Greener London:

London's Progress Towards an Environmentally Sustainable City during 2012 Olympics

CASA0003 - Group Mini Project: Digital Visualisation
Group 5

Project Output Description Table

Project Output	Output Description
Project Output Files	Zip File on Moodle
Project Website	https://casa-dv-group5.github.io/

Individual Contributions Outline Table

Task Name	Major Contributors	Additional Contributors	Relevant Chapters in Report
Concept Development	All team members		1; 2
Data preparation and integration	All team members		3.1
Waste Visualization 1	Zheng		3.2.1; 4.1
Waste Visualization 2	Zheng		3.2.1; 4.1
Emission Visualization 1	Yimin		3.2.2; 4.2
Emission Visualization 2	Yimin		3.2.2; 4.2
Emission Visualization 3	Yimin		3.2.2; 4.2
Energy Visualization	Hong		3.2.3; 4.3
Presentation video	All team members		-
Website Development	Hong	Yimin; Zheng	3.3; 3.4

Individual Contributions

Hong YANG:

In this project, I was responsible for the energy-related visualizations. Also, I was in charge of integrating all the visualization pages together and implementing the group's design. In addition, I also handled the editing of the presentation videos. In the report, I wrote the energy-related part as well as the website design and website hosting part.

Yimin FU:

I created the visualizations relates to pollutant emissions. Also, I set the structures for our presentation and the report, and helped with website design. For the report, I wrote sections related to my visualization contributions, as well as the Introduction, Limitation and Conclusion part. Moreover, I helped to improve our Literature Review and took charge of the final check of the whole report.

Zheng LIANG:

In this project, I visualized the waste management in London in city level and borough, and complete the first version of home page. In the report, I write the method, visualization and discussion of my part, and I also write the first version of literature review.

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1. Introduction

Urban transformation is a combination of urban development and urban change, usually accomplished by multiple actors including government, industry, and citizens (Peter and Hugh, 1999; Almirall *et al.*, 2016). Industrialization was once the direction of transformation for many cities, helping them to achieve higher economic benefits at the expense of the environment to some extent (Hayat, 2016). Today, more cities are shifting their goal to construct a sustainable network, where the purpose is not only to protect the environment, but also to ensure the quality of socio-economic life of present and future generations of people (United Nations World Commission on the Environment, 1987; Bibri, Krogstie and Kärrholm, 2020; Kumar *et al.*, 2020; Shamsuzzoha *et al.*, 2021).

In this context, this project focuses on London and selects the 2012 Olympics as the time period to be studied by systematic literature review. In subsequent chapters, we describe the process of designing the project, explaining how the visualization of London's sustainable transformation during the Olympics was realized. The results and shortcomings of the project will also be discussed.

2. Literature Review

While London has maintained its excellence in population, resources, and commerce over the centuries, building a resilient, healthy and stable London has always been its vision. It is said that sustainable development provides London with an integrated economic, social and environmental framework for both combating global climate problems and improving the quality of life of its citizens (London Sustainable Development Commission, 2013). London's first sustainability framework was introduced in 2002, and sustainability has been a strategic goal of London's development ever since. (London Sustainable Development Commission, 2002, 2017)。

The London 2012 Olympic Games are certainly an important component in London's sustainable development process. It considered sustainability as one of the key elements during the Games and after (as an Olympic legacy), listing improvements in air pollutants emissions, energy and waste recycling as main objectives (London Assembly Environment Committee, 2009). Moreover, in the report, *Our Promise for 2012*, 'make the Olympic Park a blueprint for sustainable living' was specifically listed as one of the legacy promises (Department for Culture Media and Sport, 2008). There is no doubt that the 2012 Games have been a driving force for sustainable development in London.

In order to achieve the three objectives raised by London Assembly Environment Committee, numbers of related sustainability policies were launched during the period. In terms of air pollutant emissions, London introduced new vehicle emission limits in 2011, and The UK Low Carbon Transition Plan, which extends the scope nationwide, is also scheduled to be launched during the Olympics (Her Majesty's Government, 2009; Croner-i, 2012). In terms of waste management and recycling, London plans to recycle approximately 70% of the waste from the games to achieve "zero waste" (London 2012, 2007). On the energy side, the Olympic Delivery Authority (ODA) planned to increase the use of renewable energy in London by building two new energy centers (Bioenergy

Insight Magazine, 2010; Olimpismo, 2012).

Although government reports have summarized the benefits of the London Olympics, the relevant results have rarely been systematically presented to the public in the form of graphs or maps (Mayor of London, 2013).The goal of this project is to visualize the distribution of data related to the three aspects of emissions, waste and energy over time and geographic space in a clear and understandable way, enhancing communication between official information and the public in a visually engaging way. We wanted to enable the users to understand the environmental situation before and after the London Olympics by looking at interactive graphs, exploring maps and reading a small number of annotations in the project product.

3. Methods & Process

3.1 Data collecting & Processing

Generally, this project used Excel, R and QGIS for data processing.

3.1.1 Waste & Recycling

The visualization of waste management and recycling mainly uses two datasets, both of which come from the London Datastore. The first dataset is on city level, shows the proportions of five methods in waste treatment in London (Greater London Authority, 2016). In these five categories, landfill refers to the proportion of waste buried into underground. Incineration with EfW (Energy from Waste) means waste is burned at temperatures above 850 degrees and used to provide energy. The original dataset contains both data of the London and UK from 2003 to 2019. Because we only need to visualize the waste treatment in London, only data on London was used.

The second dataset contains borough level data. This data set shows the recycling rate of boroughs in London (Department for Environment Food and Rural Affairs, 2020). Recycle rate indicates what percentage of the total waste is recycled and reused. We extracted the recycle rates from 2003 to 2019 from the data to keep the same period as the previous dataset and sorted them into the ideal format.

3.1.2 Emission

Through the previous literature review, we identified improvements in air pollutant emissions as one of the key goals for sustainable development in London during the 2012 Olympics. In order to process this aspect of change into a visualized product, we must first determine which indicators were chosen to quantify London's pollutant emissions. Since large-scale events like Olympics are usually accompanied by a higher level of carbon emissions, and a great number of environmental reports during the Games mentioned about concerns on CO2 emission, we could identify CO2 as one of the essential indicators (London 2012, 2007; London Assembly Environment Committee, 2009). In addition, particulate matter and nitrogen oxides were also the most important pollutants during the same period, thus included in the following discussion (Croner-i, 2012; Transport for London, 2012).

The London Atmospheric Emissions (LAEI) 2016 dataset estimates emissions of key pollutants (including NOx, PM10, PM2.5, and CO2) for 2010, 2013, and 2016, providing all of the emissions data needed for this chapter (Greater London Authority, 2019). This data was provided by the Greater London Authority, and is categorized according to various pollution sources and resolutions. Its Grid Emissions Summary sub-dataset contains specific emission data on a 1 km2 grid scale and integrated data on geographic units such as London boroughs and London as a whole, with statistical units in tons.

In addition to this primary dataset, GIS files for each geographical scale were also required. GIS data for borough level were obtained from Statistical GIS Boundary Files for London (Greater London Authority, 2014). Centroids of boroughs were generated from the borough boundaries shapefile through QGIS. Shapefile of the 1km2 grids were taken from the GIS files provided by LAEI 2016 itself (Greater London Authority, 2019).

Next, to obtain more integrated, easy-to-use files for subsequent usage, the GIS data and emission data on the same geographical scale were merged via R, outputting geojson files for each resolution, and then uploaded as Mapbox Studio tilesets.

Note that as most pollutant emissions are highly correlated with human activities such as transport and industries, London population data from 2010 to 2016 were also added in this section for context building (Department for Environment Food & Rural Affairs, 2018). Here, the mid-year population estimates updated by the Greater London Authority in 2020 were chosen (Greater London Authority, 2020).

3.1.3 Energy

The data of energy aspect, *Consumption of other fuels*, comes from GOV.UK (GOV.UK, 2020). Major energy sources such as gas, electricity and road transport fuels are excluding from this dataset since it focusses on non-mainstream energy types. The included categories are fuels of petroleum, coal, manufactured solid fuels and bioenergy & waste. The energy aspect is aiming to show how the trend of bioenergy changed during the 2012 London Olympics. So, calculating the percentage of bioenergy in all “other” fuels is necessary to observe the transformation. After processing the percentages of the dataset on Excel, we used the R to merge the geometry and calculated bioenergy proportions. Then, we uploaded the output, an integrated new geojson file to Mapbox as the new tileset.

3.2 Visualization

In terms of visualization, this project presents the data at multiple resolutions and selects different methods in a tailored manner. Frequently used libraries in this project include Mapbox gl, D3, ECharts and Google Charts.

3.2.1 Waste & Recycle

a) City Level

The first visualization for waste and recycle in London is mainly divided into two parts, a text box and an interactive line chart.

Firstly, in the text box, we briefly introduce the visualization content, the meaning of the variables, and the visualization results.

Next, in the design of the interactive line chart, we chose different colors to represent different methods to deal with wastes. When we move the mouse to a point in the line chart, the text box will show the corresponding year, method and proportion. D3 completes the functions of reading data and drawing tables in this section.

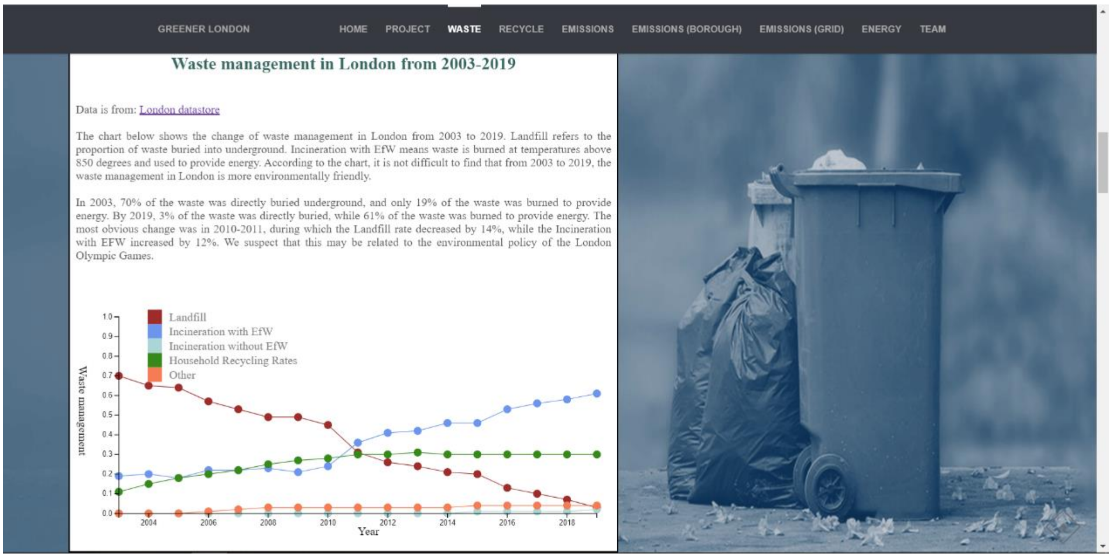

Figure.1 City level visualization of waste in London

b) Borough Level

In the second webpage, we visualize the recycle rate in borough level, On the one hand, recycle is the most environmentally friendly way to deal with wastes. On the other hand, the visualization of borough level can also let us know which area of London is doing better in waste management.

The map uses the depth of green to represent the recycle rate. There is a slider at the top of the interactive map. When we move the slider, the year of the data changes accordingly. At the same time, when we move the mouse to a specific borough, the information bar will display the name of the borough, the recycle rate of that year, and the line chart of the change in recycle rate.

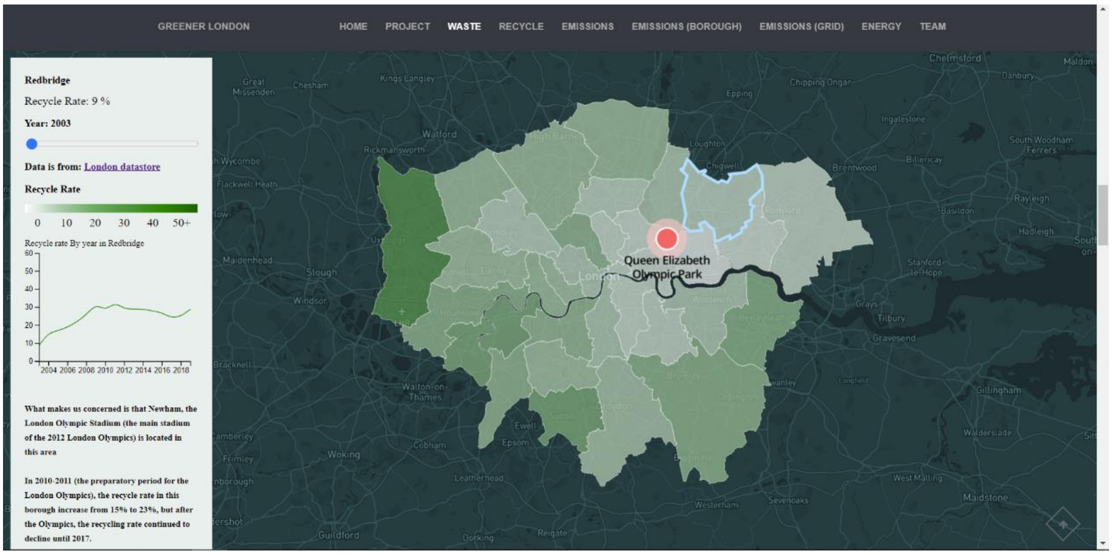

Figure.2 Borough level visualization of recycling in London

3.2.2 Emission

a) City Level

In order to give users an overall impression of the changes in London's key pollutant emissions, this project begins with a visualization of a city-wide perspective. In this step, we chose to present graphs rather than maps, as no comparisons between regions are involved.

Both column charts (vertical bar charts) and line charts are considered suitable for observing data changes over time spans. Since the emission data used in this project only contain three time points, 2010, 2013, and 2016, we chose column charts rather than line graphs to visualize each of the four pollutants separately. In addition, we wanted to add information about emission sources at this level of observation, so the presentation method was further extended to a stacked column chart - emissions from different sources will be assigned different colors and presented as part of the total emissions (or, as subgroups).

The design of these charts is achieved with D3. *D3.csv()* method is used to read the data. *D3.stack* helps us to count the accumulated values after adding each subgroup. Then, by connecting *stack.keys([string of subgroup names])*, the accumulated values are assigned to an array. The data from this process is generated as a new dataset for graphing. After this, we create the stacked charts by adding SVG rectangles. Since this project wanted to show the changes of each of the four pollutants separately, a unique SVG (Scalable Vector Graphics) variable was created for each pollutant and the above operation was implemented repeatedly.

In addition, a tooltip triggered by mouseover and a shared legend were added to the product in order to make the data more readable for users.

On the other hand, regarding the demographic data, line graphs were chosen as the visualization method. Here, due to the simplicity of the data, we adopted ECharts, a chart library that keeps the code shorter and speeds up the processing compared to D3, to implement the design. Likewise, we added tooltip to this chart to increase the interactivity and statistical information available to the user.

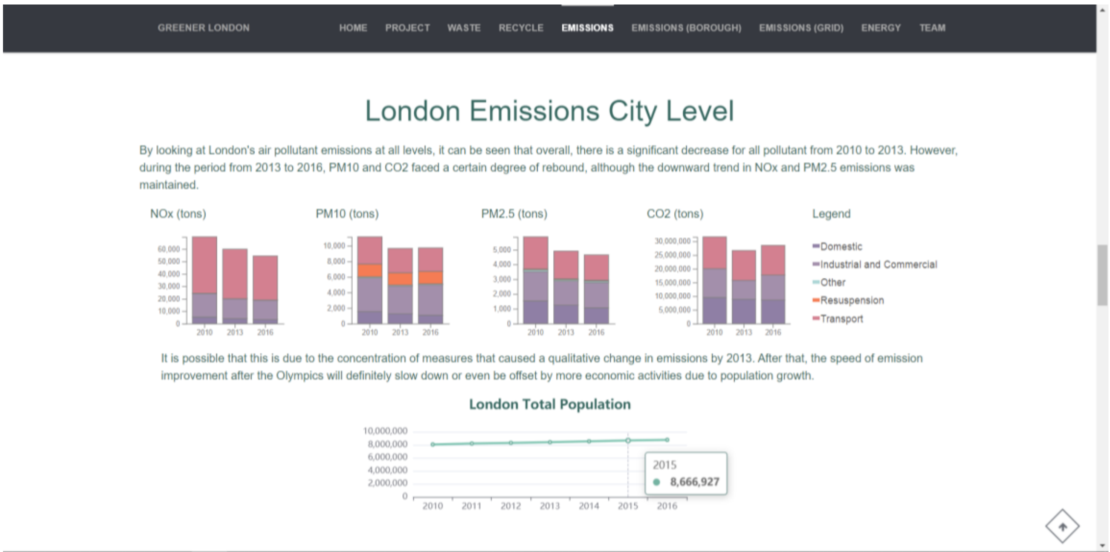

Figure.3 City level visualization of emissions in London

b) Borough Level

Next, the scale is zoomed to Borough level to allow observation of pollutant changes by areas. Since the data used are objective values of local emissions rather than relative proportions, the proportional circle is used as the main visualization method. In this visualization, a translucent overlay is placed on the left side of the window to accommodate the narratives and function buttons. The base map was created using Mapbox and a colored layer of London was added to visually differentiate the focused area in this project.

Similarly, using *map.addLayer*, separate layers were created for each pollutants. In each pollutant layer, the size and color of the proportional circles are both representing the emission volumes. The color scheme is created based on the World Air Quality Index Project, using green for the lowest emissions and purple for the highest (World Air Quality Index Project, 2021). Note that due to the significant variation in emission levels of different pollutants (e.g., the minimum emissions of CO_2 are around 200,000 tons, while the maximum emissions of NOx are less than 10,000 tons), it is difficult to effectively represent the changes in each variable using the same set of legends. Therefore, unique legends are given for different pollutants. The legend is placed in the lower left corner. Switching between the four pollutant layers is achieved via radio buttons. When the user switches to a certain pollutant, the introduction text and legend will shift to the matched content.

Also, since this project needs to reflect the change over time, a time slider is added. It triggers both the color and size change of the circles. In addition, a "mouse hover" function was created to display popups with region names, data for 2010 and 2016, as well as the calculated growth rates of emissions. This allows users to access more accurate information besides intuiting the changes based on visual inspection.

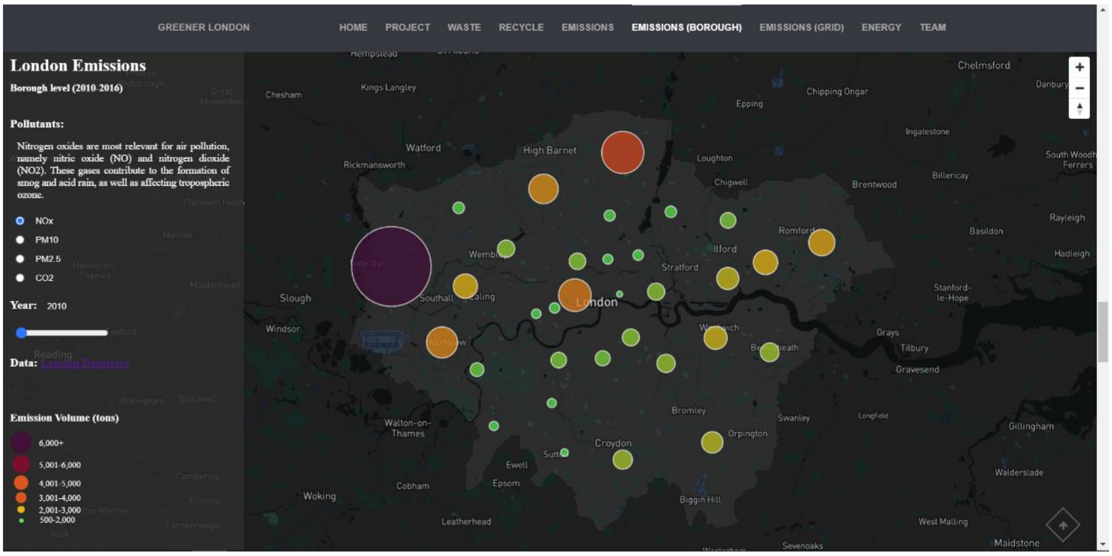

Figure.4 Borough level visualization of emissions in London

c) Grid Level

Then, we zoom to the resolution of one square kilometer grids, which is further divided again when the boundary line crosses the grid. At this level, this project chose to present a 2.5D map with fill-extrusion. Since areas along the boundaries are irregularly shaped, we divided the emissions of each observation by the size of the area, so that the value of fill-extrusion is in the same unit of tons/km2. In this way, users are able to see the geographical distribution of air pollutant emissions in London in a finer scale with the color and height of the fill-extrusion.

The functions used in this visualization are roughly the same as for the borough level: layers are created for each pollutant, with green extrusion representing the lowest emissions and purple representing the highest, and the areas where the values are missing are filled with the background color; the radio button for switching between layers and the time slider for changing the years are placed on the left side of the translucent overlay.

Unlike the previous map, the legend is in the form of a bar showing color changes rather than multiple solid circles with arranged size. And, since this map involves the use of 2.5D techniques, we wanted to guide the user to discover different viewing angles. Therefore, a set of buttons for switching the viewpoint was added. The "view height" and "airscape" buttons help the user to switch the view angle, zoom size and center of the map to the most appropriate value for each purpose. In addition, an animated pulse point with text label is used to mark the location of the Olympic Park, which allows the user to purposefully observe changes in the vicinity of the site.

Finally, since the sources and hazards of the pollutants have been generally described in the previous map, no annotations are included in this visualization to prevent repetition of information. At the same time, because the resolution of 1km2 makes the map relatively dense in objects, in order to avoid having excessive information, the popup is also eliminated.

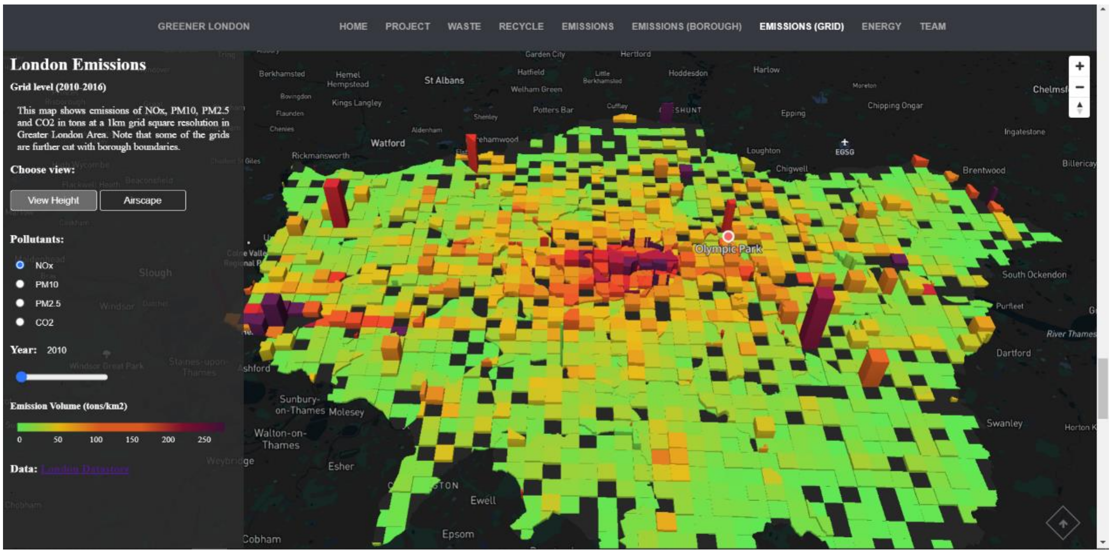

Figure.5 Grid level visualization of emissions in London

3.2.3 Energy

To show the differences between before Olympics and after Olympics, a comparison map is a convenient tool for visualization to study the changes. Choropleth is chosen as the presentation method in this visualization.

Two time-sliders of changing the time are showing on the left box, we can select the years what we want to explore, the data of comparison map will change, and the colors of boroughs will update as well. London hosts the Olympics in 2012, so we choose the time boundary of the year 2012. Dark style shows the past data (from 2005 to 2011), and light style shows the recent data (from 2012 to 2017) for comparison. And there is a comparison line in the middle of the interface, we can freely swipe the line and check the conditions of dark and light maps.

Users can check more information by clicking the specific boroughs, the details of year, name of area and percentages will appear on the box. As the legends showing, the percentages are increasing as the colors are changing from light green to dark green.

To add a different geographical dimension, we have made a line graph of the share of bioenergy (except gas, electricity and road transport fuels) by Google Charts and displayed it in the map One corner. Categories in the line chart includes Newham (where the Olympic Park is located), East London, which is radiated by the Olympic Park and the UK.

For more details of the dataset, we can also click the hyperlink of the London Datastore showing on the downside of sliders.

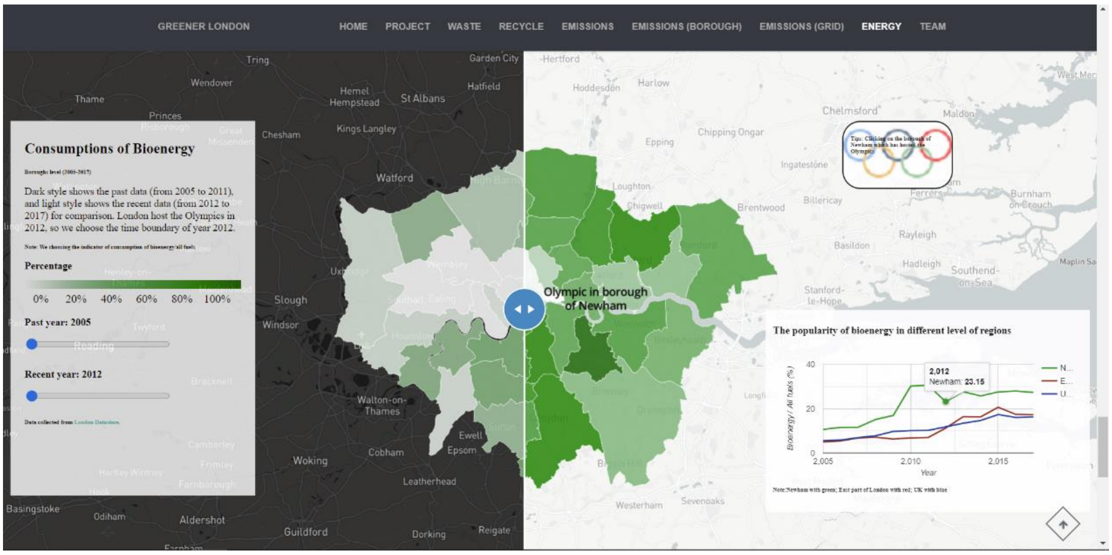

Figure.6 Visualization of bioenergy consumption proportions in London

3.3 Web Design

The index html, which combines the visualization results and supporting information, consists of a home page, a project description, visualization pages and team information. We used iframe's embedding and page-scoll to link the pre-made pages throughout the site. The user can scroll through all the content of the site in order. At the same time, we added a navigation bar to help users to jump quickly.

In the project introduction page, we also used a horizontal switch format, where the user can view the project aim and the summary of the three main sections of the project. At the bottom of each section summary, we added a "view more" button to help users jump directly to the corresponding visualization page.

In the overall style of the site, we kept the overall color palette in black and white, and added green to match the theme: "Greener London". To make it easier to distinguish, we used white as the background color for the text-based sections. On the contrary, more black was used for the visualization pages.

3.4 Web Hosting

This project uses GitHub Pages to host our website for free, GitHub is a common storage tool for us, and it supports simultaneous modification by multiple people, which makes it more convenient than other tools of the same type.

4. Result & Discussion

4.1 Waste & Recycle

According to the chart in our visualization for waste management, it is not difficult to find that from 2003 to 2019, waste management in London is more environmentally friendly. In 2003, 70% of the waste was directly buried underground, and only 19% of the waste was burned to provide energy. By 2019, 3% of the waste was directly buried, while 61% of the waste was burned to provide energy. The most obvious change was in 2010-2011, during which the Landfill rate decreased by 14%, while the Incineration with EFW increased by 12%. The recycling rate can be roughly divided into two stages. During the period 2003-2012, the recycling rate showed an upward trend, rising from 11% to 30%. After 2003, the data has stabilized at around 30%.

As for the interactive map, it is not difficult to find that the recovery rate in most of the borough has an upward trend from 2003 to 2019. In 2003, only Hillington had a high recycling rate of 34%. In 2019, the recycling rate of Sutton, Croydon, Bromley and Bexley in southeast London and Richmond upon Thames in southwest London was about 50%, proving the London authorities' efforts in environmental protection.

What makes us concerned is that Newham, the Queen Elizabeth Olympic Park, is located. In 2010-2011, the recycling rate in this borough increase from 15% to 23%. However, after the Olympics, the recycling rate continued to decline until 2017. The difference between the two time periods indicates that the restrictions were effective before and during the Games but not persisted in the later period.

For changes between Incineration with Efw (energy from waste) and landfill, the waste hierarchy rank showed below explain it well.

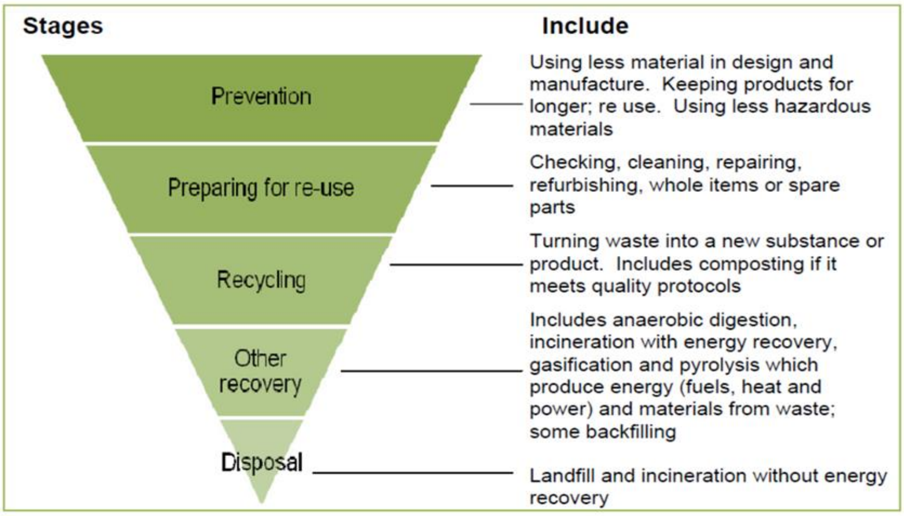

Figure.7 Department for Environment Food and Rural Affairs (2011) Guidance on applying the Waste Hierarchy. Available at: www.defra.gov.uk.

From Figure 7, it is not difficult to find that Incineration with Efw belongs to the fourth level of Other recovery, while Landfill belongs to the fifth level of Disposal. This illustrates that London's shift from landfill to incineration with energy recovery is also a step to upgrade its waste management structure.

4.2 Emission

By looking at London's air pollutant emissions at all levels, it can be seen that overall, there is a significant decrease for all pollutant from 2010 to 2013. However, during the period from 2013 to 2016, PM10 and CO2 faced a certain degree of rebound, although the downward trend in NOx and PM2.5 emissions was maintained. It is possible that this is due to the concentration of some measures that caused a qualitative change in emissions by 2013. For example, The UK Low Carbon Transition Plan, allocates about 3.2 billion to improve energy efficiency in households from 2008-2012, while the energy transition for London's vessels is also focused on 2010-2013 (Her Majesty's Government, 2009; Tim Williamson *et al.*, 2017). That is to say, the speed of emission improvement after the Olympics will definitely slow down or even be offset by more economic activities due to population growth.

The borough level map shows that East London has a slightly higher negative growth rate than the other regions. That is, the positive change is more apparent in East London. One reasonable explanation for this is that many of the sustainable development initiatives during the Olympics were centered around the Queen Elizabeth Olympic Park (QEOP) area in East London. For example, the East London scheme, which began in 2010, provides sustainable energy-based heating services to the QEOP and surrounding areas, reducing carbon emissions by at least 25% compared to conventional forms of heat generation (East London Energy, 2021; ENGIE, 2021).

4.3 Energy

It is clear that higher bioenergy rates occurred after the Olympics. Londoners of Lewisham have the consciousness to respond to the policy of using bioenergy, we can observe higher percentages than other boroughs. For example, in the area of Lewisham, the consumptions of bioenergy occupied 40% roughly of all fuels in 2005. And this proportion is increasing with the year passing, it approaching 70% in 2017.

By comparing the data, we could see that the percentages of bioenergy rise significantly during the period between 2005 and 2011. In the preparation period of the Olympics, the local authorities are required to increase the delivery of energy from renewable resources like bioenergy, which facilitates the transformation (Olimpismo, 2012). However, the proportion has a slight slope in 2012, the reason for this decline might be the general lack of sustainable energy facilities (Bioenergy Insight Magazine, 2010). In general, most boroughs have paid more and more attention to renewable energy.

Collectively, London experienced a relatively significant shift towards sustainability in all areas covered in this study during the build-up period to the London Olympic Games, i.e. up to 2012. Although the pace of development has slowed down after 2012, the improvements during this period have been successful and cannot be ignored.

5. Challenges & Limitations

One typical challenge met by the team is to organize multiple visualizations together in an elegant manner. For example, in the city level visualization of emissions, our member struggled with how to lay out those charts properly. After exploring online libraries, the layout of the charts and narrative on the page is successfully managed using Boostrap's row and column structure.

On the other hand, unsolved limitations also exist in this project. In terms of data, the visualization of pollutant emissions has a large span between the available data time points (2010-2013-2016). Thus, while the changes before and after the Olympics can be broadly captured, some specific time points that are not included, such as 2012, when the Olympics were held, cannot be observed.

Regarding the project's design, although we organized the project into three dimensions with equal importance and visualized each dimension at multiple geographical scales, users may feel that the weight of each part is not quite consistent when exploring because the structure of each section still differs. In addition, although this project has unified the style of each page to some extent in the closing stage, there are still some differences between the sections, which may make users feel a slight sense of fragmentation.

Furthermore, there are some technical issues waiting to be improved. We mentioned that our website supports both navigation bar positioning and scrolling to switch pages in the previous section. However, when entering the interactive map, continuing to scroll the mouse wheel causes a conflict between the page switching function and the map zooming function, which affects the experience of using the site.

6. Conclusion

This project visualized and analyzed London's sustainable transformation in terms of air pollutant emissions, waste recycling, and energy structure changes. Through joint negotiation and collaboration, a complete website combining visualization and textual explanation was produced. Although some of the imperfections mentioned above still exist, this project certainly communicates the relevant changes during the London Olympics in a visual and structured way to the website users. With the increasing advancement of visualization technology, governments or companies should try to communicate with the public in more diverse ways. This project stands as an attempt and provides a reference in the unexploited area.

Word Count: 4467

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