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# Global energy outlook:
## Exploring trends through data

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# Contents

# Abstract

This project focuses on the analysis of energy datasets to extract valuable insights regarding global energy consumption, electricity generation and its associated Greenhouse gas emissions. Data from various countries spanning the period between 1965 and 2021 was utilized for this purpose. The project also includes the evaluation of data visualizations through multiple user assessments.

# Chapter 1

# Introduction

## 1.1 Objective

The aim of the project is to provide an insightful and informative overview of global energy consumption, production, and its $CO_2$ related emissions. The goal is to help understand the current state of global energy dynamics and how it has evolved over time, underlying how variations on energy production mixes or on energy consumption impacts on the $CO_2$ emissions.

**Energy Consumption Trends** The first aim of this project is to create visualizations to showcase historical trends in global energy consumption. Explore how energy consumption has changed over time, identify factors influencing these changes.

**Energy Sources** The second aim is to create visualizations that break down the energy mix for different countries. Highlight the dominance of specific energy sources and their relationship with Carbon Emissions.

**Interactive Dashboard** Develop interactive data dashboard that allow users to explore the energy dataset on their own, enabling them to filter and visualize data based on their interests.

## 1.2 Dataset description

For our study, we used the *Energy dataset* by Hannah Ritchie, Max Roser and Pablo Rosado from the online publication *Our World in Data (OWID)*. The dataset includes useful data on energy consumption (primary energy, per capita, and growth rates), energy mix, electricity mix and other relevant metrics of potential interest. Also, to construct regions aggregates and variables per capita and per GDP, the dataset also presents country names, population and GDP.

In the process of generating electricity (or energy in general) many different Energy Sources can be used. The dataset presents information about the followings: biofuel, coal, gas, hydroelectric, nuclear, oil, solar and wind and other renewables. These sources can be categorized based on different criteria, such as high or low-carbon, referring to the greenhouse gas emissions associated to each unit of energy produced by that source; renewables or non-renewable.

For each energy source there are multiple variables, conferring a lot of information. Following is a quick description of each energy source:

- **Renewable sources:** renewable sources refers to energy sources that are naturally replenished and can be used indefinitely without depleting their supply. Renewable energy sources include solar power, wind power, hydropower, biomass and other renewable sources used to a lesser extent, such as geothermal, tidal or waves energy. Renewable energy sources are considered clean and sustainable, as they produce little to no greenhouse gas emissions during operation (*Low-carbon energy sources*), contributing to mitigating climate change.
  - **Biofuel:** biofuel is a type of fuel derived from renewable biological sources, such as plants, crops, or organic waste. The production and use of biofuels utilizes biomass or organic matter, contributing to reducing greenhouse gas emissions and dependence on non-renewable energy sources, for a more sustainable energy future.
  - **Hydropower:** hydropower refers to the use of flowing or falling water to produce electricity or to power machines. Hydropower is a clean and renewable energy source as it does not produce direct emissions of greenhouse gases during electricity generation. However, the construction of large-scale hydropower projects can have environmental and social impacts, such as altering ecosystems and displacing local communities.
  - **Solar:** solar energy refers to the energy derived from the sun's radiation. It is a renewable and sustainable energy source that can be harnessed through various technologies, primarily solar photovoltaic (PV) systems and solar thermal systems. Solar energy is abundant and widely available, making it a promising alterna-

tive to fossil fuels. It is a clean source of energy, producing no greenhouse gas emissions or air pollutants during operation.

- **Wind:** wind energy refers to the renewable energy derived from the natural movement of air currents. It is harnessed by wind turbines, which convert the kinetic energy of the wind into mechanical energy and then into electrical energy. Wind energy is clean and sustainable, as it produces no greenhouse gas emissions or air pollutants during operation. It is a renewable energy source that relies on the Earth's natural wind patterns, which are continually replenished.

- **Non-renewable sources:** refers to energy derived from finite resources, that cannot be replaced quickly enough to keep up with the consumption speed. They mainly include *nuclear energy* and *fossil fuels*, which are natural resources formed from the remains of ancient plants and organisms that lived millions of years ago, such as coal, oil, and natural gas. Fossil fuels have been massively used for many years due to their high energy density and availability, but their combustion releases carbon dioxide and other greenhouse gases, contributing to climate change and air pollution.

  - **Coal:** coal is a fossil fuel formed from the remains of plants that lived and died millions of years ago. It is primarily composed of carbon, along with various other elements and impurities. Coal has been widely used for centuries due to its abundance and relatively low cost. However, burning coal releases significant amounts of carbon dioxide and other pollutants into the atmosphere, contributing to air pollution and climate change.
  - **Oil:** oil, also known as petroleum, is a fossil fuel that is extracted from the Earth's crust. Oil has been a dominant energy source due to its high energy density, ease of transport, and widespread availability. However, burning oil releases carbon dioxide ($CO_2$) and other greenhouse gases into the atmosphere, contributing to climate change. Oil spills during extraction, transportation, or accidents can also have severe environmental consequences.
  - **Gas:** gas, in the context of energy, refers to natural gas, a fossil fuel primarily composed of methane ($CH_4$). Natural gas is considered a cleaner-burning fossil fuel compared to coal and oil, as it produces lower carbon dioxide emissions and fewer pollutants when burned. However, it still contributes to greenhouse gas emissions and climate change.

- **Nuclear:** nuclear energy is a type of energy produced through the process of nuclear fission, which releases a significant amount of energy in the form of heat. Unlike fossil fuels, nuclear energy does not produce greenhouse gas emissions during the operation and are totally related to the construction of the infrastructures. However, it does generate radioactive waste, which requires proper management and disposal to ensure environmental and public safety.

For our analysis we mainly focused on Primary Energy Consumption, Primary Energy Consumption per capita Electricity Generation, Electricity Generation per capita and Carbon intensity for electricity Generation.

Primary Energy Consumption refers to the total amount of energy used directly from natural resources before any conversion or transformation occurs. It represents the sum of energy derived from various sources, including fossil fuels (such as coal, oil, and natural gas), nuclear energy, renewable energy (such as solar, wind, hydropower), and biomass. Primary Energy Consumption per capita, measures the average energy usage per person within a given population. It is calculated by dividing the total primary energy consumption in a country or region by the population.

Electricity Generation refers to the process of producing electrical energy from various sources. It involves the conversion of primary energy sources, such as fossil fuels, nuclear energy, or renewable sources, into electricity that can be used for various purposes, including powering homes, businesses, industries, and infrastructure. Electricity Generation per capita measures the average electricity production or consumption per person within a specific population. As per any measurement per capita, it is calculated by dividing the total electricity generation in a country or region by the population.

## 1.3 Process

Exploring the visualizations we created, which will be discussed in the next chapter, some interesting observations can be made.

Due to developement and population growth, we observe a constantly growing trend in the primary energy consumptions, which we observe to have quadrupled over time. However, there are 4 noticeable falls:

- *First Oil Crisis (1973-75)*: Nixon's economic support to Israel during the Yom Kippur war against the Arab states led to the institution of an oil embargo on USA (and other countries supporting Israel) by the Organization of Arab Petroleum Exporting Countries (OAPEC): oil production cuts were made and prices nearly quadrupled

- *Second Oil Crisis (1978-79)*: Iranian oil industry was damaged as a result of Iranian revolution and Iran-Iraq war, leading to large losses of output and a corresponding rise in oil prices

- *Economic Crisis (2009)*: a strong decline in industrial production (GDP dropped drastically) led to less demand, so less consumption

- *Covid-19 pandemic (2019-2020)*: decline in production and demand, together with other reasons, led to a drop in energy consumption

Greenhouse gas emissions also have a growing pattern, with drops during the crises, due to the decreased economic activity and the growth of renewable sources.

In addition to the factors mentioned above, there are other complex factors that can affect energy consumption, electricity generation and greenhouse gas emissions. These include changes in climate, technological innovation, government policies and many other aspects.

*We hope our dashboards and summary observations encourage users to explore the visualizations themselves to identify interesting and meaningful trends, and eventually find their explanations by going more into details.*

# Chapter 2

# Dashboards

All our visualizations have been created using Tableau Public and are displayed through interactive dashboards. In particular, we created two dashboards showing our information through two main approaches:

- **Spatial approach**: our main dashboard (*Maps Dashboard*) uses this approach, which consists in selecting a specific year to be able to easily compare data in the space dimension, through a map which shows a side-by-side comparison of the world's countries. For example, we can easily see which country has more $CO_2$ emissions between Italy and Spain in 2008.

- **Temporal approach**: our *Time Dashboard* uses this completely opposite approach, which consists in selecting a specific country to be able to easily compare data in the time dimension, through area charts and line charts which provide a year-by-year trend, to make it immediate to compare data through time. For example, we can see how energy consumption changes every year.

## 2.1 Maps Dashboard

Our main dashboard presents the viewer with four main components:

- **World map:** a global map showing each observed country colored according to the value registered in the dataset of the selected filter (so, as we introduced already, Electricity Generation (total or Per capita), Primary Energy Consumption (total or Per capita), Carbon Intensity Electricity, with annexed legend;

- **Year slider:** a slider that allows the viewer to select the desired year among the available ones;
- **Pie chart:** a pie chart showing the mix for primary energy consumption or electricity generation;
- **Bar chart:** a leaderboard classifying the countries according to the highest values registered in the dataset.
- **Tutorial button:** a useful button that shows the four main steps to interact effectively with our dashboard.

We will now see each component in detail.

### 2.1.1 Choropleth map

The first and most noticeable component of our dashboard is the World Map in the center of the visualization. It is technically a choropleth map, which is a thematic map that is used to represent statistical data using the color mapping symbology technique. It displays enumeration units, or divided geographical areas or regions that are colored, shaded or patterned in relation to a data variable. In our case, every country is colored according to a custom scale we composed to create a better distinction between countries.

#### Electricity Generation [TWh]

For the Electricity Generation view, we created a custom scale in order to separate well the various countries. We used a blue gradient, in which the lightest color indicated the lowest electricity generated, measured in TWh, while the darkest tone of blue was used for the countries that generated the most electricity. The values used to allocate each county were chosen keeping in mind the need to create seven distinct groups. Using uniforms bins across the board resulted in a aggregation of counties with too different values, so the scale we settled on was: 0-50, 50-100, 100-250, 250-500, 500-1000, 1000-2500, $\geq$ 2500, No data.

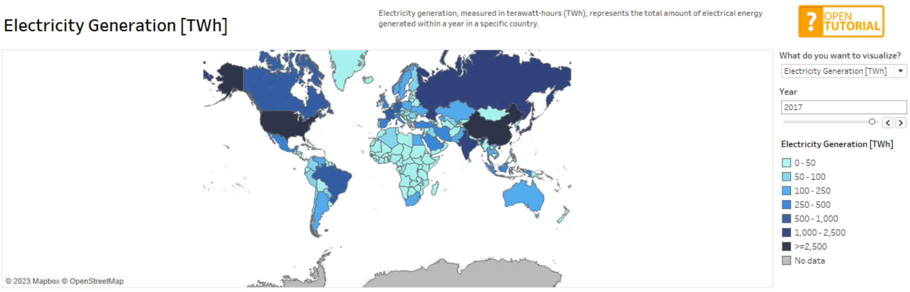



Figure 2.1: Electricity Generation Choropleth map

### Electricity Generation Per capita [kWh]

The Electricity Generation Per capita view is an alternative way to view the amount of electricity generated, but instead of considering the country's total amount, we focus on the per capita amounts. We used a scale of colors starting at a pastel yellow, which indicate the lowest amounts, and arriving at a dark blue, which indicate the highest amount of electricity generation per capita, which is measured in kWh. Just like every other map, we used a custom scale: 0-250, 250-500, 500-750, 750-1000, 1000-2000, 2000-4000, 4000-8000, 8000-10000, 10000-15000, ≥15000, No data.

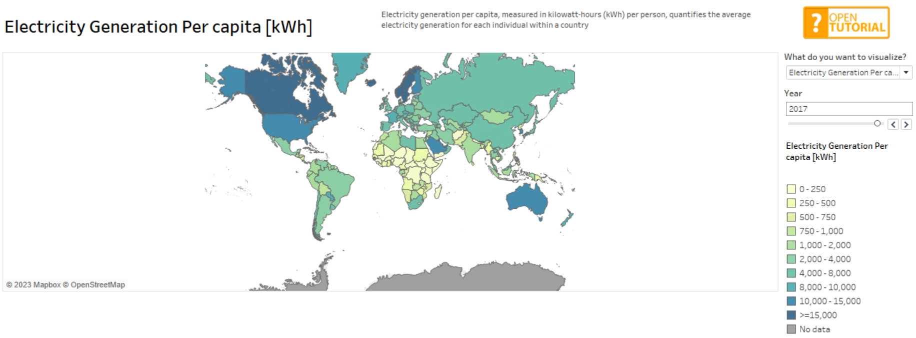



Figure 2.2: Electricity Generation Per capita Choropleth map

### Primary Energy Consumption [TWh]

The Primary Energy Consumption view illustrates a choropleth map of the world, coloring the countries of the world with an orange scale palette according to the value registered in the dataset. The lightest tone indicates the lowest consumption value, while as the color gets darker the value gets higher. As every other map, we created custom bins to better highlight the distinction of groups of countries. In this case, the values separating the bins were: 0-500, 500-1000, 1000-2500, 2500-5000, 5000-10000, ≥10000, No data.

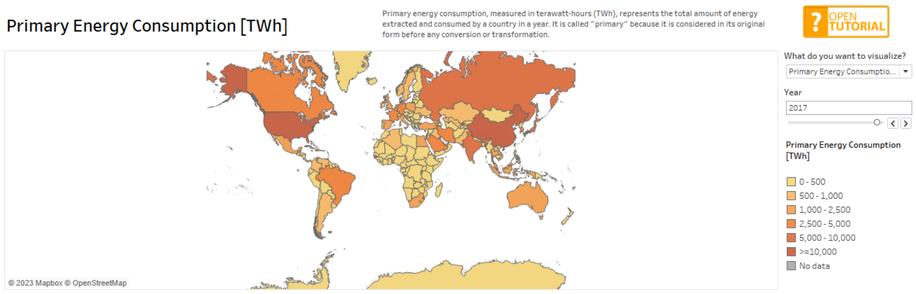



Figure 2.3: Primary Energy Consumption Choropleth map

### Primary Energy Per capita [kWh]

The Primary Energy Per capita view, like the Electricity Generation Per capita view, is an alternative way to view the amount of energy consumed by countries, focusing on the per capita values. We chose a palette ranging from light orange to dark red. The values used for our custom scale were ranges: 0-1000, 1000-2000, 2000-5000, 5000-10000, 10000-20000, 20000-50000, 50000-100000, 100000-200000, ≥200000, No data.

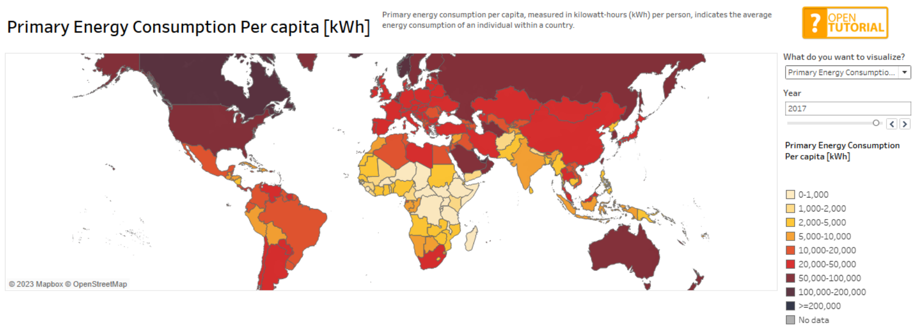



Figure 2.4: Primary Energy Per capita Choropleth map

### Carbon Intensity Electricity [$gCO_2/kWh$]

The Carbon Intensity Electricity view illustrates our world map by colouring each state according to the registered values in the dataset. We chose a palette ranging from a light pastel yellow (the lowest values) to a dark pink (the highest values). Our custom scale was composed by: 0-10, 10-50, 50-100, 100-200, 200-500, ≥500, No data.

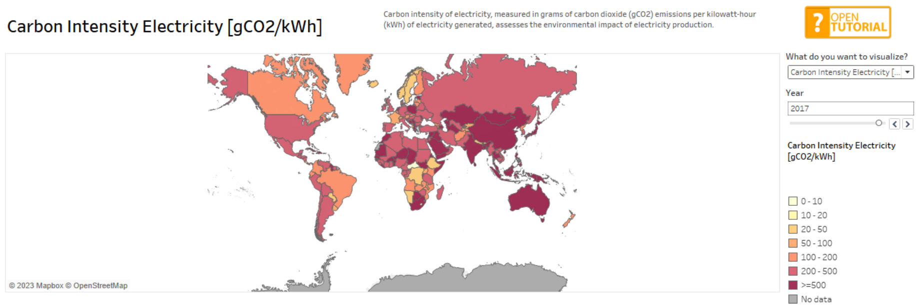



Figure 2.5: Carbon Intensity Electricity Choropleth map

#### Interaction

All the choropleth maps are not only images. They all offer interactive features. First of all, by hovering over a country a first preview is shown, indicating the group in which the country has been allocated according to our custom bins, the name of the country, and the year from which the data has been extracted. By clicking on any desired country of the world, the borders of the selected country are highlighted and the rest of the world gets put out of focus, and in the bottom left of the dashboard the viewer will notice the pie chart change. In the next section we will describe the function of said pie chart.

### 2.1.2 Pie chart

In the bottom-left half of our dashboard, there is a Pie chart. By the legend present to it's right, we can see the different energy sources, and their respective colours. The Pie chart shows the selected country's energy mix (or, if no country is selected, the world's). The Pie chart adapts to any of the four visualizations from the map, and adjusts the values that are being shown accordingly. So, for example, if we have selected Italy while visualizing the Electricity Generation, the Pie chart will be divided according to the various energy sources that make up Italy's electricity generation.

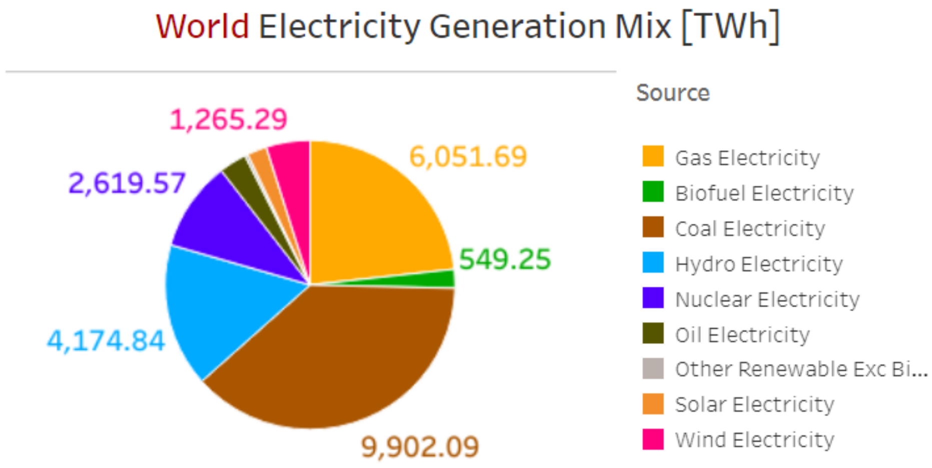



Figure 2.6: World Electricity Generation Mix Pie chart

#### Interaction

The Pie chart, like the choropleth maps, offer interactive features. In fact, the Pie chart works closely with the horizontal Bar chart adjacent to the Pie chart itself, which we will describe later. By clicking on any of the areas of the Pie chart, in fact, the Bar chart is set to show the leaderboard of the world's countries, ranked by the consumption of the selected energy source. In this new leaderboard, the country that has been selected from the choropleth map is highlighted so that it is identifiable, and therefore possible to see in which position the selected country places itself in the leaderboard.

### 2.1.3 Bar chart

The last chart in this dashboard is the Bar chart in the bottom-right of our dashboard. The bar chart function as a leaderboard, showing rank, the name of the country and the value for each country. By default, the Bar chart shows the global leaderboard of the subject of the visualization. So, for example, when we are visualizing the Electricity Generation [TWh] map, the countries are ranked according to the amount of electricity generated. By scrolling, all 215 countries are displayed.

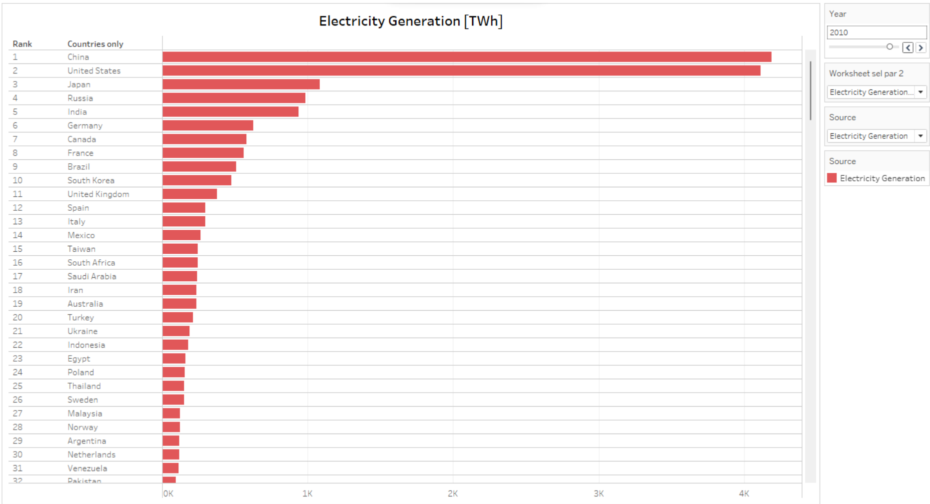



Figure 2.7: Electricity Generation Bar chart

### Interaction

More than being interactive itself, the Bar chart is often subject to interaction from the other charts and maps. By selecting a country from the choropleth map, the selected country gets highlighted on the leaderboard so it's identifiable and it's possible to see the exact value of the subject of the visualization. As introduced in the previous section, the Bar chart closely interacts with the Pie chart. As just mentioned, by default the Bar chart ranks the countries according to the totals amounts for each country. However, by selecting an energy source by clicking on respective area on the Pie chart, the Bar chart will update and rank the world's countries according to the selected energy source.

## 2.2 Time Dashboard

In our second dashboard, we created a series of area and line charts that can display four separate topics. Line charts are particularly useful for showing trends, patterns, and changes in data over time or across different categories. An area chart, also known as an area graph, is a type of data visualization that is used to represent quantitative data over a continuous interval or time period. It is similar to a line chart but with the area below the line filled with color or shading, which helps emphasize the magnitude of change over time or across categories.

The topics we decided to visualize are the following: Electricity Generation, Primary Energy Consumption, Electricity Generation Percentage and Primary Energy Consumption Percentage.

### 2.2.1 Area Charts

#### Electricity Generation

Electricity generation refers to the total amount of electricity that is produced or generated by power plants, generators, or other sources of electrical energy. Our x-axis represents the years (in this case starting from 1985), and our y-axis represents the electricity generation expressed in TWh.

The various energy sources are displayed and colour the area according to their respective amounts recorded. The energy sources displayed are: biofuel, oil electricity, solar electricity, wind electricity, nuclear electricity, hydro electricity, gas electricity, coal electricity and other renewable electricity.

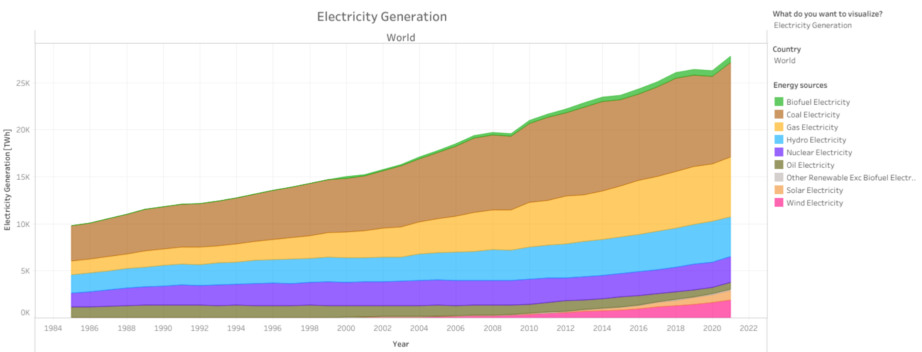



Figure 2.8: Electricity Generation Area chart

#### Primary Energy Consumption

Primary Energy Consumption represents the total amount of energy that is produced or extracted directly from natural resources before any conversion or transformation. It includes all forms of energy sources, such as fossil fuels, renewable energy sources, nuclear energy, and more. It represents the raw energy available to a country or region before any losses that occur during generation, conversion, and transmission. Our x-axis represents the years (which in this case starts from 1965), and our y-axis represents the primary energy supply expressed in TWh.

The same energy sources as the previous chart are shown.

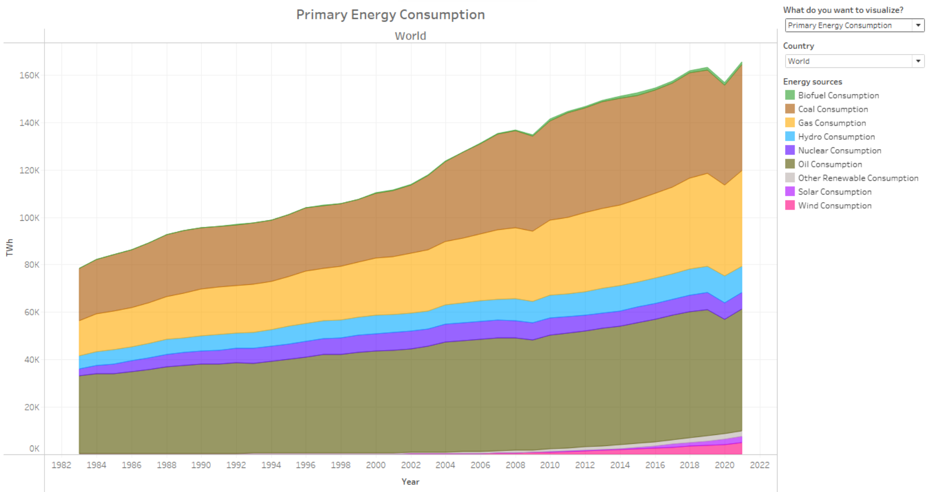



Figure 2.9: Primary Energy Consumption Area chart

#### Interactions

The interactive features of the Area charts consist in highlighting a specific energy source by clicking directly on the area on the chart, or by clicking on the name of the energy source in the legend. By doing so, and by hovering the cursor over the charts, the total value in that specific year and country is shown.

There are also two drop down menus. The first one allows the user to select which of the five visualization to visualize. The second drop down menu offers the function to visualize the charts for specific countries. We note that not all countries have the same year range: this is due to a lack of data collection, or for geopolitical reasons (for example, Primary Energy Supply for the USSR is available from 1965 to 1984, while for Italy it is available from 1965 to 2021).

### 2.2.2 Line Charts

#### Electricity Generation Percentage

Electricity generation percentage refers to the proportion or percentage of total electricity generation that is attributed to a specific energy source, technology, or category. It is used to express the contribution of different energy sources to the overall electricity supply. Our x-axis represents the years (in this case starting from 2000), and our y-axis represents the percentage.

The energy sources that are displayed are: coal, gas, nuclear, oil, renewable.

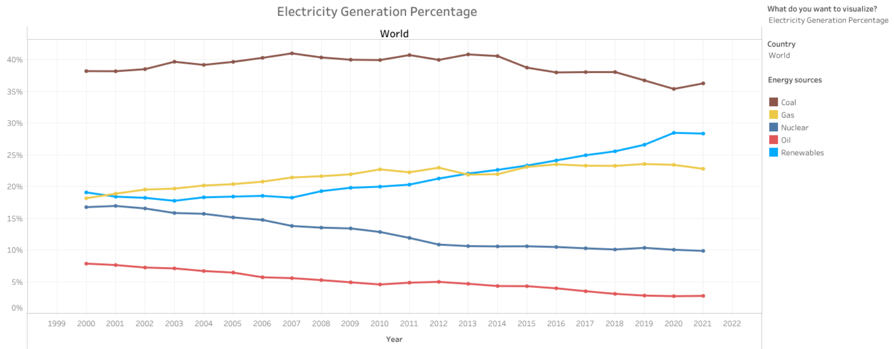



Figure 2.10: Electricity Generation Percentage Line chart

### Primary Energy Consumption Percentage

Primary energy supply percentage refers to the proportion or percentage of the total primary energy supply that is attributed to a specific energy source or category. It is used to express the contribution of different energy sources to the overall energy supply of a country, region, or the world. Our line chart shows how the percentages of the various energy sources change over time.

The energy sources displayed are the same five as the previous chart.

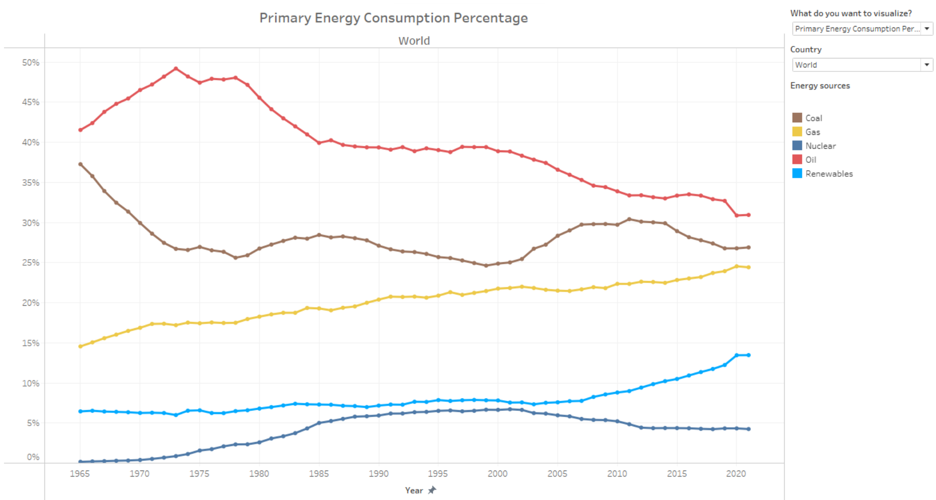



Figure 2.11: Primary Energy Consumption Percentage Line chart

### Greenhouse gas emissions for Electricity Generation

Greenhouse gas emissions from electricity generation refer to the release of gases that trap heat in the Earth's atmosphere as a result of producing electricity. These emissions contribute to global warming and climate change. Our x-axis represent the years, while our y-axis represent the greenhouse gas emissions expressed in Mt $CO_2$.

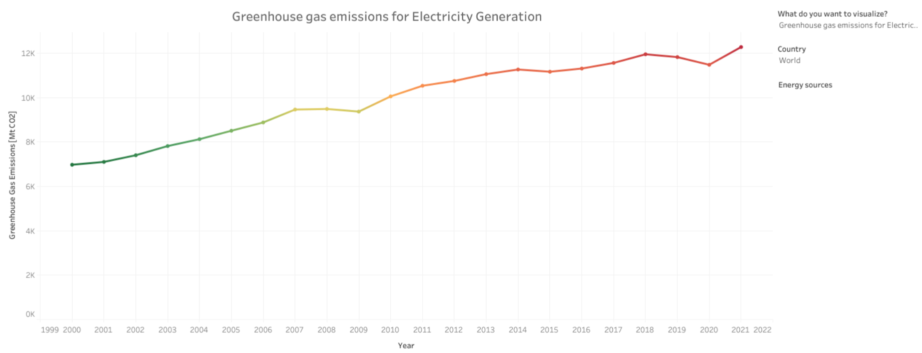



Figure 2.12: Greenhouse gas emissions for Electricity Generation Line chart

### Interactions

The interactive features of the Line charts consist in highlighting a specific energy source by clicking directly on the line on the chart, or by clicking on the name of the energy source in the legend. By doing so, and by hovering the cursor over the charts, the percentage value in that specific year is shown, similarly to what we have already seen in the Area charts.

Similarly, there are also two drop down menus. The first one allows the user to select which of the five visualization to visualize. The second drop down menu offers the function to visualize the charts for specific countries. Also here we note that not all countries have the same year range.

# Chapter 3

# Quality Assessment

Assessing the quality of data visualizations is crucial to ensure that the information is effectively communicated, accurate, and meaningful to the audience. We therefore performed three types of assessment: heuristic evaluation, user test, psychometric test.

## 3.1 Heuristic Evaluation

Heuristic evaluation is a method commonly used in user interface and user experience (UI/UX) design to assess the usability and user-friendliness of a digital product or interface. The goal is to identify usability issues and areas for improvement.

We conduced the heuristic evaluation on a sample of 5 users, asking each of them to interact with the visualizations and "think aloud", so that we could collect information about eventual improvements.

- **User 1:** the first user appreciated the interactiveness of the dashboard, specifically the fact that the pie chart showed the nation's mix when a country is selected. The user suggested to fix some colour gradients to emphasise the distinction between some intervals. Overall, the dashboards were clear enough to understand the context of the visualizations.
- **User 2:** the second user found the overall dashboards clear and informative. The second user also commented on some unclear colour choices, and in some cases the legend presented too many intervals.
- **User 3:** the third user had no experience with the software we used, so most of the misunderstandings were due to a lack of user experience:

for example the user suggested a way to insert manually a year or a country, a feature already implemented in our dashboard. Overall, the dashboards were clear, except for some suggested tweaks to some colour schemes.

- **User 4:** the fourth user suggested to change a colour scheme to emphasise more the differences in the intervals. The user also suggested to adjust some intervals, as the ones we had chosen were not much used or unclear. Overall, the user appreciated the beauty and interactiveness of the dashboards.

- **User 5:** The fifth user did not understand immediately some of the interactive features and also would appreciate some context description for each visualization.

## 3.2 User Testing

User testing, also known as usability testing, is a crucial method for evaluating the usability and user-friendliness of a product, website, application, or any other digital interface. It involves observing real users as they interact with the interface to identify usability issues, gather feedback, and improve the overall user experience.

We decided on six tasks to ask our subjects to carry out for the first dashboard and another six for the second one.

**Maps Dashboard:**

- **Task 1:** Which are the top 3 countries that produced most electricity in 2010? Which is the main electricity generation source for each one? [Answer: 1) China with 4187 TWh, main source: Coal; 2) United States with 4114 TWh, main source: Coal; 3) Japan with 1082 TWh, main source: Gas.]

- **Task 2:** How much primary energy did a single person consume in Argentina in 2007? Is it more or less than the per capita consumption in Spain in the same year? [Answer: 21737 kWh - It is less: 40818 kWh]

- **Task 3:** Which country had the highest hydro consumption in 2013? Does it coincide with the country with the highest hydro consumption per capita? [Answer: No, it's China in total hydro consumption and Iceland in per capita hydro consumption]

- **Task 4:** By just looking ad the map, which were the two countries in Africa with the highest electricity generation per capita in 2013? Based only on their colour, in which value range will their electricity generation be? [Answer: Libya and South Africa - Between 4000 and 8000]

- **Task 5:** By interacting with the map, which European country has the lowest carbon intensity in 2014? What is its generation mix mainly based on? (Consider the top 3 most used sources) [Answer: Albania 23.3 gCO2/kWh - Hydro]

- **Task 6:** Zoom on France and Belgium. By looking at the map, in 2018, which one has the highest primary energy consumption? What about per capita primary energy consumption? [Answer: France (2791 TWh); Belgium (63411 kWh/pp)]

**Time Dashboard:**

- **Task 1:** What was the main electricity generation source globally used in 2011? [Answer: Coal - 41% ]

- **Task 2:** What is the n° of TWh of Primary Energy produced using Gas in United States in 2011? [Answer: 6582 TWh]

- **Task 3:** What is the percentage of electricity generated by renewables in 2008 in Italy? [Answer: 19%]

- **Task 4:** How many Mt of CO2 did Finland Emitted in 2017 for electricity production? [Answer: 12,64 Mt]

- **Task 5:** Did CO2 emissions for electricity production increase or decrease from 2000 to 2020 in Europe, and what is the year of maximum emissions in this span? [Answer: Decreased from 1631.5 to 1251.8 Mt, 2007 with 1832.8 Mt]

- **Task 6:** What was the percentage of coal usage and renewable usage for electricity generation in 2000 in Europe? How did the percentages change in 2021? [Answer: Coal: 27%, Renewable: 19%; Coal: 15%, Renewable: 35%]

We performed user testing on thirteen users, in person and via telematic means. Before performing the tasks, we first allowed the users to explore our dashboards without any context. We then explained the features of our dashboards after receiving an initial feedback from the users. Following that, we started performing the twelve tasks and time the completion time for each one. All tasks were completed correctly, allowing for some minor suggestions if the user was slightly on the wrong track.

The following table registers the completion time (in seconds) for the six tasks we had performed for the first dashboard: the Maps Dashboard.

| user | task 1 | task 2 | task 3 | task 4 | task 5 | task 6 |
|---|---|---|---|---|---|---|
| **1** | 165 | 37 | 46 | 65 | 105 | 79 |
| **2** | 96 | 46 | 53 | 40 | 110 | 55 |
| **3** | 100 | 100 | 60 | 41 | 104 | 77 |
| **4** | 81 | 81 | 105 | 65 | 69 | 53 |
| **5** | 48 | 68 | 48 | 80 | 58 | 26 |
| **6** | 112 | 91 | 50 | 43 | 123 | 105 |
| **7** | 88 | 76 | 57 | 40 | 90 | 60 |
| **8** | 111 | 67 | 85 | 40 | 104 | 90 |
| **9** | 100 | 60 | 56 | 35 | 46 | 40 |
| **10** | 74 | 44 | 66 | 52 | 79 | 62 |
| **11** | 82 | 56 | 70 | 49 | 104 | 38 |
| **12** | 39 | 65 | 53 | 39 | 37 | 25 |
| **13** | 40 | 42 | 74 | 34 | 102 | 38 |

Table 3.1: Completion Times for tasks in Maps Dashboard

We now show some descriptive statistics regarding the completion times of the first six task:

| | task 1 | task 2 | task 3 | task 4 | task 5 | task 6 |
|---|---|---|---|---|---|---|
| **Mean** | 87.38 | 64.07 | 63.30 | 47.92 | 87.00 | 57.53 |
| **Median** | 88 | 65 | 57 | 41 | 102 | 55 |
| **Std Deviation** | 32.77 | 18.60 | 16.17 | 13.39 | 25.80 | 23.73 |
| **CI 95%** | 87.38 ± 17.8 | 64.07 ± 10.1 | 63.30 ± 8.79 | 47.92 ± 7.28 | 87.00 ± 14 | 57.53 ± 12.9 |

Table 3.2: Descriptive Statistics of the Completion Times

We now report the completion times for the six tasks we had performed for the second dashboard: the Time Dashboard:

| **user** | **task 1** | **task 2** | **task 3** | **task 4** | **task 5** | **task 6** |
|---|---|---|---|---|---|---|
| **1** | 41 | 47 | 37 | 19 | 27 | 59 |
| **2** | 35 | 76 | 24 | 37 | 29 | 50 |
| **3** | 55 | 72 | 22 | 18 | 32 | 42 |
| **4** | 17 | 32 | 28 | 18 | 15 | 45 |
| **5** | 15 | 24 | 17 | 32 | 21 | 31 |
| **6** | 20 | 21 | 17 | 32 | 22 | 65 |
| **7** | 9 | 87 | 32 | 15 | 49 | 67 |
| **8** | 23 | 62 | 30 | 50 | 35 | 67 |
| **9** | 11 | 35 | 20 | 25 | 26 | 50 |
| **10** | 37 | 51 | 27 | 41 | 37 | 62 |
| **11** | 19 | 44 | 26 | 31 | 30 | 61 |
| **12** | 35 | 46 | 23 | 19 | 21 | 33 |
| **13** | 35 | 31 | 32 | 21 | 14 | 19 |

Table 3.3: Completion Times for tasks in Time Dashboard

We now show some descriptive statistics measure regarding the second half of tasks we had performed:

| | **task 1** | **task 2** | **task 3** | **task 4** | **task 5** | **task 6** |
|---|---|---|---|---|---|---|
| **Mean** | 27.07 | 48.30 | 25.76 | 27.53 | 27.53 | 50.07 |
| **Median** | 23 | 46 | 26 | 25 | 27 | 50 |
| **Std Deviation** | 13.08 | 19.85 | 5.81 | 10.23 | 9.17 | 14.80 |
| **CI 95%** | 27.07 ± 7.11 | 48.30 ± 10.8 | 25.76 ± 3.16 | 27.53 ± 5.56 | 27.53 ± 4.98 | 50.07 ± 8.05 |

Table 3.4: Descriptive Statistics of the Completion Times

In order to summarize the results shown in these tables and to ease the comprehension of these figures, we chose to build two violin plots (one for each dashboard). Each “violin” represents a task, while the shape represents the density estimate of the variable: the more data points in a specific range, the larger the violin is for that range.

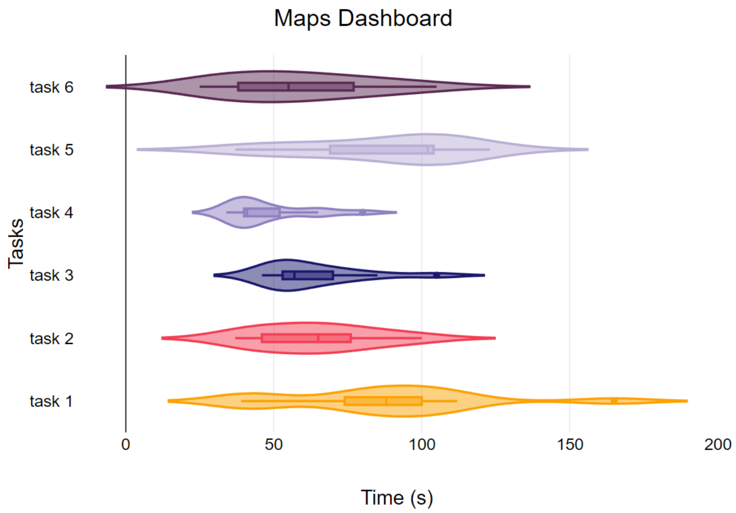



Figure 3.1: Violin plot for the Maps Dashboard

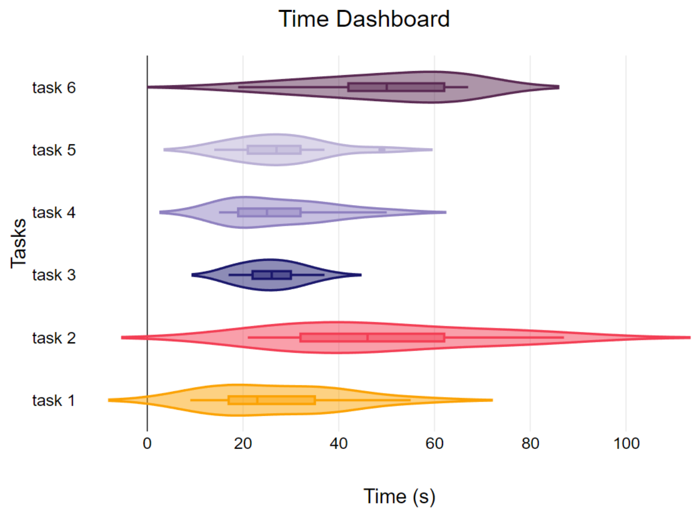



Figure 3.2: Violin plot for the Time Dashboard

## 3.3 Psychometric Test

A psychometric test is a standardized assessment designed to measure an individual's psychological attributes, such as cognitive abilities, personality traits, attitudes, and skills. Psychometric tests are developed based on established psychological theories and statistical methods, and they aim to provide objective and reliable measurements of psychological constructs.

Specifically, in order to carry out the psychometric questionnaire we decided to use the Cabitza-Locoro scale. This choice allows us to assess the quality of the infographics, on a scal from 1 to 6 for the following fields:

- Utility
- Clarity
- Informativeness
- Beauty.

This scale also requires to give an overall value to the infographic in order to assess the quality.

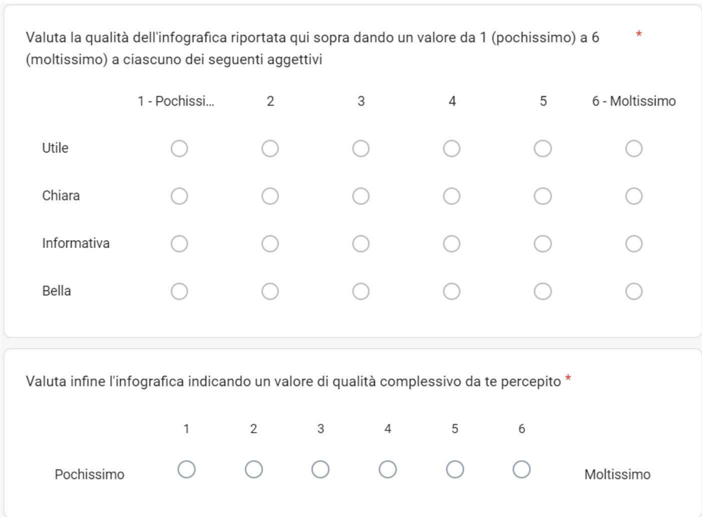
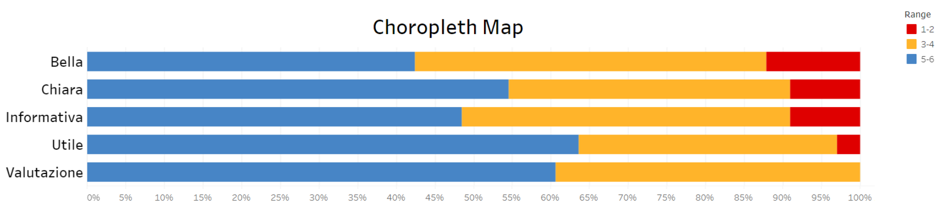
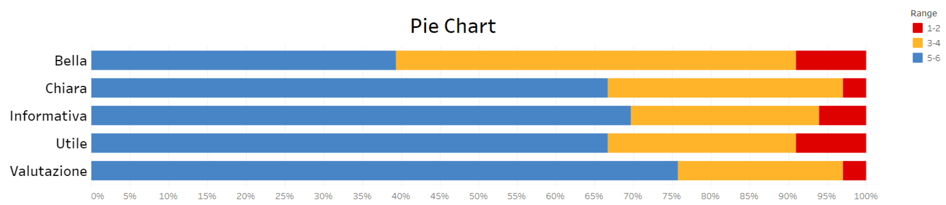
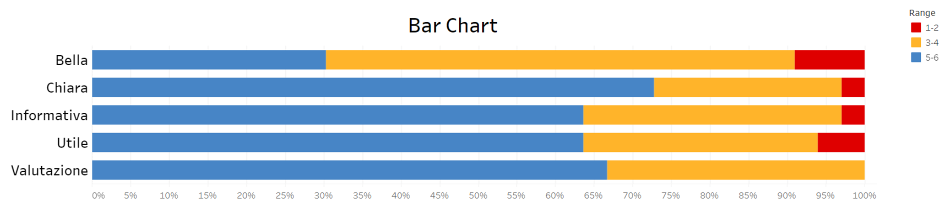


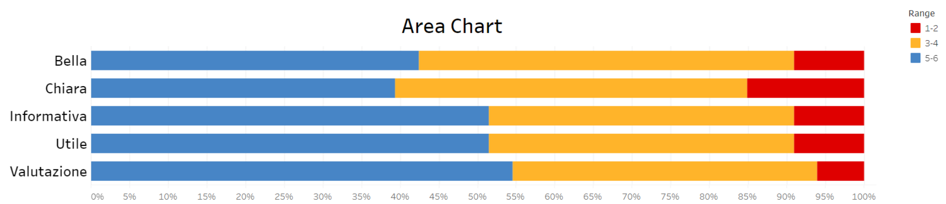

Figure 3.3: Example of psychometric questionnaire using the Cabitza-Locoro scale

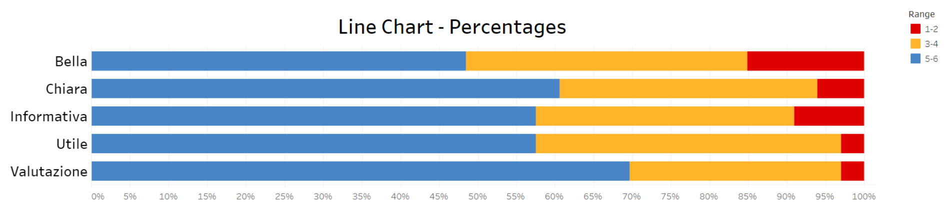
Following we report the results of our questionnaire's questions regarding the multiple categories and the overall evaluations of our proposed visualizations:

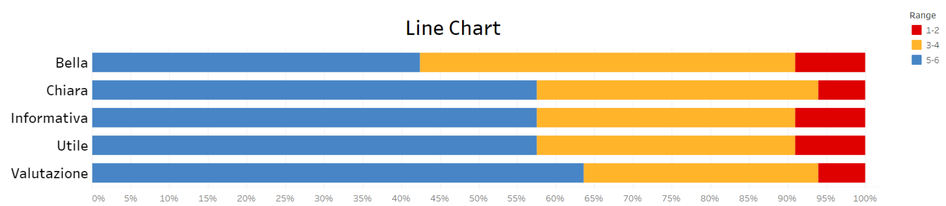




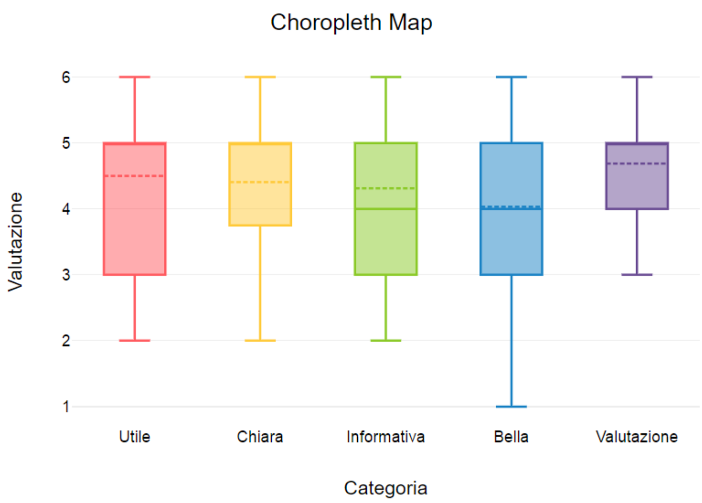

The overall feedback from our questionnaire was positive, as most users assigned middle to high points when scoring our proposed visualizations.

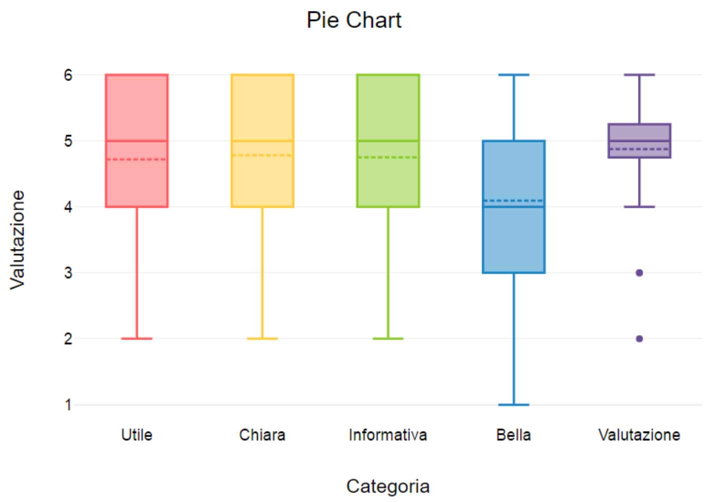
Following are some rough conclusions we can determine from these results:

- Beauty: the Line Chart - Percentages obtained the highest number of high marks, as 48,48% of users assigned a a score of 5 or 6.

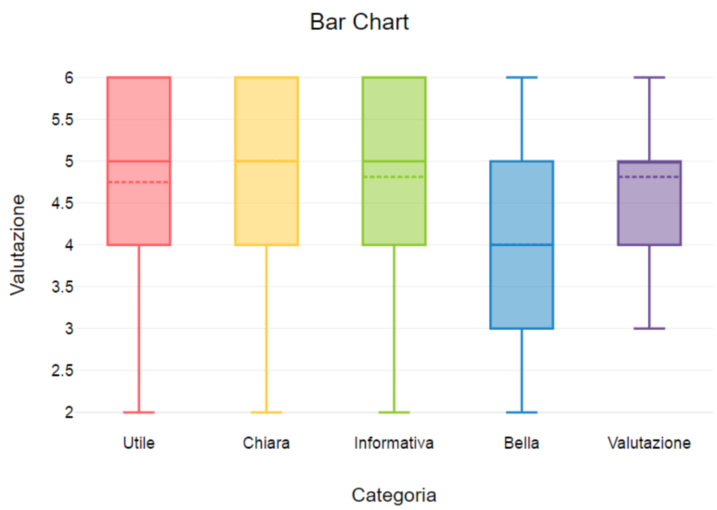
- Clarity: the Bar Chart resulted being the most clear, as 72,73% of users assigned high marks.
- Informativeness: the Pie Chart resulted being the most informative: 69,70% of users gave the Pie Chart a score of 5 or 6.
- Utility: the Pie Chart again was considered the most useful chart, as 66,67% of users assigned a score of 5 or 6.
- Overall: the best overall chart was, again, the Pie Chart: 75,76% of users assigned the Pie Chart a score of 5 or 6 in the final question (the overall value of the infographic).

Let's visualize these results in box plots:

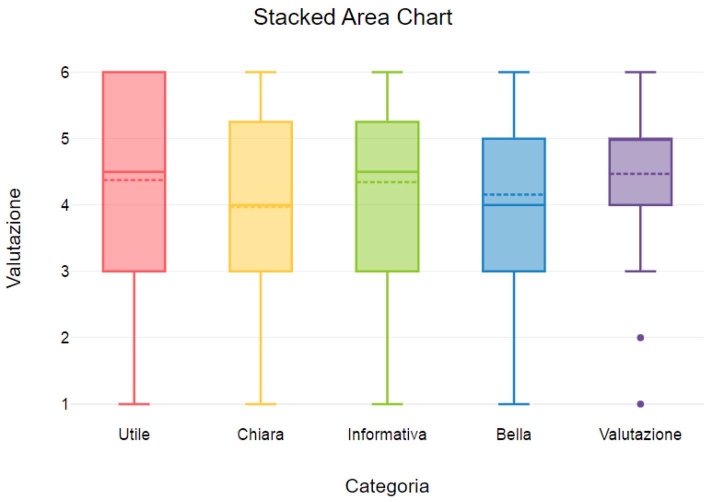




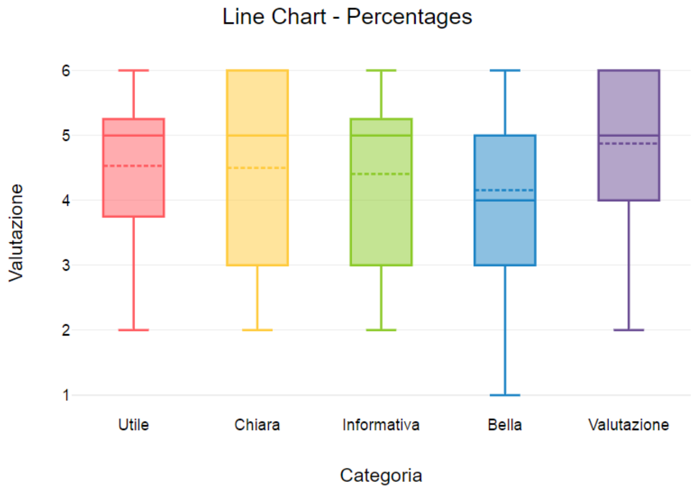
Pie Chart
Valutazione
6
5
4
3
2
1
Utile
Chiara
Informativa
Bella
Valutazione
Categoria

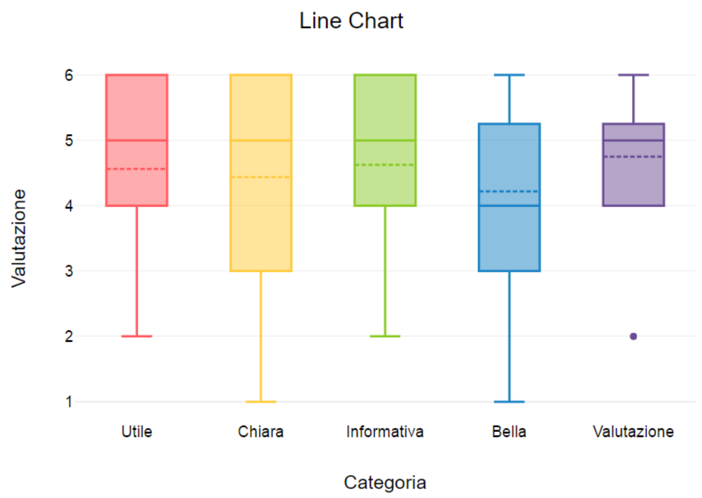
Bar Chart
Valutazione
6
5.5
5
4.5
4
3.5
3
2.5
2
Utile
Chiara
Informativa
Bella
Valutazione
Categoria



Stacked Area Chart
Valutazione
6
5
4
3
2
1
Utile
Chiara
Informativa
Bella
Valutazione
Categoria

Line Chart - Percentages
Valutazione
6
5
4
3
2
1
Utile
Chiara
Informativa
Bella
Valutazione
Categoria


Line Chart
Valutazione
6
5
4
3
2
1
Utile
Chiara
Informativa
Bella
Valutazione
Categoria

# Chapter 4

# Conclusions

The main objective of our project was to create dashboards that allowed users to explore global or country's Primary Energy Consumption, Electricity Generation or $CO_2$ emissions.

We did this through two approaches: spacial and time. We created two dashboards to distinct these approaches.

Our first dashboard consisted mainly in a spacial approach. The main component of the first dashboard is an interactive world map, which works along side a pie chart and a bar chart to show generation and consumption of a county or the whole world. A year slider is present, however, the most noticeable aspect of this dashboard is the explicit choice and navigation around the world to observe a specific country.

Our second dashboard consists in a selection of area and line charts, which by their nature emphasise the time aspect of this approach by showing the evolution of data over time. Through these charts, trends and patterns over time are more clear and noticeable.

After initial development of our dashboards, we performed user test in various formats.

From the results of the heuristic evaluation we adjusted some aspects of the dashboards, for example adjusting a color scale for the Carbon Intensity Electricity map (all users commented on the previous choice), and adjusting the scaling of some intervals which didn't separate clearly some categories. From a first time software user, we received a suggestion of adding some kind of tutorial for the dashboard, so we implemented the tutorial button too.

From the user tests we tested the usability and clarity of our dashboard, receiving a good response, as all the tasks ended up being completed, even if some needing more time than others. The task assigned for the Map Dashboard took longer, as the dashboard and the tasks themselves were more complex, but also due to more intense computational demand, slowing down slightly the execution time of the tasks.

From the psychometric test we obtained specific and overall evaluations from 32 users. Although some users assigned low marks for some visualizations, the overall response was positive for all the proposed charts and visualizations.

Each of these types of evaluation provided us with useful insights:

- the heuristic evaluation allowed us to adjust some aspects of our initial dashboards by communicating directly with users, receiving their opinions on aspects that they didn't find as clear as intended, allowing us to adjust said aspects to improve the overall quality of our dashboards;

- the user test allowed us to verify the usability of our work, and observe how different users approached the tasks in different ways, demonstrating that there are multiple ways to arrive at a solution;

- the psychometric test, being the test that had the most reach, allowed us to gain feedback from a larger set of users. However, being a questionnaire, it's difficult to identify specific aspects that lowered some marks.