Portugal Electricity and Renewable Energy Analysis

Samuel Robalo*
s.robalo@campus.fct.unl.pt
NOVA School of Science and Technology
Almada, Setúbal, Portugal

Alexander Denisov**
a.denisov@campus.fct.unl.pt
NOVA School of Science and Technology
Almada, Setúbal, Portugal

Figure 1: Wind Farm picture by Shutterstock/AngelaRohde.

ABSTRACT

With this paper we aim to better understand the situation of Portuguese Electric in the context of the 2030 Agenda for Sustainable Development, adopted in 2015 by the United Nations, with a focus on electricity, and aspects of its production and consumption in terms of renewable energy.

We will use datasets with data from Portugal, Europe and the World, containing information on electricity consumption and production, ranging from dates since 1990 to 2019 and locations of Portuguese renewable energies sources, to check how progress is going and the future trends on Ecological Footprint.

Some of the questions we try to answer are the share of renewable energy in Portugal in the domestic energy market, how is the production/consumption of renewable energy in Portugal compared to other countries, the locations of renewable energy sources and how much energy they produce and if what has been done so far is enough to reach the objectives set by 2030.

These and other questions are answered in this paper.

KEYWORDS

FCT Nova, Computer Science, IDV, Interactive Data Visualization, Datasets, Analysis, Electricity, Ecological Footprint, Sustainable Development, Renewables

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*Both authors contributed equally to this research.

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1 INTRODUCTION

Following the 2030 Agenda for Sustainable Development by the United Nations, there is a worldwide effort to go green, with solar panels, wind power and other alternative energy sources, which have been gathering momentum now days.

It is a must for humanity and future generations to follow a more sustainable world based on renewable energy, our study will help by giving better insight on this matter using techniques from the course of Interactive Data Visualization.

It is important to follow this sustainable process, so we seek to find answers related to electricity and how much renewable energy Portugal is producing and consuming through the years, as well which districts have most renewable sources.

We want to examine how Portugal compares to European Countries in renewable energy and to find out which districts in Portugal that are the most efficient in renewable energy, analysing the data and take a guess if the objectives can be reached by 2030, we will provide graphical visualisation and interpretation of the data, which we plan to make simple and understandable, using dashboards and stories, this will be explored in more detail on the proposal section.

We have searched and gathered enough information from distinct datasets, data collected from 1960 to 2019, from reliable sources such as INE (Instituto Nacional de Estatística), e2p (Energias Endógenas de Portugal) and Gapminder, containing geographic information, districts, renewable energy consumption and production, power indicators, dates of renewable power source start of activity, and many others.

Next section we discuss the research questions, followed by the datasets used for research, their description and metadata, followed by state of the art, where we give some insight and overview on this subject as it is presently, we proceed to answer our questions with resort to images and graphics, we will then evaluate and take conclusions from the research, also in annex there is detailed table information of the datasets.

For this data analysis we will be using Tableau, process the raw data from the sources into Datasets, using technique's such as pivoting to prepare data for visualization. Proceeding to Exploratory Data Analysis, we try to explore our data in an isolated manner, to see if we have enough data to answer our questions, but also combining it using Tableau datasets to see if we can find any new interesting features that we can use, this is also an important step to better understand, what and how we can organize our dashboards to present results later on.

2 RESEARCH QUESTIONS

We will start by answering Portugal related questions, such as, which is the most adopted renewable energy source in Portugal, where are the solar, wind and hydroelectric sources located at in Portugal, which districts have the most renewable energy sources and which are the top clean energy producers.

How did the electric power consumption and production evolved in Portugal throughout time?

How does clean energy consumption and production compare to each other?

What is the growth rate of renewable sources in the context of the Portuguese electrical system in the last decades?

At the current pace, can Portugal achieve `30%` Clean Energy share proposed by the United Nations 2030 Agenda?

We know our questions can be answered, hence this research.

3 DATASETS

Our paper uses datasets from 3 sources, Instituto Nacional de Estatística [1], Endogenous Energies of Portugal [2] and Gapminder [3], these datasets and their information are described below.

Filename: `e2p_E_F_H.xlsx`
Source: Energias Endógenas de Portugal
Records: 428 Rows and 8 Columns
Has geo-spatial information: Yes
Spatial resolution: District
Has temporal information: Yes
Primary Variables: Latitude [WGS84, °], Longitude [WGS84, °], Distrito/Região Autónoma, Potência Instalada [MW], Tecnologia
Dataset Size: 35KB
Description: The dataset contains geo-spatial information in WGS84 Degree format of Latitude and Longitude about Solar, Hydro and Eolic renewable power source location in Portugal and in which District, installed power (MW), start-up year and current state of activity.
Observation: The dataset was created from 3 other datasets, each had unique Technology, Wind, Solar and Hydro, due to having same source and domain, information was appended.
Check detailed table information on Table 1.

Filename: `INE_Resum.xlsx`
Source: Instituto Nacional de Estatística
Records: 344 Rows and 38 Columns
Has geo-spatial information: Yes
Spatial resolution: District
Has temporal information: Yes
Temporal granularity: Years
Temporal resolution: 1 Year
Temporal extent: 2011-2019
Primary Variables: Countries, Years, Household, Industry, Agriculture, Total Consumption
Dataset Size: 185KB
Description: The dataset contains Electric energy consumption by consumer (kWh/ cons.), for each type (Household, Industrial, Agriculture, and Total), and for each District in Portugal.
Observation: The dataset was created from other 4 datasets, each relative to electric energy consumption by the consumer in Industry, Agriculture, Household, and Total respectively. Due to having the same source and domain, information was appended.
Check detailed table information on Table 2.

Filename: `electricity_generation_per_person.xlsx`
Source: Gapminder

[1] https://www.ine.pt/
[2] https://e2p.inegi.up.pt/
[3] https://www.gapminder.org/

Records: 77 Rows and 36 Columns
Has geo-spatial information: No
Has temporal information: Yes
Temporal granularity: Years
Temporal resolution: 1 Year
Temporal extent: 1985-2019
Primary Variables: Countries, Years, kW/h
Dataset Size: 90KB
Description: The Dataset contains Electric energy generation per person in kilowatt-hours by country.
Check detailed table information on Table 3.

Filename: `electricity_use_per_person.xlsx`
Source: Gapminder
Records: 138 Rows and 56 Columns
Has geo-spatial information: No
Has temporal information: Yes
Temporal granularity: Years
Temporal resolution: 1 Year
Temporal extent: 1960-2014
Primary Variables: Countries, Years, kW/h
Dataset Size: 176KB
Description: The dataset contains Electric power consumption measures the production of power plants and combined heat and power plants less transmission, distribution, and transformation losses and own use by heat and power plants.
Observation: There are some energy values missing on certain countries from early years and some on later years.
Check detailed table information on Table 4.

Filename: `hydro_power_generation_per_person.xlsx`
Source: Gapminder
Records: 118 Rows and 53 Columns
Has geo-spatial information: No
Has temporal information: Yes
Temporal granularity: Years
Temporal resolution: 1 Year
Temporal extent: 1960-2011
Primary Variables: Countries, Years, toe
Dataset Size: 150KB
Description: The Dataset contains the amount of hydropower generated per person during the given year, counted in tonnes of oil equivalent(toe).
Observation: There are some energy values missing on certain countries from early years and some on later years.
Check detailed table information on Table 8.

Filename: `hydro_power_generation_total.xlsx`
Source: Gapminder
Records: 118 Rows and 53 Columns
Has geo-spatial information: No
Has temporal information: Yes
Temporal granularity: Years
Temporal resolution: 1 Year
Temporal extent: 1960-2011
Primary Variables: Countries, Years, toe
Dataset Size: 149KB
Description: The dataset contains information of total hydropower generated per year per country worldwide, counted in tonnes of oil equivalent (toe).
Observation: There are some energy values missing on certain countries from early years and some on later years.
Check detailed table information on Table 7.

Filename: `residential_electricity_use_per_person.xlsx`
Source: Gapminder
Records: 130 Rows and 50 Columns
Has geo-spatial information: No
Has temporal information: Yes
Temporal granularity: Years
Temporal resolution: 1 Year
Temporal extent: 1960-2008
Primary Variables: Countries, Years, kW/h
Dataset Size: 144KB
Description: The dataset contains information about the residential energy use per person in a year per country worldwide, given in kilowatt-hours (kWh), there are some energy values missing on certain countries from early years.
Check detailed table information on Table 5.

Filename: `residential_electricity_use_total.xlsx`
Source: Gapminder
Records: 130 Rows and 50 Columns
Has geo-spatial information: No
Has temporal information: Yes
Temporal granularity: Years
Temporal resolution: 1 Year
Temporal extent: 1960-2008
Primary Variables: Countries, Years, kW/h
Dataset Size: 174KB
Description: The dataset contains information about the residential energy use totals in a year per country worldwide, given in kilowatt-hours (kWh).
Observation: There are some energy values missing on certain countries from early years.
Check detailed table information on Table 6.

The datasets from same sources where compatible.

4 STATE OF THE ART

There is paper from E2P, on Portuguese Wind Farms[3], which we explored, as they also use datasets from E2P, which are the same used in our project. In general, comparing our questions and topics in the E2P paper, we found few points which overlap, they are listed below:

- "Accumulated installed generating capacity - Portugal" which relates to a question we want to find an answer "What is the growth rate of renewable sources in the context of the Portuguese electrical system in the last decades?"

- "Wind generation vs Electricity demand" the graph lines out with our question "How do clean energy consumption and production compare to each other?

- "Installed capacity per district" we could find correlation in "What districts in Portugal are producing the most renewable energy?"

- "Location of the wind farms" can answer partially "Where are the solar, wind, and hydroelectric sources located in Portugal? And which districts have the most renewable energy sources?"

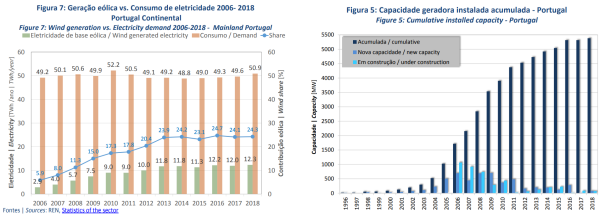

Figure 2: Production vs Consumption and Accumulated Power, graphs from E2P Wind Farm Paper

The examples of graphs found on the E2P paper, shown in the Figure above, are a good representation of what we plan on creating in a dashboard, to compare production versus consumption power of clean energies.

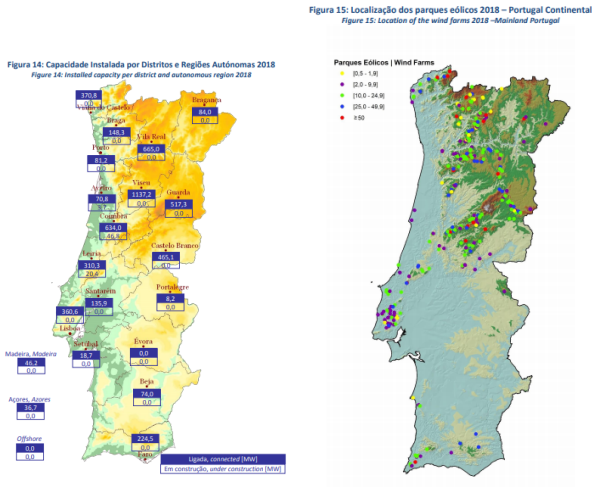

Figure 3: Location of Wind Farms

In the figure above on the right map, we also have some considerations, one of them is the choice of the map background, which contains poor color choice as terrain elevation, it looks like Portugal is filled with water on low coastal zones, we don't consider this to be an ideal color scheme.

In the big scope "ourworldindata" website[2] under section Renewable Energy, it is possible to find similar questions, data, and graphs related to our paper.

- "How much of our primary energy comes from renewables?" This website seeks to answer this question, and a similar question is asked in our paper "How do European, Asian, African, and American Countries compare with each other in the renewables field?"

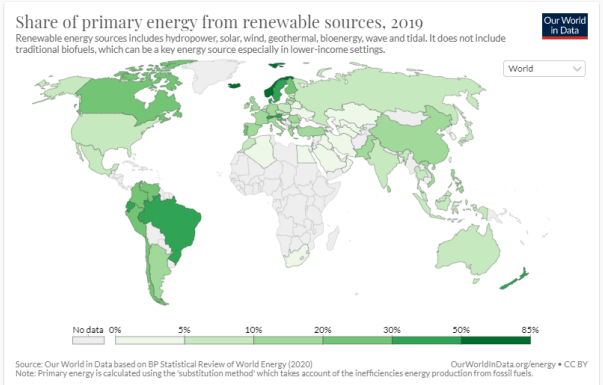

Figure 4: Share of primary energy from renewable sources

We found this web page that explores the question of "What Are The Most Efficient Forms Of Renewable Energy"[1], that gives some insight on the top energy sources, our work focuses mostly on exploring Wind, Solar and Hydro, which are the most talked renewable sources, and we set these apart from geothermal an nuclear sources. On this web page they claim Wind is the most efficient, followed by Hydro and Solar, we want to explore this approach to confirm this claim, graphically of course.

5 PROPOSAL

We plan on building some informative and interactive Dashboards, one will be about Portugal's Wind, Solar and Hydro sources, will contain density maps of these locations and of the sources that have most power installed, to give a better understanding of the concentration of these sources and where most power is focused on, a sketch of a planned dashboard can be seen in the figure below:

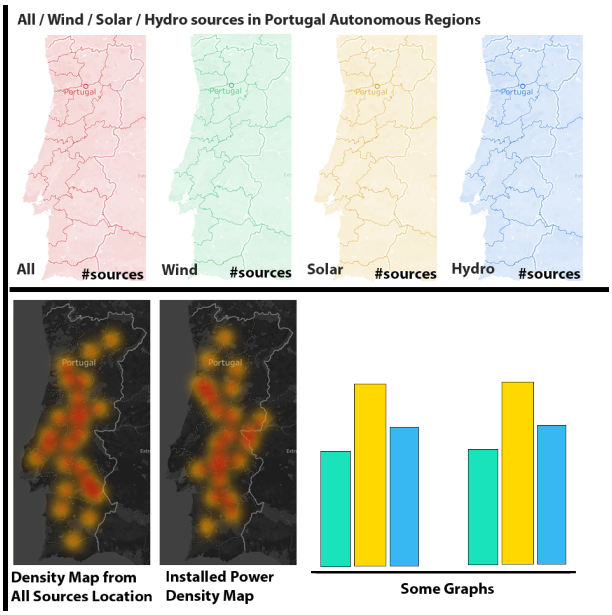

Figure 5: Sketch of planned dashboard about energy sources

The dashboard will contain number of renewable power sources per district, distinguished by different colors of technology, red for sum of all source types, green for wind, yellow for solar and blue for hydro, because some graphs are more easily interpreted by their color schemes. We will use color to show different types of energy and their relationship.

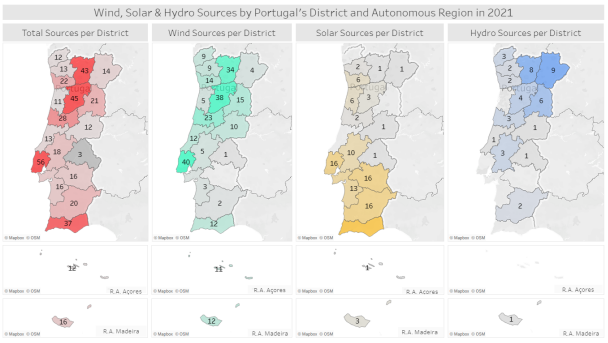

Figure 6: Dashboard about Wind, Solar & Hydro Sources by Portugal's District and Autonomous Regions in 2021

This is the dashboard created beyond its sketch, mentioned previously, it also had to be divided in two distinct dashboards, one related to sources and the other to sources density by power and by location. On the first dashboard there is a side by side comparison that allows the user to quickly compare the different sources, not only by the amount but also where they are mostly located at, for extended user interaction, on mouse over the districts, they are highlighted throughout the maps.

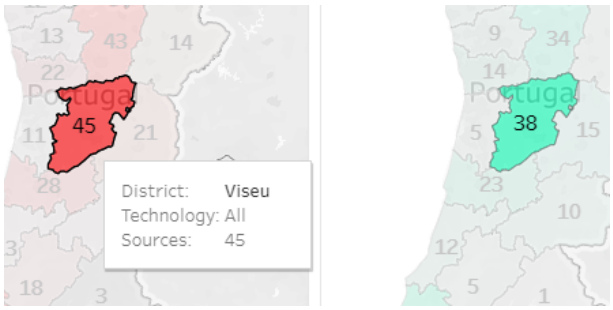

Figure 7: District Side-by-side comparison

There was also necessity of creating multiple map views for Autonomous Regions as they wouldn't fit in a single map, this required 12 separate sheets with maps to make the dashboard with a consistent proper view.

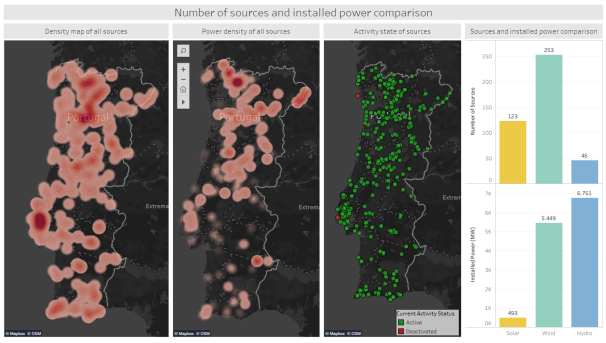

Figure 8: Dashboard about number of sources and installed power

This is the other dashboard, created from the division of the initial sketch, the density map helps to understand where all sources are concentrated versus where most of the power is being generated, we choose a dark map because it came highly recommended, as it allows better visualization of the density.

All sources that aren't activated are filtered an not part of the graphical display. We also included a map that shows sources location, with dots colored by there current state of activity, with tool tips that provide extended information for the user, like the registered source name, the district it belongs to and a textual description, containing information about Technology used and installed power at the facility, also shows the year when it started working and if the year happens to be null in the dataset, it will show a text telling that such information is unknown.

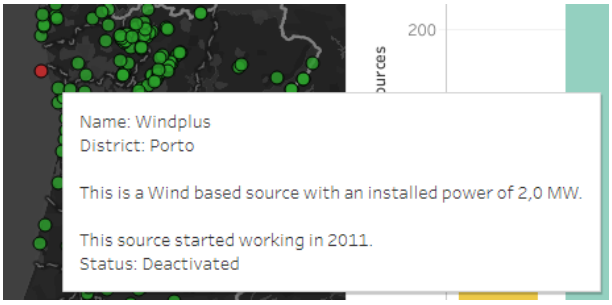

Figure 9: Map information display - Tool tip.

There is also two vertical bar graphs that further allows to understand the number of source by technology versus the capacity of power generation, we choose this type of graph because it easier to understand given the context, we could conclude from this that most installed power came from Hydro sources.

Also planned out, is a graph about the renewables evolution in Portugal from the installed power throughout the years, similar to the graph below, from the E2P Wind Farm paper[3], but focused on Wind, Solar and Hydro.

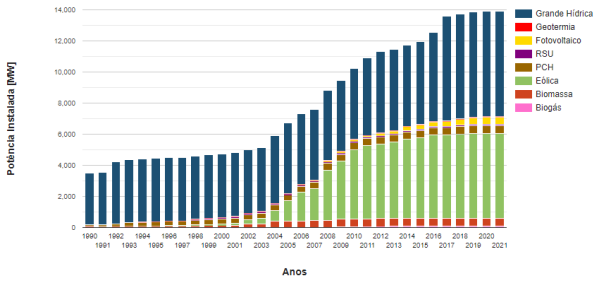

Figure 10: Installed electrical capacity in Portugal since 1915

We planned out graphs, about the sources start of operation, one of them, with spaced intervals of 5 years, as 1 year resolution didn't met our visualization needs, we made use of Bins and also omitted dates that had null values, as they had no information for their start of operation, so they wouldn't be useful. Similar process applied for the second graph, but this is built upon the Sum of Installed Power through the years, both graphs can be seen next.

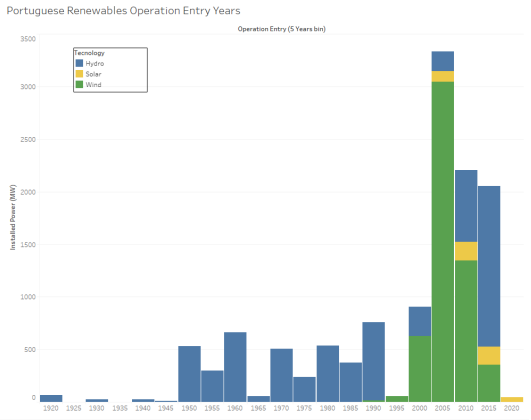

Figure 11: Portuguese Renewables Operation Entry Years

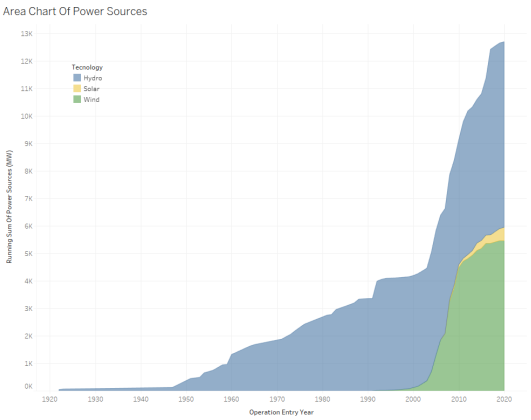

Figure 12: Area Chart of Power Sources by Years

The final dashboard, comprised of the 2 dashboards can be seen next, where we can see how Hydro overtakes Wind and Solar in power, as each new installed Hydro Source provides big power increase.

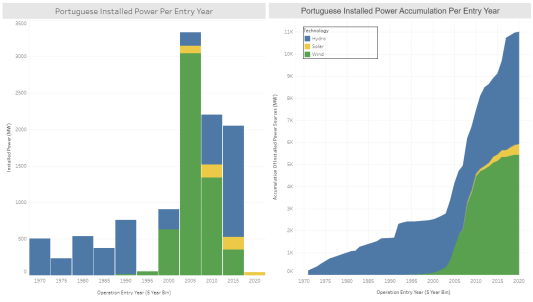

Figure 13: Dashboard about Sources Activity Start (Entry Years)

Another dashboard will contain information about progress in renewable energy in the world.

In the dashboard, we will see the comparison of electrical power consumption per person, electrical use per person, and Hydro Power generation per person. This comparison can give some understanding of the Country's power Needs and Their Hydro Production to understand if Hydro is enough on average.
Forth graphic of the dashboard will represent this exact analysis of values from the previous three graphs. Because Hydro Power Generation is expressed in Toes we will convert it to MW by division of Values in Toes by the product of 11.63 and 60. The final comparison aim to a better understanding of what is Hydro production potential as main source of power.

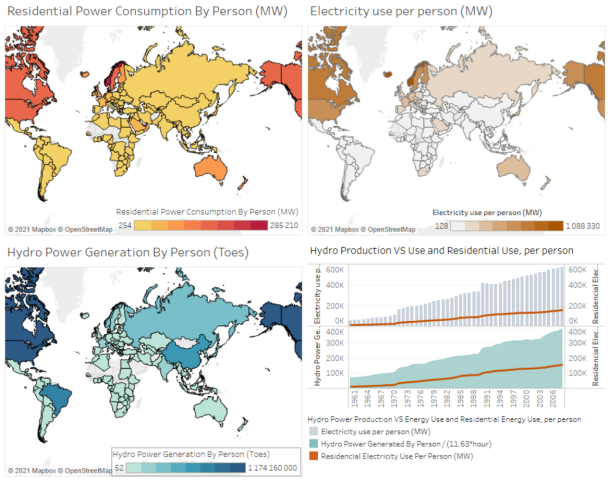

Figure 14: World Residential Electricity Consumption and Hydro Generation

What is an Energy Consumption through Portugal? What are Districts with bigger consumption? The dashboard on Agriculture and Industry is what we choose to use to answer these questions. Agriculture and Industry where datasets we choose because they have the largest disparities that show a correlation between Industrialized and Rural areas. The datasets need to be Pivoted to use the time variable for further use in pages. We had data with the city's energy consumption, the bigger cities were considered as being representative of the districts (Ideally, we would later on group and sum all cities under the same district). With the use of this dashboard, we concluded that normally districts with greater agriculture are low in terms of industry vice-versa, and from 2011 to 2019 some districts forfeit agriculture in favor of industry.

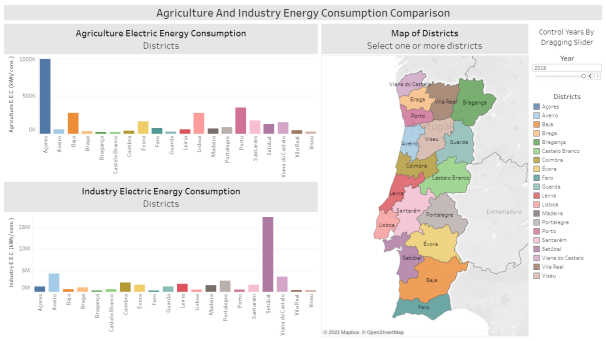

Figure 15: Agriculture And Industry Energy Consumption Comparison

Here is example of interaction with dashboard, where we can select a multiple number of districts in the map or select a certain Year and the graphs will refresh with new filtered information provided by the Parameters.

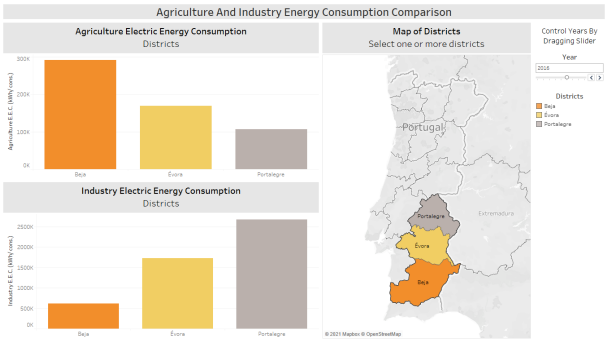

Figure 16: Agriculture And Industry Energy Consumption Comparison Selected Évora Beja Portalegre

The last dashboard is focused on world data, we choose to compare residential power consumption with total power consumption and with data from Hydro power production. To understand what is exactly the situation with renewable power, we think Hydro power is representative because it generates more energy as we have seen before and requires more manpower and work to properly function. We came across some difficulties figuring out color gradients and color stepping for the map legend. Original data on hydro production comes in TOE, energetic oil barrel equivalent, the normal conversion could be done as TOE divided by 11,63 an hour. We concluded that in some cases, residential energy needs could be fulfilled with only hydro sources.

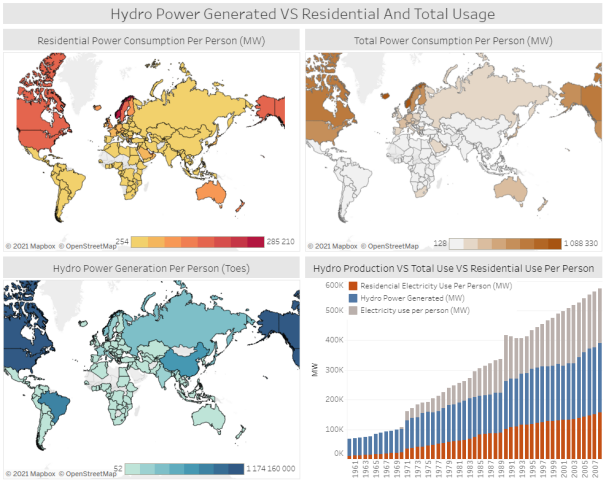

Figure 17: Agriculture And Industry Energy Consumption Comparison

6 EVALUATION & CONCLUSIONS

We made some conclusions from our research questions, some about the United Nations 2030 Agenda, it is hard to accurately predict the outcome, there is no data to predict the future outcome even at the current pace, what we mean by that is, most of the power generated comes from Hydro sources, followed by Wind and Solar, new Hydro sources are unlikely to appear as they are expensive, Solar are proven to be inefficient while Wind Farms seem to be the best option, requiring less investment and generating decent power in comparison, solar sources are starting to appear but they don't provide a big power output.

Most Wind farms are located in Lisbon, Central and North of Portugal, whilst Hydro sources, are located mostly on North of Portugal and provide the biggest electric supply.

On a World wide view we discovered that some countries residential consumption can be fully covered by the country's own Hydro sources, for example, Norway, as the Industry and Agriculture sectors have higher energetic demands.

Creating analysing displaying data visually requires time, dedication and effort, to reach our goals, regardless of who is the end user or who will view or interact with the dashboards, after this project and paper we are assured that they have important role and an incredible expressive power.

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[1] New Jersey Institute of Technology's Online Master of Science in Electrical Engineering program. 2017. *"The Most Efficient Form of Renewable Energy."*. "https://www.borntoengineer.com/efficient-form-renewable-energy"

[2] Hannah Ritchie and Max Roser. 2020. Renewable Energy. *Our World in Data* (2020). https://ourworldindata.org/renewable-energy.

[3] Wind Farms in Portugal 2018. *"Parques Eólicos em Portugal Wind Farms in Portugal"*. "http://e2p.inegi.up.pt/relatorios/Portugal_Parques_Eolicos_2018.pdf"

Table 1: E2P

Field name	Variable type	Comments
Nome	Categorical	Name of the renewable source provider
Tecnologia	Categorical	Type of technology Wind/Solar/Hydro
Distrito/Região Autónoma	Categorical	A Portugal District/Autonomous Region
Latitude [WGS84, º]	Numerical	Latitude in World Geodetic System by Degrees
Longitude [WGS84, º]	Numerical	Longitude in World Geodetic System by Degrees
Potência Instalada [MW]	Numerical	Power installed on facility in Megawatts
Estado	Categorical	Last reported state of activity
Ano de entrada em funcionamento	Numerical	Start of operation year

Table 2: INE

Years	Districts		
	Field name	Variable type	Comments
2011-2019	Household	Numerical	Household consumption of electric energy by consumer (kWh/ cons.) by Geographic localization (NUTS - 2013); Annual
	Industry	Numerical	Consumption of electric energy in industry by consumer (kWh/ cons.) by Geographic localization (NUTS - 2013); Annual
	Agriculture	Numerical	Consumption of electric energy in agriculture by consumer (kWh/ cons.) by Geographic localization (NUTS - 2013); Annual
	Total consumption	Numerical	Total consumption of electric energy by consumer (kWh/ cons.) by Geographic localization (NUTS - 2013); Annual

Table 3: Gapminder-Electricity generated per person

	Year 1985-2019		
	Field name	Variable type	Comments
Countries	kW/h	Numerical	The amount of electricity generated per person during the given year, counted in kilowatt-hours (kWh).

Table 4: Gapminder-Electricity use per person

	Year 1960-2014		
	Field name	Variable type	Comments
Countries	kW/h	Numerical	The amount of electricity consumed per person during the given year, counted in kilowatt-hours (kWh).

Table 5: Gapminder-Residencial Electricity use per person

	Year 1960-2008		
	Field name	Variable type	Comments
Countries	kW/h	Numerical	The amount of residential electricity consumed per person during the given year, counted in kilowatt-hours (kWh).

Table 6: Gapminder-Residencial Electricity use total

	Year 1960-2008		
	Field name	Variable type	Comments
Countries	kW/h	Numerical	The total amount of residential electricity consumed during the given year, counted in kilowatt-hours (kWh).

Table 7: Gapminder-Hidro Electricity production total

	Year 1960-2011		
Countries	`Field name`	Variable type	Comments
	`toe`	Numerical	The amount of hydro power generated during the given year, counted in tonnes of oil equivalent (toe).

Table 8: Gapminder-Hidro Electricity production per person

	Year 1960-2011		
Countries	`Field name`	Variable type	Comments
	`toe`	Numerical	The amount of hydro power generated per person during the given year, counted in tonnes of oil equivalent (toe).