**CS 621 – Project (Analysis of Renewable Energy Plants)**

**Student Details:**

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| Aim for Project | To analyze the spatial data using implementation of various concepts of spatial analysis using PostGreSQL, PostGIS as well as visualization in QGIS and in the form of WebMap. |

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**Introduction:**

Renewable energy is energy that is collected from renewable resources, which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat. Renewable energy often provides energy in four important areas: electricity generation, air and water heating/cooling, transportation, and rural (off-grid) energy services. Renewable energy resources exist over wide geographical areas, in contrast to other energy sources, which are concentrated in a limited number of countries. Renewable energy systems are rapidly becoming more efficient and cheaper. Their share of total energy consumption is increasing.

In the following project, Renewable energy source specific to electricity generation is studied for the year 2014. First, on broader scale, the distribution of electricity generation from renewable energy source is analyzed across the world. By zooming in to specific country, the plants distribution across France, Germany and Switzerland is studied with categories as various sources including solar, hydro, fossil fuels, wind, etc. The project explains the concept in three different ways for three different countries.

1. Distribution of number of plants as well as its density (i.e. number of plants per area) is shown for France.
2. The distribution of Solar, Wind, Fossil Fuels, Bioenergy and Hydro type of renewable electricity generation plants across Germany is shown.
3. Locations of plants in the form of different colored points for all categories are shows for Switzerland.

By looking at the output, we can analyze how the distribution of renewable energy sources is present across the continents. Also how the plants are penetrated across the France as per the geographic area as well as needs. The German data shows, how the distribution is present as per the type of energy source plant, which reflects the availability of natural resources.

**Spatial Data Used:**

Spatial data is data which contains come spatial information, i.e. data related to space. For the analysis of physical quantities on the earth, we need to specify the location in terms of geographical coordinates, and that’s how the spatial data is constructed. For the analysis in the given project, spatial data sets are needed for percentage of renewable electricity for all countries in the world. Also for specific countries analysis of Germany, France and Switzerland, the data showing points for plants is required.

Following data sets are used and the sources for them are listed in the tabular format below:

|  |  |  |
| --- | --- | --- |
| Sr No | Data Set | Source |
| 1.1 | Renewable electricity share of Total energy for all countries in the world | http://databank.worldbank.org/data/reports.aspx?source=sustainable-energy-for-all# |
| 1.2 | Renewable power plants for Germany, France and Switzerland | https://data.open-power-system-data.org/renewable\_power\_plants/2017-07-03/ |

Apart from it, we need some boundary data as well in the form of Shapefile which are listed as follows:

|  |  |  |
| --- | --- | --- |
| Sr No | Data Set | Source |
| 2.1 | World Country wise boundary file | <https://www.zensus2011.de/EN/Media/Background_material/Background_material_node.html> |
| 2.2 | Germany and France County wise boundary file | <http://www.gadm.org/country> |

And hence with the help of combination of above all data sets, the analysis has been done for the project.

**Analysis:**

1. At first, the pattern showing how the renewable energy sources are contributed in total energy production for each country across the world is analyzed using the data set 1.1. The data set 1.1 can be joined with country wise boundary file using PostGIS. The joined data can be exported as a view with the fields of interests and the view can be seen on the QGIS with background layer of OpenStreetMap. The distribution can be observed as the increasing values show the increasing color intensity of Green color. By looking at the map, we can make interpretations as,
2. Around half part of Africa has maximum share of renewable electricity generation, i.e. 80%-100%. One Fourth part of Africa is showing 40%-60% production of total electricity. Rest part of Africa is having very less production of renewable electricity i.e. 0%-20% for countries Algeria, Libyan Arab Jamahiriya, Morocco, Mauritania,Nigeria,Chad,Niger,Somalia,South Africa, Botswana,etc. Hence African countries have good amount of renewable electricity production.
3. Most part of North America as well as South America shows very good i.e. 60%-80% renewable electricity production including countries Greenland,Canada,Brazil,Colombia,Venezuela, etc. The remaining around 20% Part shows very lees renewable electricity production including United States, Mexico, Argentina and Bolivia.
4. Most of Asian countries show vey less generation of renewable electricity. China, Pakistan and Uzbekistan shows 20% to 40% amount of renewable electricity generation. Kyrgyzstani, Afghanistan, Tajikistan, Nepal, Bhutan and Lao People’s Democratic Republic have 60%-80% amount of renewable electricity generation. Burma, Korea and Cambodia shows 40%-60% amount of renewable energy generation. Rest of the countries shows very less amount of renewable energy i.e. 0%-20%.
5. Europe part has equal distribution of renewable electricity generation for all the countries. Norway, Georgia, Austria, Albania, etc. have 80%-100% share of renewable energy sources. Rest part of Europe has less percentage of renewable energy.
6. The share of renewable electricity in the Australia region is very less as compared to rest of the world as per 2014 statistics.
7. Analysis of France is done in two ways for number of plants and density for number of plants. Here point in polygon analysis is implemented.
8. The pattern shows county wise distribution of number of renewable energy plants in France. At North, East and South West part of France, larger number of plants can be seen as compared to other part of country. Western as well as central part of France has lesser amount of renewable energy plants. The detailed map has been shown in the output screenshots provided.
9. Another pattern shows county wise distribution of renewable energy plants density in France, i.e. number of plants per given geographical area. The Area for each part of France is calculated using ST\_Area function query in PostGIS and accordingly the density is calculated which is displayed on the QGIS for the visualization. The distribution shows that the Northern, Eastern as well as two counties in south western part of France show more density. All other part of France shows the almost constant distribution of number of plants density which is having lesser values.
10. As well as the heatmap for number of plants of France is shown which is confirming the previous analysis, i.e. at north as well as eastern part of France, the distribution is more, which is relatively of higher values in southern part of France.
11. Germany country has been studied in the form of number of plants of various categories as explained in following way. The dataset has been modified and added columns which give the count for each category of plant in each geographical area using point in polygon analysis.
12. The number of renewable energy plants in Germany as shown in the form of Map as shown in attached map. We can see that there is more number of plants at South East corner of Germany. As well as southern and North west part has larger number of plants. Other part of Germany has lesser number of plants. Now let us see the distribution by each category of plant energy.
13. By looking at solar energy plants, we can say that there are highest numbers of solar energy category plants across Germany. Hence the nature is almost similar to total number of plants irrespective of category.
14. As far as wind energy plants are concerned, they are mostly situated at Northern part of Germany because of natural gifts which make it compatible.
15. Bioenergy plants are situated at Northern part of Germany as well as some can be found in South Eastern part.
16. The Hydro energy plants are found in some southern part as well as center of Country.
17. There are very less fossil fuel plants which can be found in Western part of German Counties.
18. All plants for the renewable energy are seen for the Switzerland country. The map shown in the output shows how various types of renewable energy plants are distributed across country. There are three types of plants as solar, bioenergy and hydro. The data is classified into various categories using the Categorized option in style. As per the color, the points are differentiated and hence the analysis can be done. By looking at the points on map, maroon colored points show the solar energy plants across the country. Also the blue colored points are of Hydro energy plants. Also Green colored plants are of Bioenergy renewable energy. By looking at the data points, we can conclude that there is highest number of solar plants spread across the country. After number of solar plants, there are Hydro energy power plants across the country. Also there is least number of Bioenergy plants across Switzerland.

Apart from maps analysis, some PostGIS analysis can be done. The distance between all solar energy plants can be calculated using the ST\_Distance queries and hence 10 closest solar energy plants can be found. Similarly, Farthest Hydro energy plants can be found. Using the ST\_Distance queries, the distance between any two plants or and specific pattern can be studied. Then, the plants around the Bern city in the radius of 10km are found out using the ST\_Dwithin query for which ST\_GeomFromText is used for considering center for Bern city. There are 35 different types of plants around 10km of the Bern city. Also, we can consider some specific area as per requirement and can find which and how many plants are there in the geographic are using the ST\_MakeEnvelope query. For all those distance related queries, the distance in KMs is considered for which, the current geometry is transformed into geometry having SRID 2163 using ST\_Transform which represents meter based projections and hence the efforts are minimized.

1. Another most important aspect of the analysis for this project is Web Map. Here two data sets are shown on the Web Map.
2. First, Choropleth map shows the distribution of renewable electricity plants across France i.e. section II above is represented in terms of Web Map with the help of Web Map as provided, we can say that the number of plants in Northern and southern plant as well as eastern boundary of France shows good amount of Renewable Energy plants in the France.
3. Second, the point data shows how the solar, bioenergy and hydro power plants are distributed across Switzerland i.e. section IV above. There is highest number of solar plants spread across the country but mostly in the northern and central part of the country, similar is the case with Bioenergy plants. But as per the observations, the Hydro energy plants are spread across the entire country.

**Conclusion:**

We can conclude the analysis as:

1. The production of renewable energy is in increasing order from Australia, Asia, Africa, Europe and highest in Americas.
2. There is highest number of solar plants in Germany, France and Switzerland. Next to Solar plants, there are Bioenergy and Hydro plants in all three areas. Germany has very few Fossil fuels and Wind plants. In France, a good distribution of renewable energy plants can be seen.

**Summary:**

The most important aspects of Data Analysis are data manipulation and data visualization. Here, the data manipulation has been done using PostgreSQL and PostGIS and data visualization is carried out using QGIS and Web Map.

In the Project here, analysis of Renewable energy sources across the globe has been studied for the year 2014. Using boundary data of world for all countries and the spatial data provided by world data bank, the analysis has been done with the help of Table Join using PostGIS and then visualization in QGIS.

Further, three different countries in the Europe are studied in three different ways, Germany for distribution plants of various types, France density wise and Switzerland for actual locations of plants. For this, visualization is done using QGIS as well as Web Map. Various spatial concepts are implemented for this analysis, including Point in Polygon analysis, Intersection of Polygon with points analysis, various spatial functions, table joins, working with GeoJSON, Leaflet + GeoJSON, transformation to various geometries, etc.