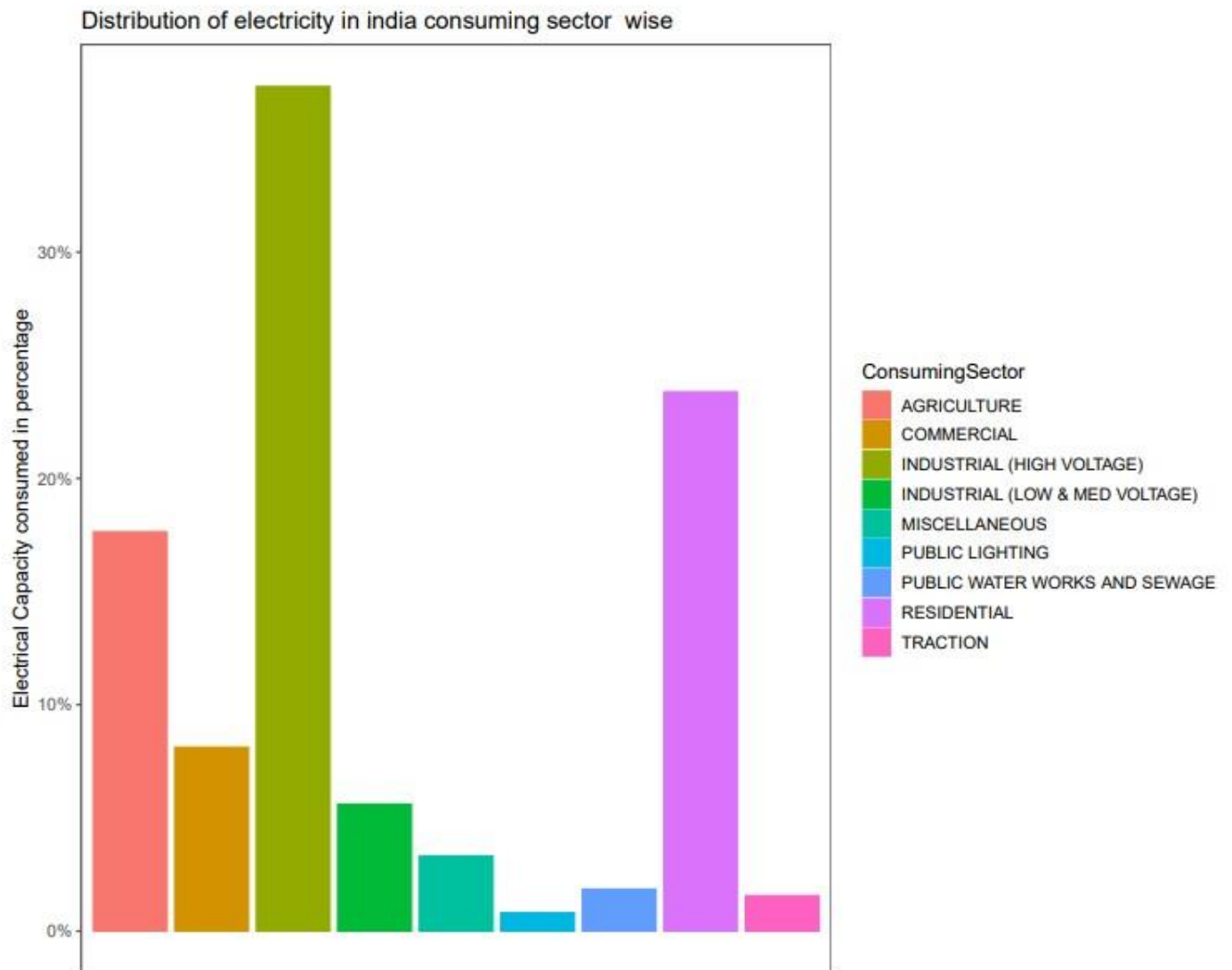
Same here as we required to show the trend we used the line plot.

We can observe that there is like a competition among 3 states, U.P, Maharashtra, Gujarat.

With U.P being the top generator till 2013, then Gujarat being at top from 2013 to 2017 and then from 2017 to now Maharashtra is the highest generator.

Now we try to go to a completely different parameter, which is comparison by sector the electricity.

CONSUMPTION OF ELECTRICITY BY CONSUMING SECTOR:

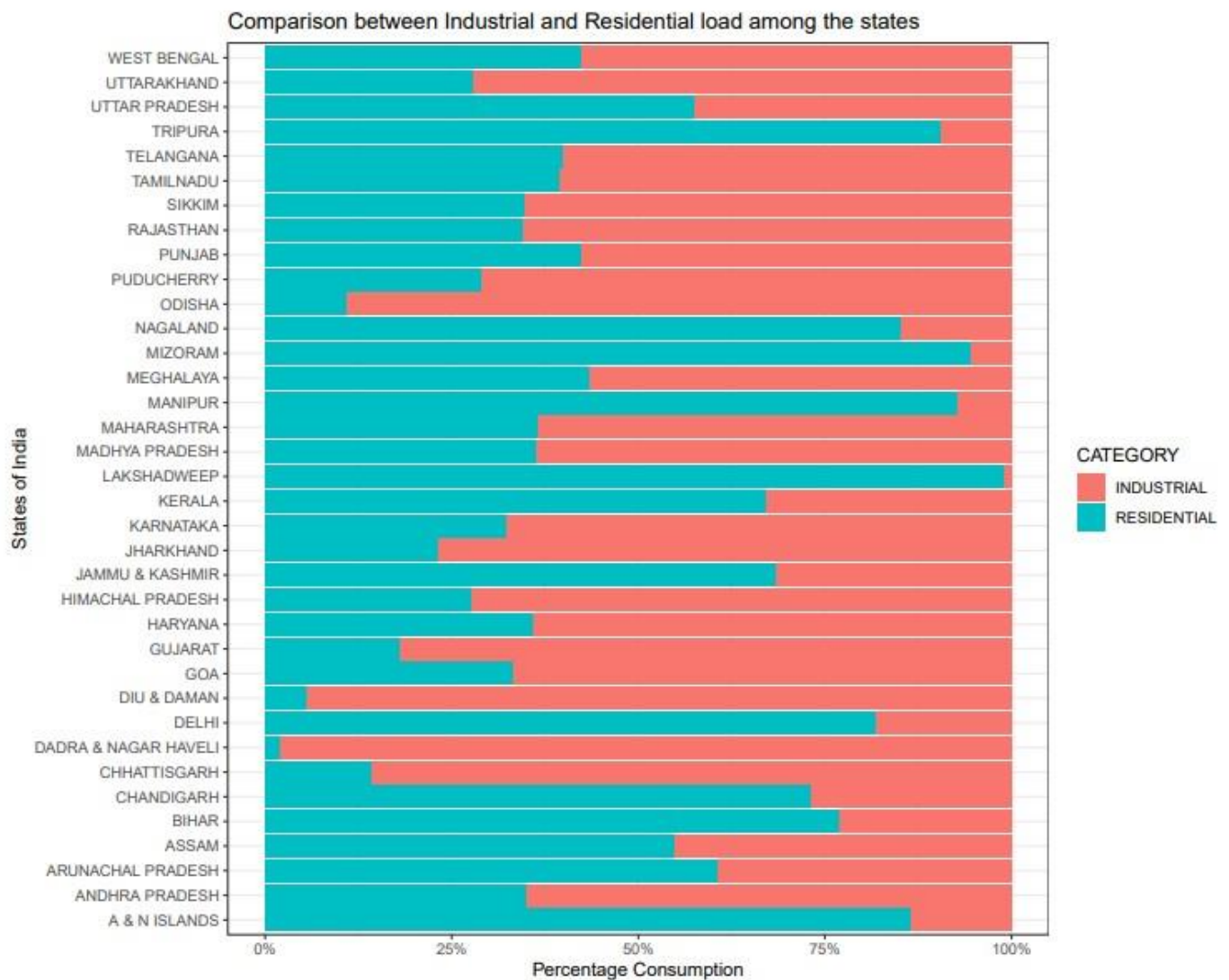


As there are different categories, bar plot is best suited for this.

From the above as we see that Industrial (High voltage) and Residential are the highest consuming sectors.

So, for these two loads only we now will compare the states.

STATES COMPARISON OVER INDUSTRIAL AND RESIDENTIAL LOAD:

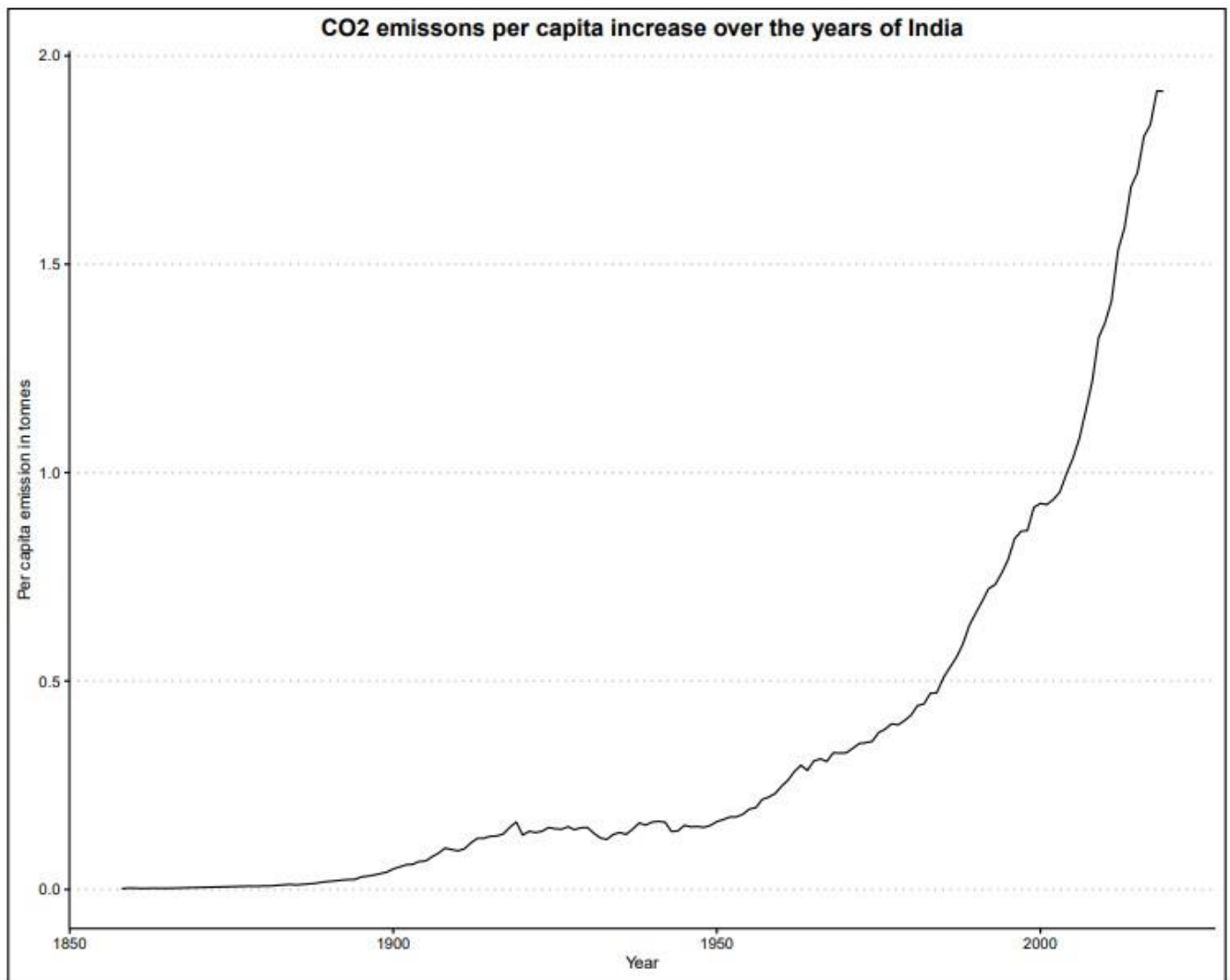


In this stacked bar plot is made with the colours showing the categories in percentage basis.

This tells us immediately in which states the Industrial load is high, like Chhattisgarh and Dadar and Nagar Haveli and in which Residential load is high like Lakshadweep, Mizoram.

Now as we have seen the energy generation, consumption, resources, and their division by sectors also. Now we try to understand the emission related to it. So first we look at per capita emission increase over the years.

CO2 EMISSIONS PER CAPITA:

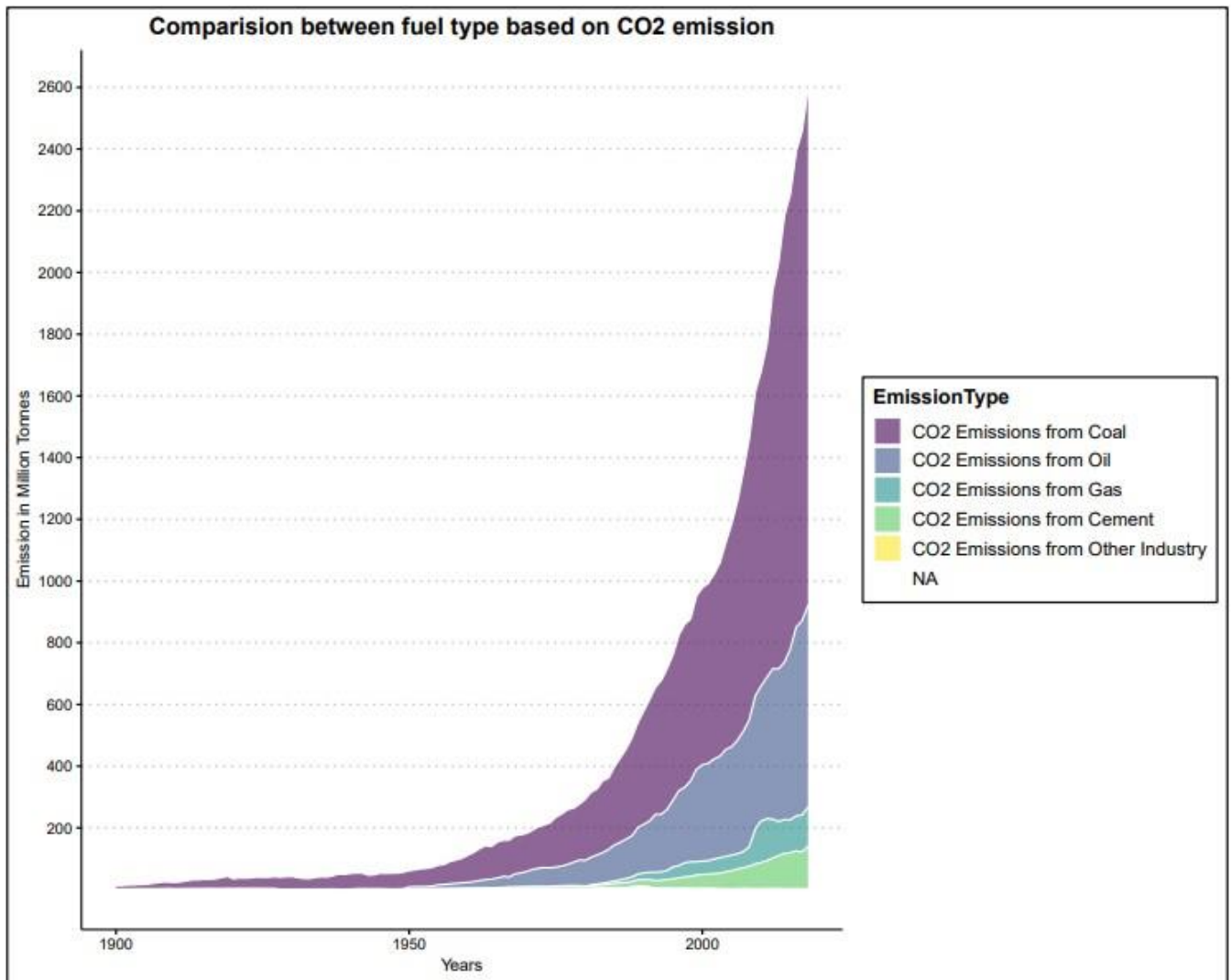


We want to see the trend for this line plot is best suited.

We can see that how rapidly in the past 50 years the CO2 emissions per capita have increased.

Now we will look at emission from different sectors.

CO2 EMISSION SECTOR WISE:



Areas chart is chosen for this as the graph is over a period of time and signifies the dominance of categories.

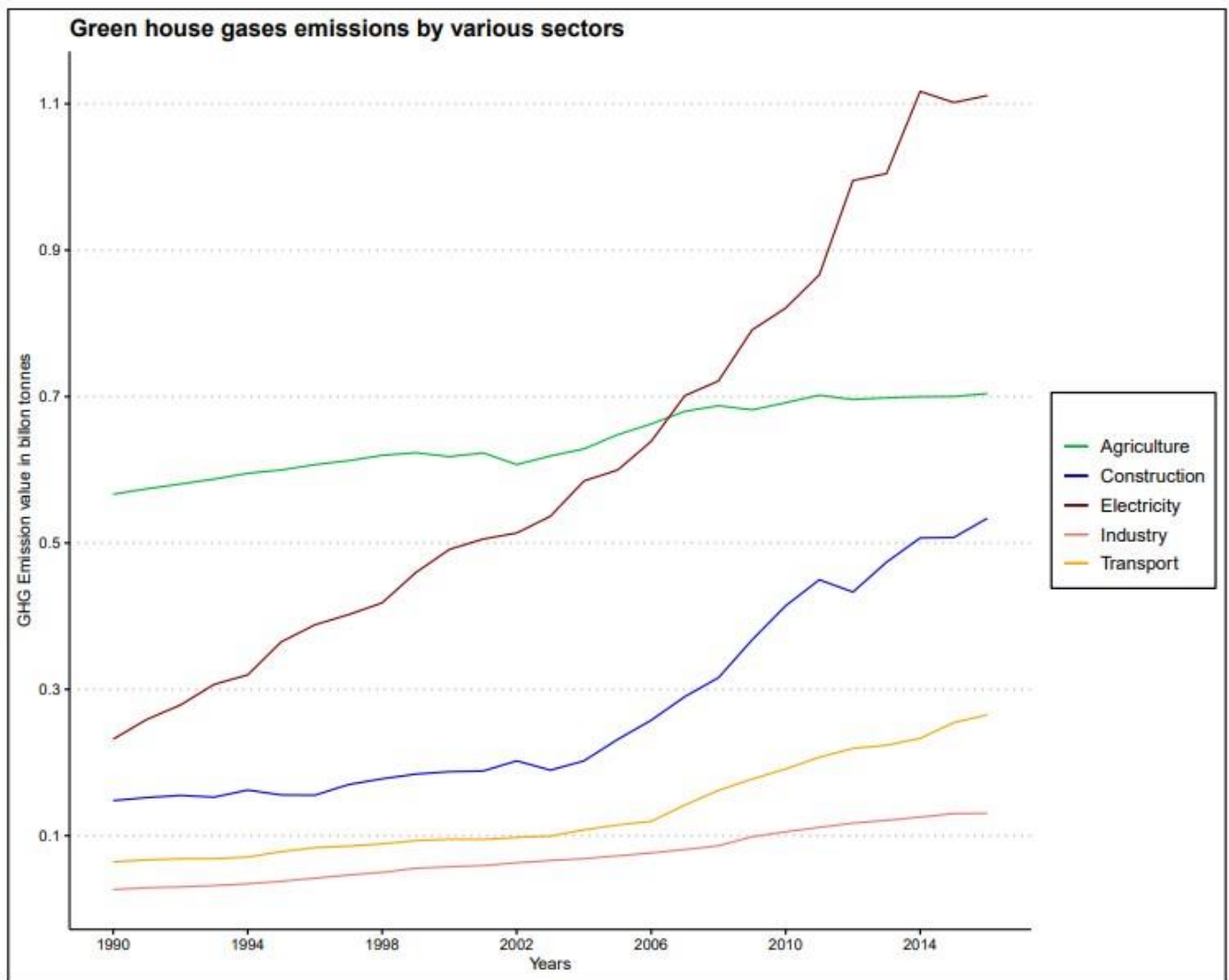
We can see that how after 1950's the CO2 emission has risen rapidly and the biggest contributor to this is Coal.

Emissions from other industry such as Cement and others are not even close to CO2 emissions from Coal.

Also, emissions from Oil are also rising gradually.

Now lastly, we compare the greenhouse gases emission from different sources.

GHG EMISSIONS SECTOR WISE:



For this line plot is made to see which sector is increasing/decreasing over the years.

We can clearly see from above that how green house emission from electricity has risen over the years, and after 2006 it has surpassed the agriculture sector, and continues to increase.

CONCLUDING REMARKS:

Energy sector in India continues to rise for both the non-renewable and renewable sector. The renewable sector in the past 5 years has increased rapidly but still needs to grow to take up the share from the Coal and Oil resources.

The emissions from these resources are one of the major parts of CO₂ and GHG emissions by a country, eventually a major part in the climate change and although various majors are taken to reduce emissions in power plants, they still capture the highest share in the CO₂ emissions in India.

Our energy demand will not decrease, instead as the standard of life increases so does the energy requirement. The goal should be to utilize the various others resources like Nuclear (which is very low in India), Hydro, Solar, Wind etc in the future so that we could tackle these issues and build a sustainable future.