Assignment 3: Data Analysis Report

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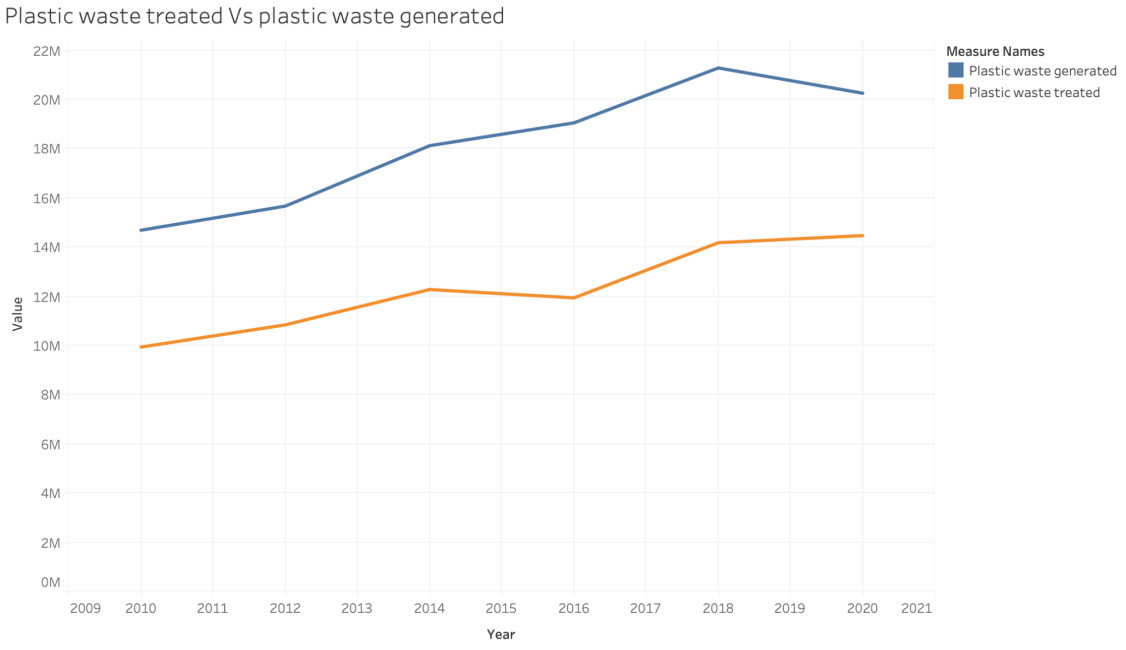
Initial Analysis Questions:

Overarching Question: How is plastic treated in different countries of the EU, how is the trend evolving over the last years and what is the relationship between plastic waste treatment and plastic waste generation?
Question 2: How has the amount of plastic treated evolved throughout the years compared to the total generation of plastic waste?
Question 3: What is the trend of plastic waste management operations in EU countries?
Question 4: How much plastic waste is left untreated?

Discoveries & Insights

Our analysis starts with plotting individual variables to assess the distribution and quality of data. Following this, we will build up multidimensional views to get more insights that will help to answer our questions.

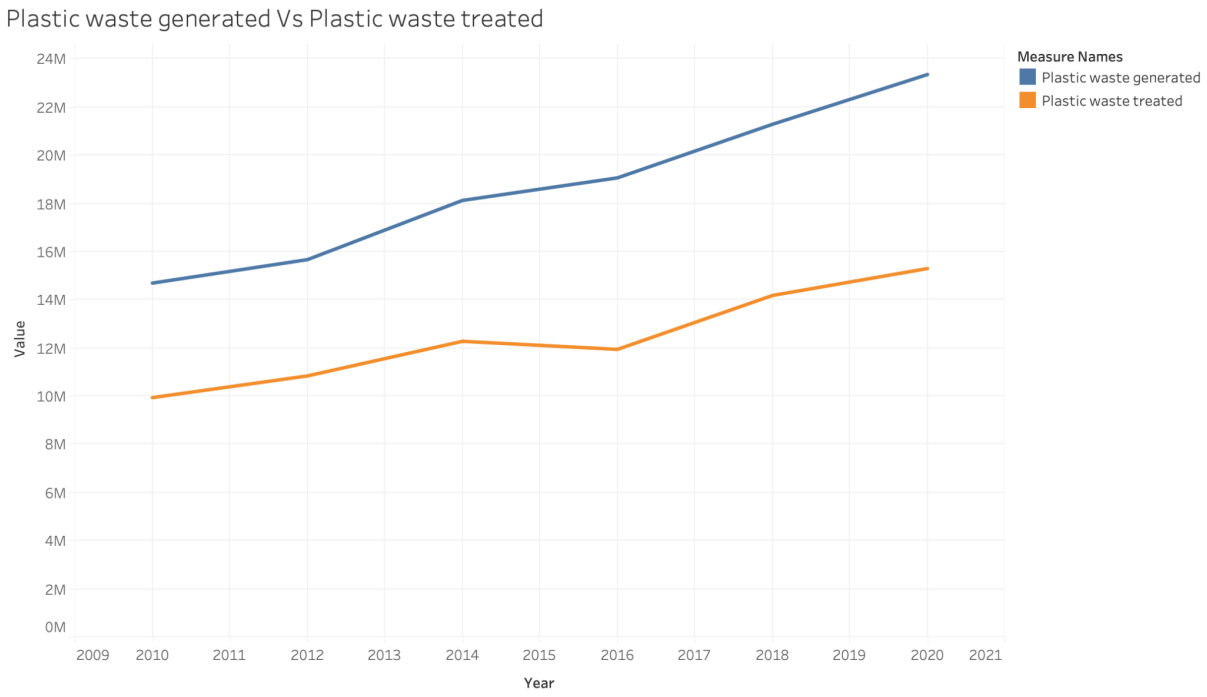
The first thing we realised by trying to look at the evolution of the overall waste generation against the overall plastic waste treated across the years, is that during the cleaning process we removed the United Kingdom values for 2020 since these were nulls because of the recent Brexit.
However, as can be seen in the graph below, this affects the comparison of the cumulative trend as the United Kingdom was a major contributor to both the generation and treatment of plastic.



Contribution: Davide Rendina

This chart shows how plastic waste generated and plastic waste management amount evolved over time. As we can see in 2020 there seems to be a decrease in overall plastic generation in EU countries, while the treatment of waste increases. It is important to note that the main research question was aimed to investigate the trend and relationship in individual countries across the years, therefore, the choice of removing United Kingdom nulls

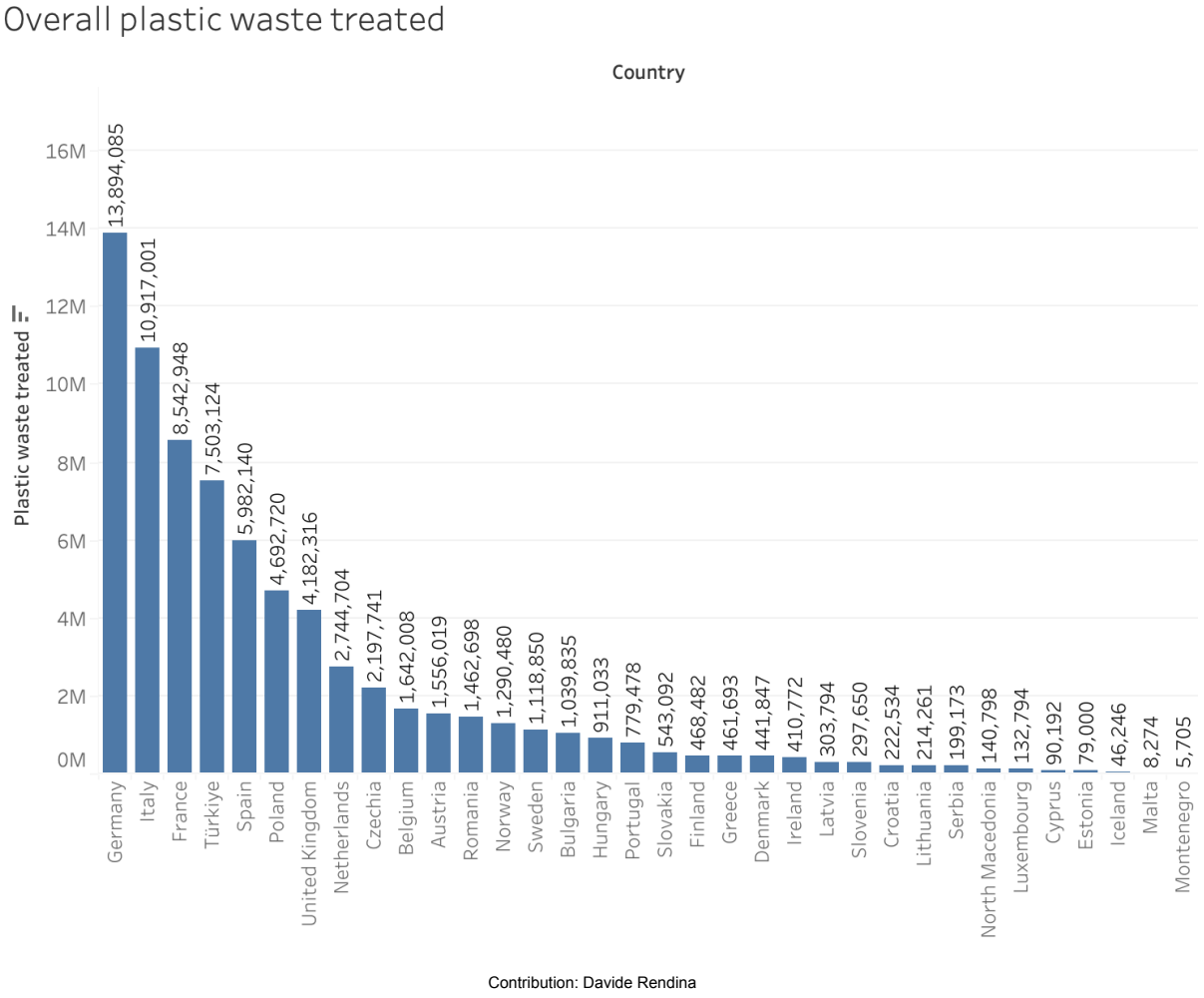
in 2020 was driven by this fact, given that the United Kingdom was no longer part of the EU in 2020.
However, in order to have a fair comparison of the trends across years when considering the cumulative of all EU countries, it would be better to have these included especially given the major contribution of the United Kingdom in the years before Brexit.
Given this, the most appropriate way to deal with this would be using imputation to replace the null values. However, given that this is not the main goal, for simplicity we decided to add manually the same values that were present for the year 2018, assuming a stable trend. For coherence, the same was done for Ireland and Iceland which had only missing values in 2020 and for North Macedonia and Montenegro which had only missing values for 2016 and 2010 respectively.
As a result, we can plot again the overall trend of plastic waste generation against the treatment of plastic waste across different years.



Contribution: Davide Rendina

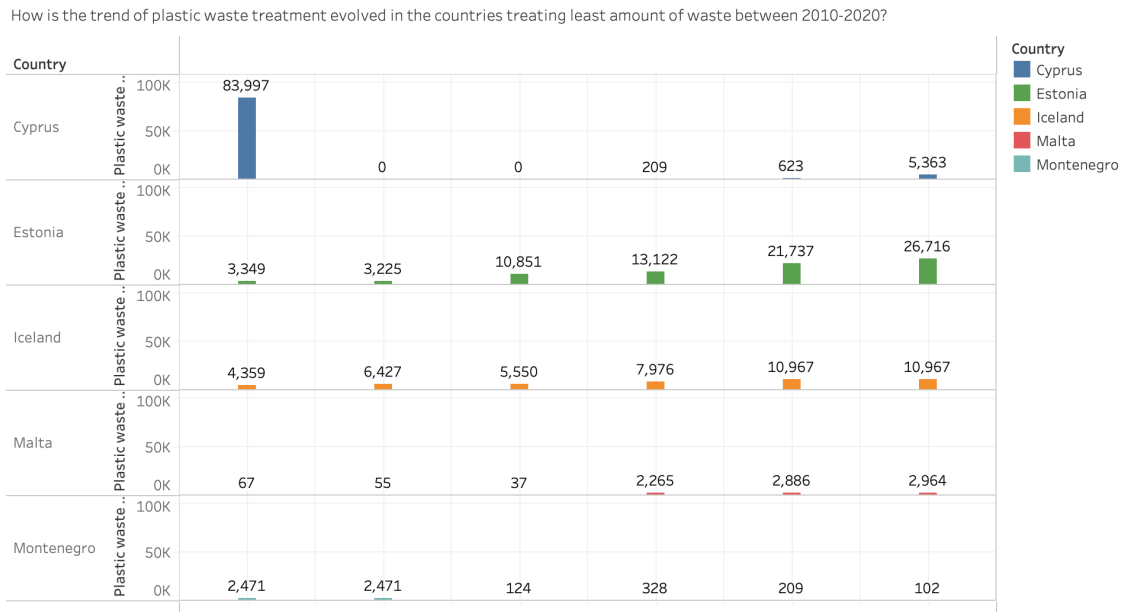
This chart shows the same trend reported in the previous figure, but with the new dataset. As we can see now the trend is steadily increasing from 2018 to 2020 concerning the generation of plastic waste. As expected, also there is an increase also in the treatment of plastic waste in 2020. However, we can note that plastic waste generation is increasing compared to plastic waste treated, which implies that more plastic has been left untreated.

Now we can continue with our data quality assessment by plotting the cumulative plastic waste treated in each individual country.



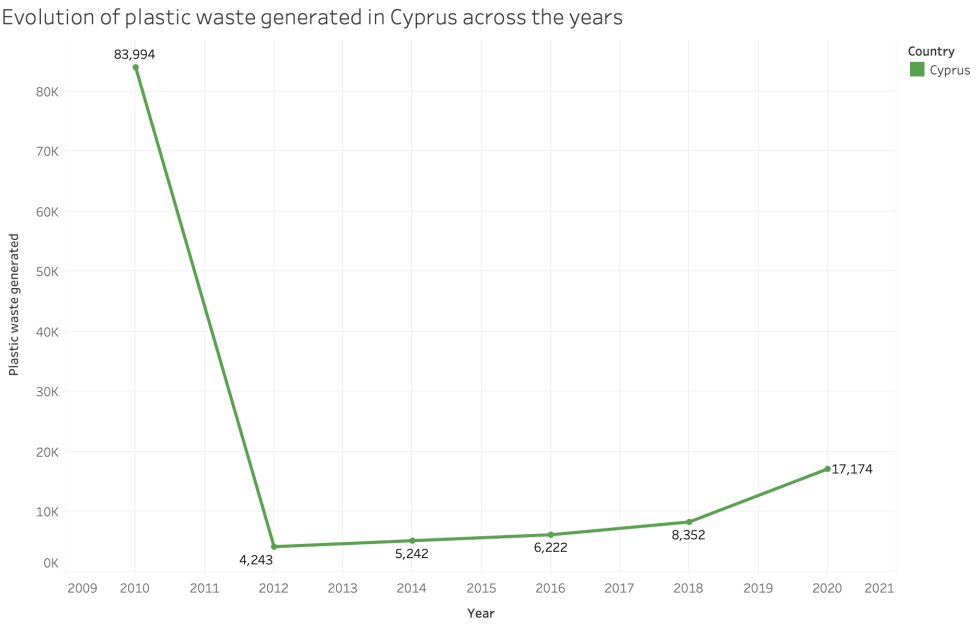
Contribution: Davide Rendina

This chart shows the cumulative plastic waste treated in the different EU countries, with the amount of waste expressed, as always, in tonnes. First of all, we can see that there is no null value and data is collected for every country in the dataset.
It is immediately evident that some countries treat considerably more plastic waste than others; with Germany, Italy and France being the countries with more overall plastic treated and Malta and Montenegro having the least amount of plastic waste treated.
However, although some countries have a smaller population compared to others (i.e. Malta), it is odd that given that the data is collected every 2 years from 2010 to 2020 countries with similar populations have such a low amount of plastic waste treated when compared.
Therefore to investigate this further we might want to have a look at how this waste treatment is evolving over the years, in particular, we have a look at how plastic waste treatment has evolved in countries with less than 100,000 tonnes of plastic waste treated between 2010 and 2020, namely Cyprus, Estonia, Iceland, Malta and Montenegro.



Contribution:Davide Rendina

This chart illustrates the evolution of plastic waste treated across the years in Cyprus, Estonia, Iceland, Malta and Montenegro. We can see how the amount of plastic waste treated increases steadily in Iceland, Estonia and Malta. However, we can see how Cyprus has a peak in plastic waste treatment in 2010 with 83,997 tonnes, while in the following years this drastically decreases reaching 0 in 2012 and 2014.
To see if this data is coherent we plot the overall plastic waste generated in Cyprus across the years.

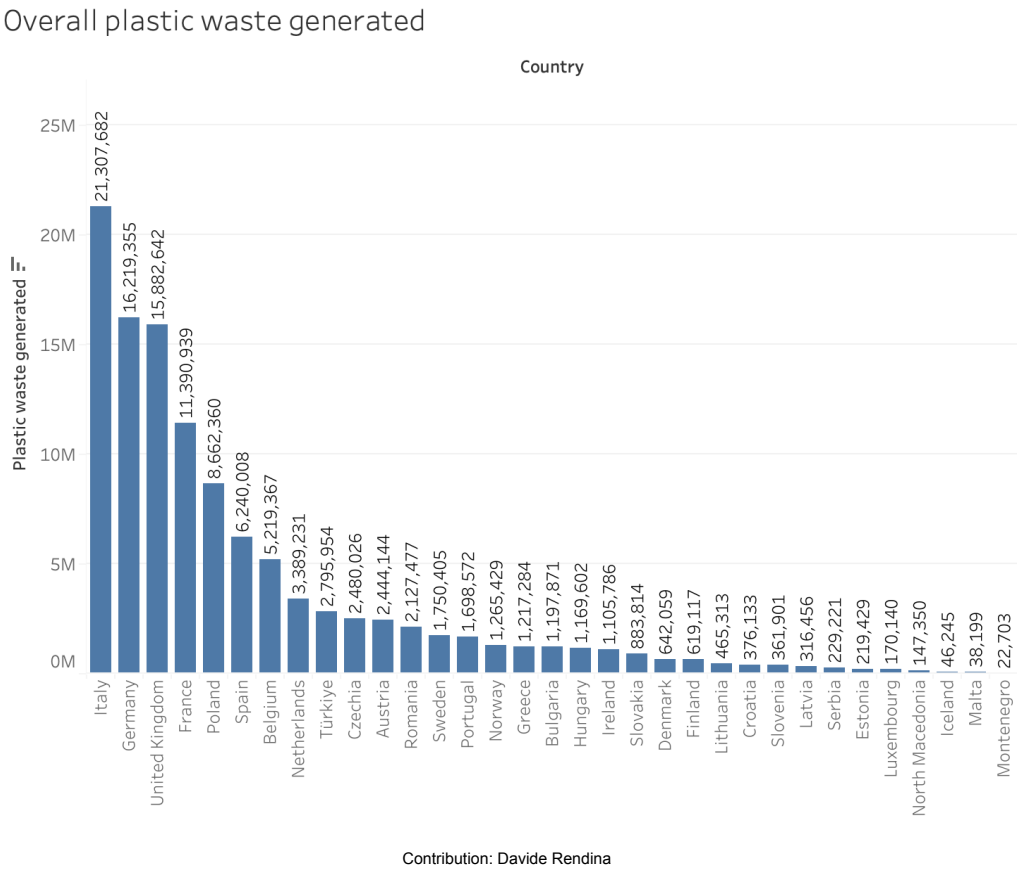


Contribution: Davide Rendina

This chart shows the evolution of plastic waste generated in Cyprus over the years.

As we can see there seem to be something off about the data collected in Cyprus as the amount of plastic waste treated in 2010 (83,997 tonnes) exceeds the overall plastic waste produced in that year (83,994).
Considering these factors and the fact the in following years data for both plastic waste generated and plastic waste treated dramatically decrease, we decide to exclude Cyprus from further analysis.

Now we can have a look at the plastic waste generated to assess the quality of the data.



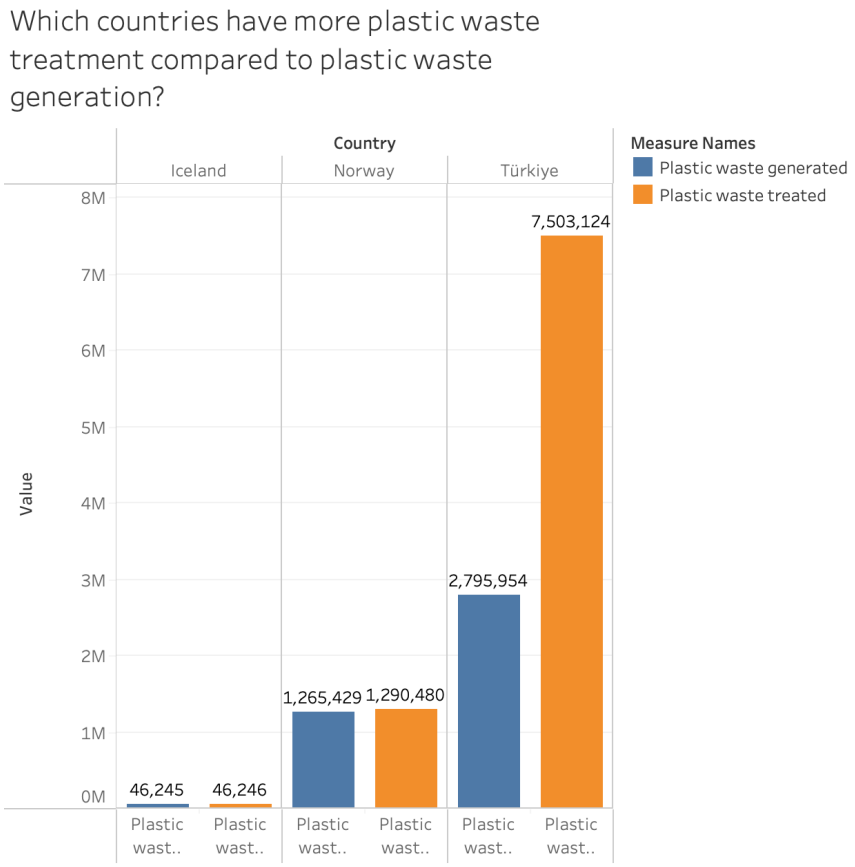
This plot shows the cumulative plastic waste generated in the different EU countries.
As we can see, no null values are present. We can observe that the countries such as the United Kingdom, France, Poland and Italy that were leading in plastic waste treatment, are also leading in plastic waste generation, which is intuitive as the more plastic waste is produced the more must be treated. However, we can notice that Italy is leading in plastic waste generation, while it was behind Germany in plastic waste treatment, meaning that a great part of the plastic waste produced is not treated. Conversely, Türkiye was among the top 5 for plastic waste treated while it is now behind the Netherlands for plastic waste generation.
Since what happened with Cyprus could be occurring in other countries, we check if any country has more plastic waste produced than plastic generated. For doing so we create a calculated field that checks whether a country has more plastic waste treatment than a plastic waste generation.
This is then used to filter countries that have more plastic waste treated than plastic waste generated.

Which countries have more plastic waste treatment compared to plastic waste generation?

Year	Country	Plastic waste generated	Plastic waste treated
2010	Iceland	4,358	4,359
	Latvia	8,116	29,810
	Luxembourg	27,304	37,544
2012	France	1,646,794	1,933,997
	Latvia	21,576	34,849
	North Macedonia	10,860	13,250
	Sweden	175,836	201,753
	Türkiye	214,580	361,662
2014	Bulgaria	196,124	196,126
	Latvia	23,397	40,230
	Luxembourg	26,325	27,592
	Norway	244,118	253,930
	Türkiye	223,381	784,069
2016	Bulgaria	213,449	230,365
	Iceland	7,975	7,976
	Norway	244,217	260,782
	Türkiye	658,164	1,118,240
2018	Czechia	565,453	628,510
	Iceland	10,966	10,967
	Netherlands	561,249	575,030
	Norway	275,537	293,222
	Slovenia	69,460	73,429
	Türkiye	725,276	2,024,401
2020	Hungary	159,808	204,069
	Iceland	10,966	10,967
	Serbia	65,698	76,452
	Türkiye	757,243	3,026,287

Contribution: Davide Rendina

This table shows the countries which, in a given year, have more plastic treated than plastic generated.
As we can see, there are multiple countries that in given years have more plastic waste treated than produced. In particular, Türkiye and Norway seem to be recurrent.
To have a better look we can plot the cumulative plastic waste generated against the cumulative plastic waste produced in these countries.



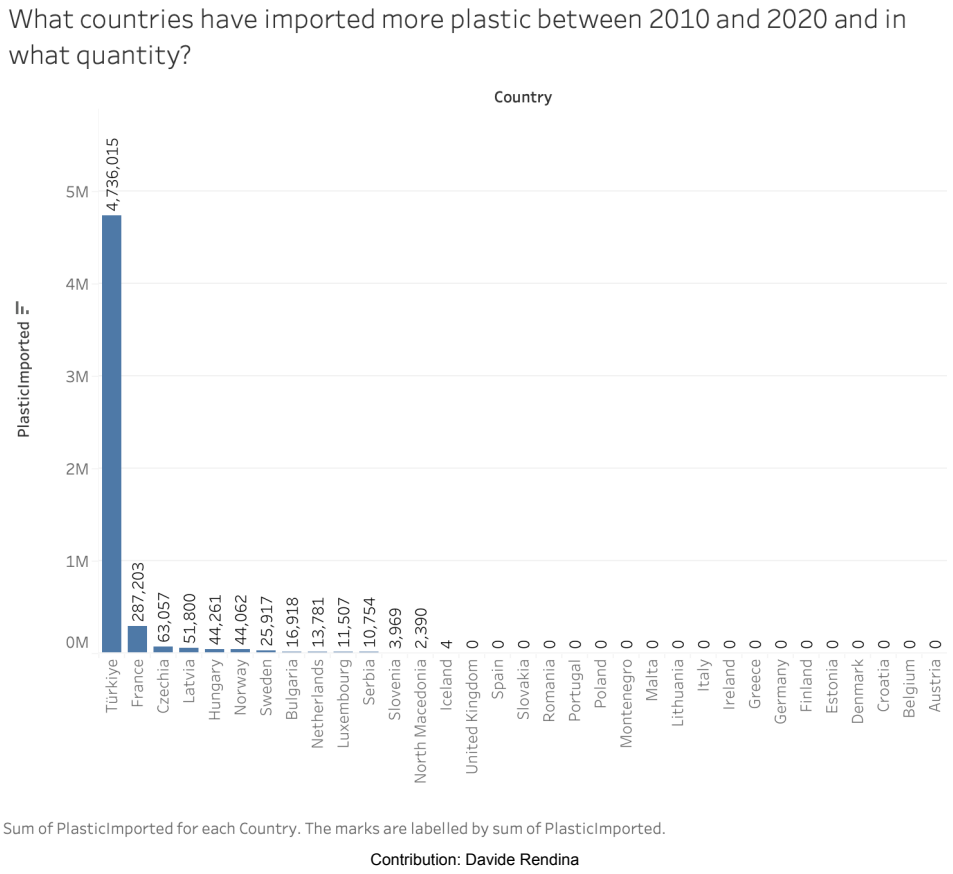
Contribution: Davide Rendina

This chart shows the plastic waste generated against the plastic waste treated in Iceland, Norway and Türkiye. From this, It can be seen how Türkiye treats almost 3 times more plastic waste than the one that produces. This led us to further investigate the reason behind this, as it seems unrealistic and it could seem a mistake in the data. However, after some research we came across this article: [In Turkey, Europe's trash can, plastic recycling poses serious risk to health and environment]. Investigations have shown that imports of plastic in Türkiye increased by 1,200% between 2016 and 2020, which explains the drastic difference displayed in the chart.

It is clear now that in the cases in which the plastic waste treated is more than the plastic waste produced, this could be due to imports. Therefore, we decided to investigate what countries import plastic and in what quantity.

To do this we decided to create a calculated field 'PlasticImported' to identify the countries that import plastic, as follows: `Max([Plastic waste treated]-[Plastic waste generated],0)`

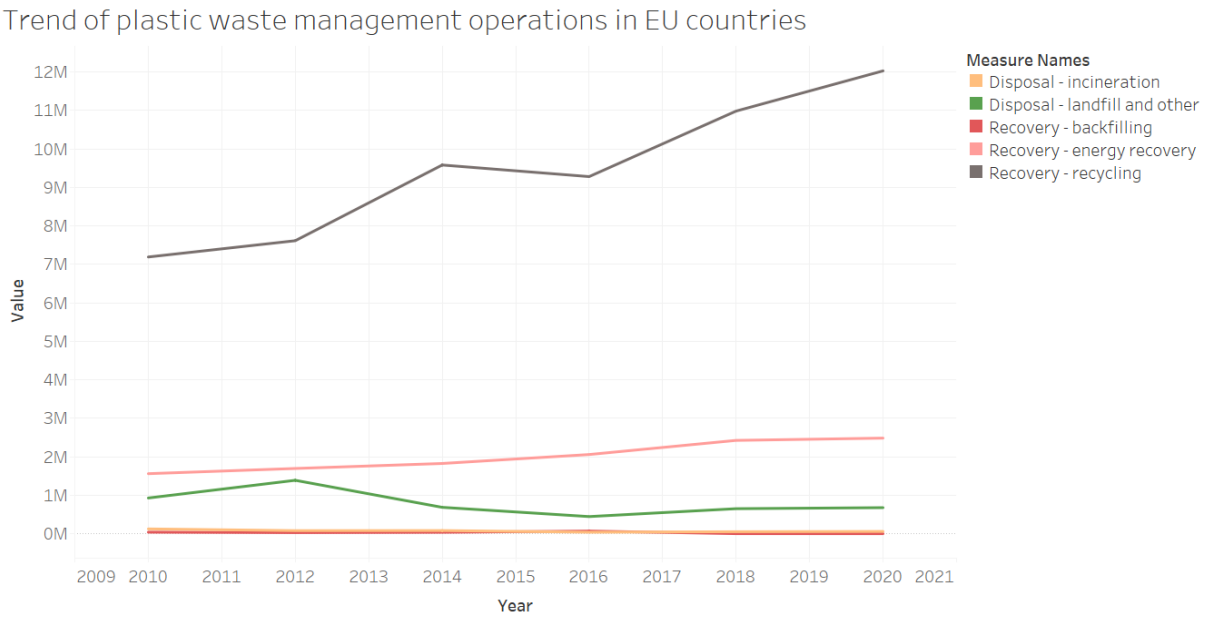
This was then plotted, producing the following chart:



This chart shows each country and the quantity of plastic imported between 2010 and 2020. It is immediately clear that Türkiye is the major importer, followed by France. On the other hand, the majority of countries did not import any plastic waste in those years.

We now move to examine our third question, which concerns the plastic waste management operations trend in EU countries. There are two main categories of operations: recovery and disposal. The definition of recovery from Eurostat is "*any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy.*" Recovery has three subcategories: recycling, energy recovery and backfilling. Likewise, the definition of disposal from Eurostat is: "*any operation which is not recovery even where the operation has as a secondary consequence the reclamation of substances or energy.*" Disposal has two subcategories: incineration and landfill disposal. Given these definitions and categorisations, we can now start with the analysis of plastic waste management operations.

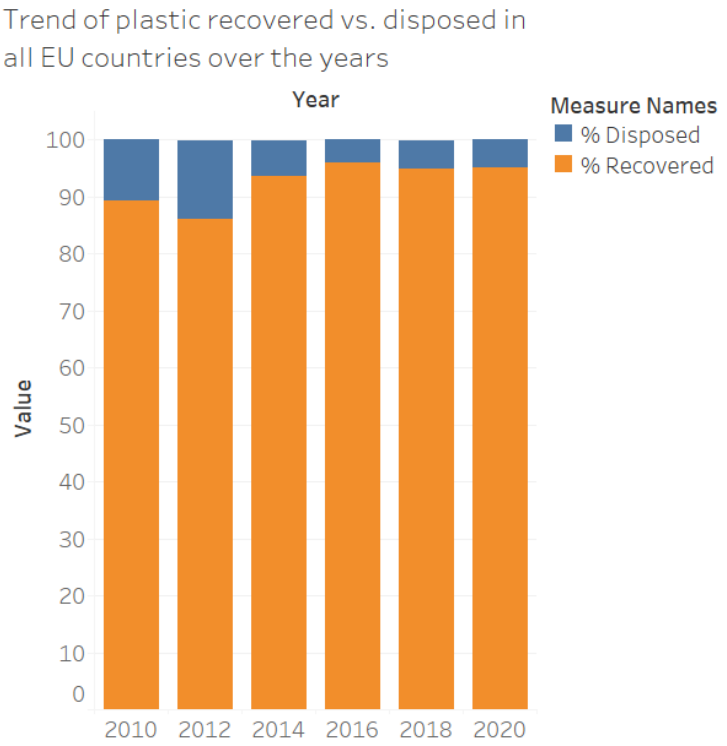
We will first try to answer the statement mentioned above by plotting the aggregated plastic waste management operations for all EU countries over the years.



Contribution: Margarita Hernández Casas

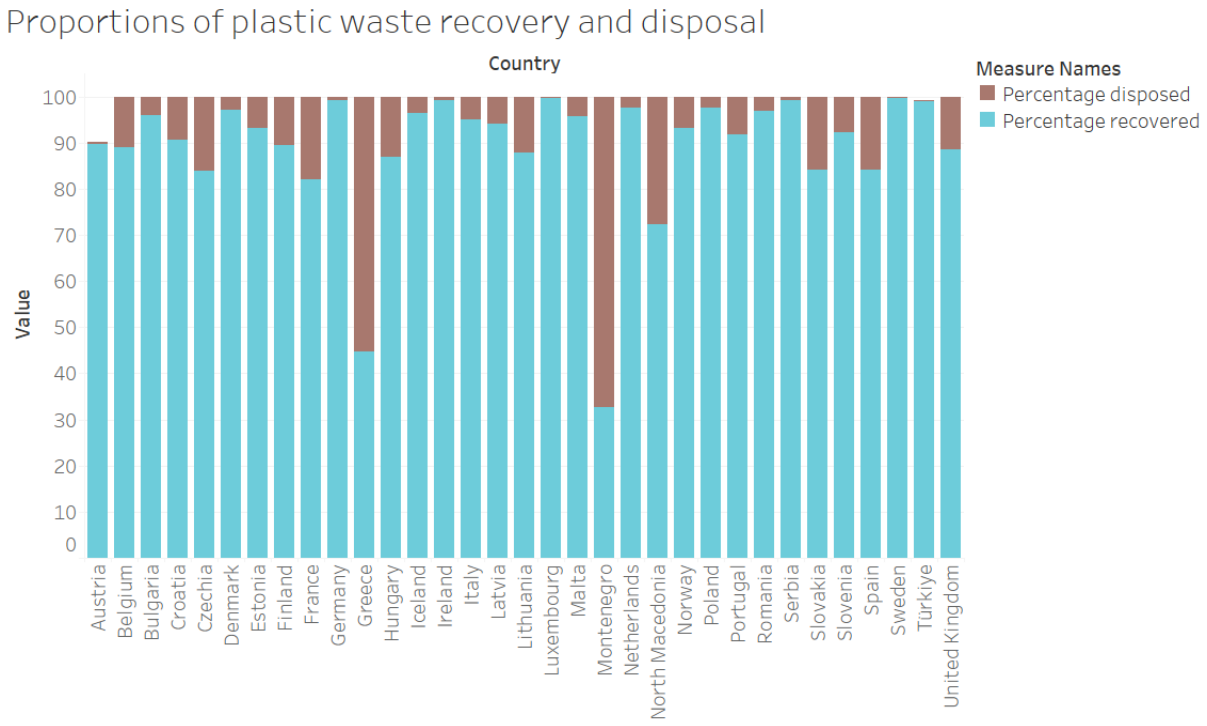
This figure shows how the trend of different plastic waste management operations has evolved in EU countries over the years. We can see that the amount of plastic waste being recycled is increasing fast. Energy recovery has also a positive trend, although slower than recycling. Landfill disposal is slowly decreasing, and the other two operations are not comparable in absolute figures to those previously mentioned.
We would have expected to see these trends, recovery operations going up and disposal operations decreasing, giving space to greener policies in the EU. However, recovery is not taking over disposal, it is just increasing. As seen at the very beginning of this report, plastic waste generation is increasing at a fast pace. Recycling seems to be just increasing proportionally to plastic waste generation, meaning that plastic regulations don't seem to be working so well.

Now, plotting the proportions of disposed and recovered plastic waste of all countries of the EU in the last years, we can observe what we just mentioned. There's a slight trend of recovery operations increasing, but they still confirm what we suspected, which is that recovery is not taking over disposal, just increasing proportionally.



Contribution: Margarita Hernández Casas

We would now like to discover how the different countries in the EU are treating plastic waste between disposal and recovery, so we can find out if there are discrepancies in the chosen management operations among countries. For this purpose, we calculate two new fields that will show the percentage of each category for each country.



Contribution: Margarita Hernández Casas

This chart shows the proportion between the percentage of plastic waste recovered and the percentage of plastic waste disposed in different countries.

We can see two main things at a glance: there are two countries (Montenegro and Greece) that are clearly not following the same plastic waste treatment strategy as the others, and it seems that at least Austria has some data quality issues. We will now try to go deeper into these two insights.

In order to find out why some countries may not be adding up correctly to 100%, we perform some data checking. We calculate the sum of disposal and recovery, which should add up to our column named *"Plastic_waste_treated"*. Then, subtracting this amount from our calculated field, we observe that Austria and Turkey have a discrepancy between the two, as can be seen below.

Discrepancy between sum of total disposal and total recovery, and plastic waste treated

Country	Year	Disposal - Total	Recovery - Total	Plastic waste treated	Disposal+Recovery	Diff with real value
Austria	2010	351	193,439	193,790	193,790	0
	2012	298	351,636	351,934	351,934	0
	2014	0	187,436	230,008	187,436	42,572
	2016	0	280,979	320,094	280,979	39,115
	2018	2,246	191,226	234,604	193,472	41,132
	2020	1,771	192,214	225,589	193,985	31,604
Türkiye	2010	0	186,791	188,465	186,791	1,674
	2012	8,187	328,218	361,662	336,405	25,257
	2014		769,366	784,069	769,366	14,703
	2016		1,116,354	1,118,240	1,116,354	1,886
	2018	1,380	2,005,825	2,024,401	2,007,205	17,196
	2020		3,024,089	3,026,287	3,024,089	2,198

Contribution: Margarita Hernández Casas

This table shows that there are some discrepancies between the value of plastic waste treated and the actual of the waste recovered and disposed.
There are some missing values which could be the reason why they don't add up. Doing another check to see if this was an error when preprocessing or from the source dataset, we referred to Eurostat and realised that their figures matched ours, meaning there is a problem in the data. As previously mentioned, a way to deal with missing values could have been imputation, however, for simplicity and to not have to adjust values (i.e. totals not adding up) we decided to keep some of the missing data and deal with them in each case. There would be two solutions in this case: either adjusting the missing values with the subtraction of the total and the subcategories amounts or assuming them to be 0 and adjusting *"Plastic_waste_treated"* to our calculated field.

Discrepancy check for Austria and Türkiye

Country	Year	Disposal - Total	Disposal - landfill and other	Disposal - incineration
Austria	2010	351	13	338
	2012	298	0	298
	2014	0	0	
	2016	0	0	
	2018	2,246	2,246	
	2020	1,771	1,771	
Türkiye	2010	0		0
	2012	8,187	8,058	129
	2014			
	2016			
	2018	1,380		1,380
	2020			

Contribution: Margarita Hernández Casas

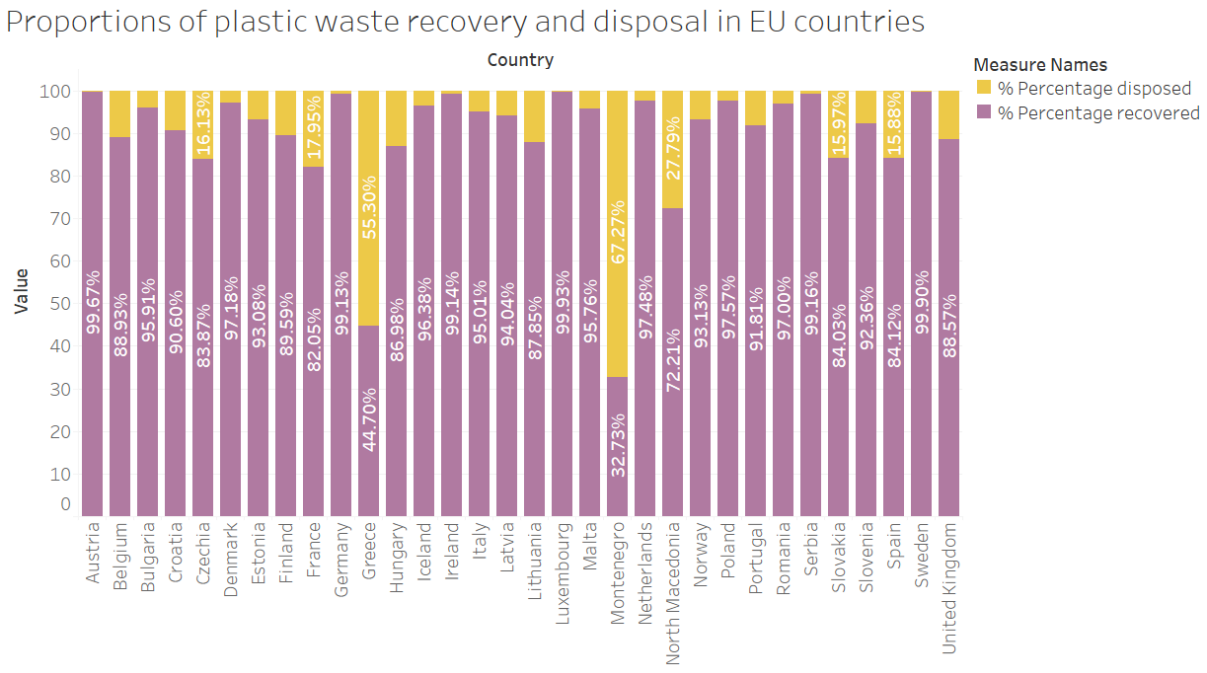
Discrepancy check for Austria and Türkiye

Country	Year	Recovery - backfilling	Recovery - energy recovery	Recovery - recycling	Recovery - Total
Austria	2010	0	126,192	67,247	193,439
	2012	0	39,845	311,791	351,636
	2014	0		187,436	187,436
	2016	0		280,979	280,979
	2018	0		191,226	191,226
	2020	0		192,214	192,214
Türkiye	2010	0	12,360	174,431	186,791
	2012			328,218	328,218
	2014		12,820	756,546	769,366
	2016	0	74,512	1,041,842	1,116,354
	2018	0	5,466	2,000,359	2,005,825
	2020	0	4,140	3,019,949	3,024,089

Contribution: Margarita Hernández Casas

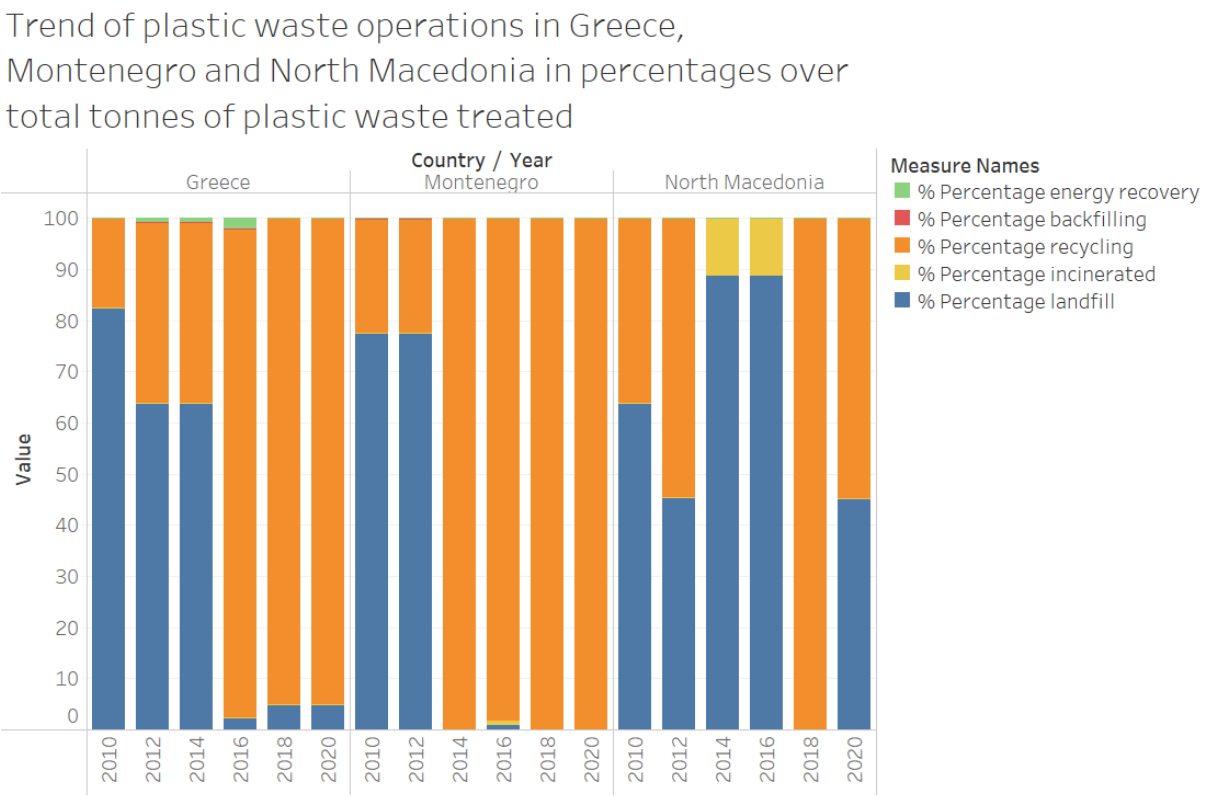
The first table shows the amount of plastic waste disposed in Türkiye and Austria across the years, while the second table shows the amount of plastic waste recovered in Türkiye and Austria over those years.
After having a better look at the data available for Austria and Türkiye (the table was split for easier visualisation in the document) we decided to make different changes for each. Given that Türkiye has no total value for disposal, performing the latter of the two options mentioned would imply that the country does not dispose of any plastic waste at all. Compared to other countries, this value is never 0, which, as it will be mentioned in detail later in another section of the document, we think may be an indicator of either the fact that Türkiye is a huge importer of plastic waste for other EU countries and may be advanced in recovery techniques (leaving almost no plastic waste -or none- to disposal operations) or a sign of lack of transparency in EU countries regarding plastic waste. As we do not have enough information to completely trust any of our hypotheses with Türkiye, we will just omit the country in this part of the analysis. However, Austria is only missing some of the records for subcategories (incineration and energy recovery), not the total values for disposal and recovery, so we have decided to act differently for Austria, assuming 0 for the missing values.

After these modifications, we replot the previous figure, where we first observed the data quality issues.



Contribution: Margarita Hernández Casas

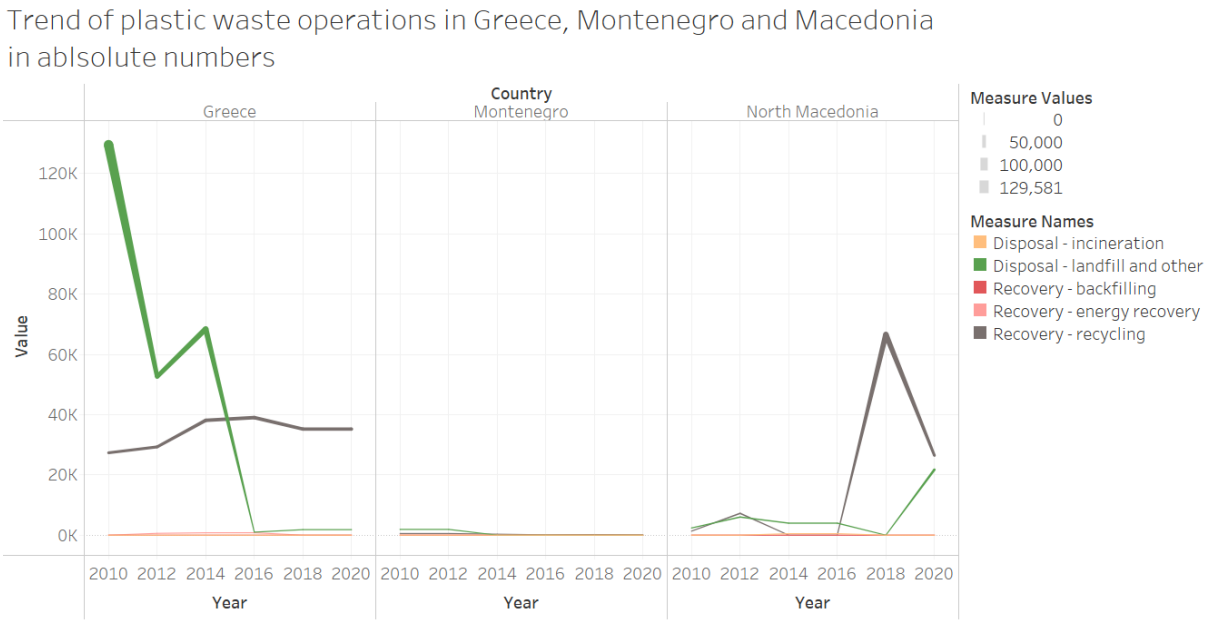
This chart illustrates the proportion of plastic waste recovered and the percentage of plastic waste disposed in different countries, after the adjustment performed on the data
As previously mentioned, Montenegro and Greece have a very remarkable percentage of disposed plastic waste. We will go deeper in detail for countries with more than 25% on this operation, which also includes North Macedonia. We will compare both percentages of the total plastic waste treated as well as the absolute numbers of these amounts.



Contribution: Margarita Hernández Casas

This chart shows how the trend of different plastic waste management operations evolved across the years in Greece, Montenegro and North Macedonia.
We can see from this figure that recycling seems to be gaining more popularity among these countries over recent years, taking over landfill disposal. Greece seemed to consider energy recovery for some years, similar to North Macedonia for incineration. It seems quite weird that North Macedonia recycled 100% of its plastic waste given its trend.

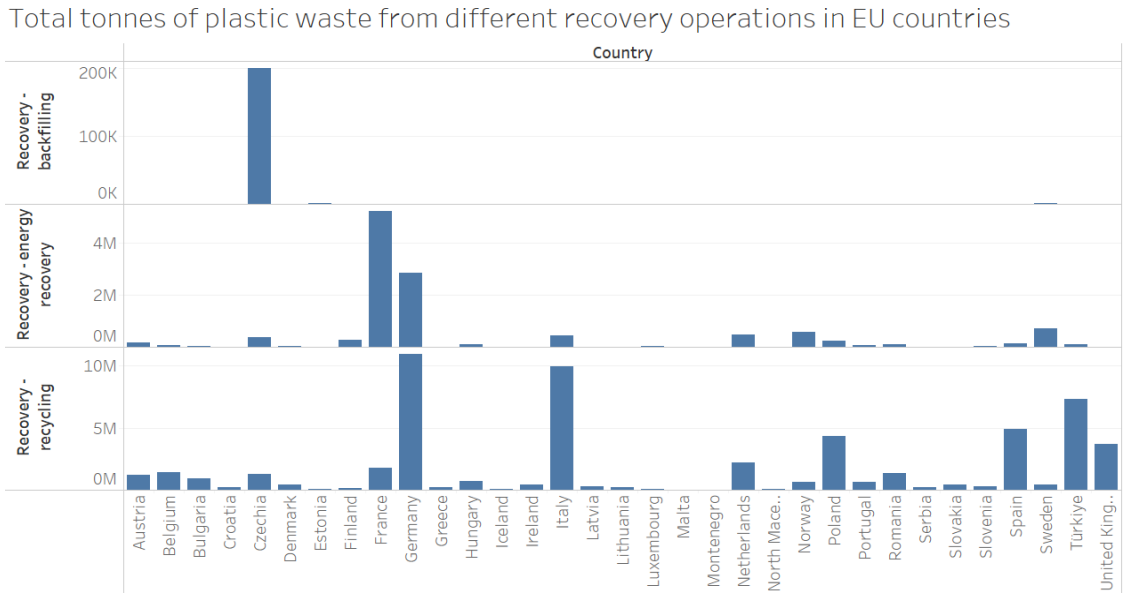
When plotting the same information in absolute values, we can add some more context to the previous plot.



Contribution: Margarita Hernández Casas

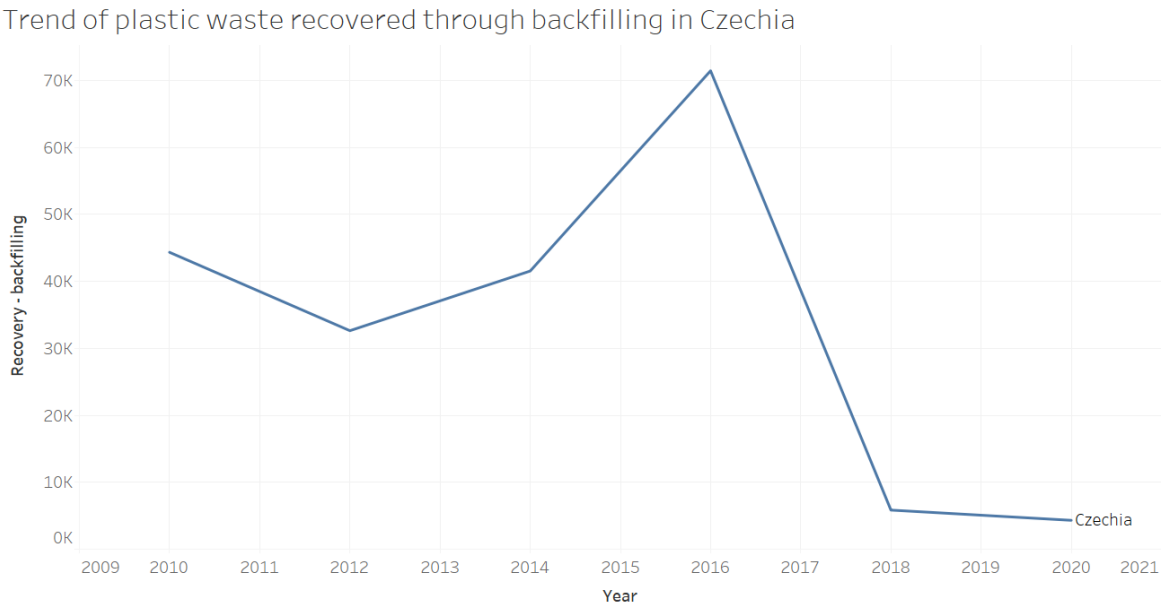
This chart represents a variation of the previous one, but with absolute values instead of percentages.
For North Macedonia we still keep similar insights, just adding that landfill increased notoriously in 2020. In the case of Greece, however, we get some extra information: recycling was not replacing landfill disposal, but it is the latter that is decreasing at a rapid pace, resulting in recycling having a higher percentage of the total amount treated.
Montenegro is generating a much lower amount of plastic waste than other countries, so we can't add more information than indicated before.

Moving on to analysing recovery and disposal operations separately, we will start by plotting the total amount of plastic waste recovered in EU countries from 2010 to 2020.



Contribution: Margarita Hernández Casas

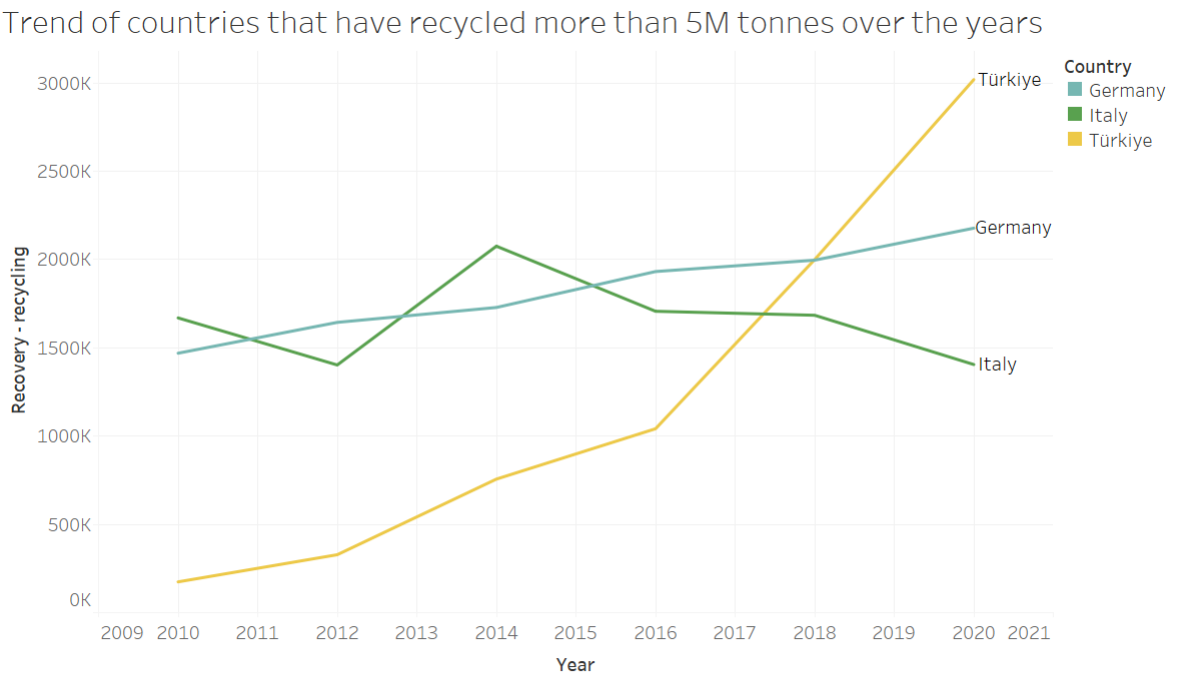
This figure shows the total amount of plastic waste treated in the different recovery operations in all the EU countries considered.
Starting from the bottom, Germany, Italy and Türkiye are the countries recycling the most. For energy recovery, France and Germany are using this operation much more than others. Finally, for backfilling, we see that only 3 countries are performing this operation: Czechia, Estonia and Sweden. Czechia is remarkably the most contributor to plastic waste backfilling.



Contribution: Margarita Hernández Casas

This plot shows the trend of plastic waste recovered via backfilling in Czechia over the years. We notice a big peak in 2016 but the trend seems to be decreasing overall.

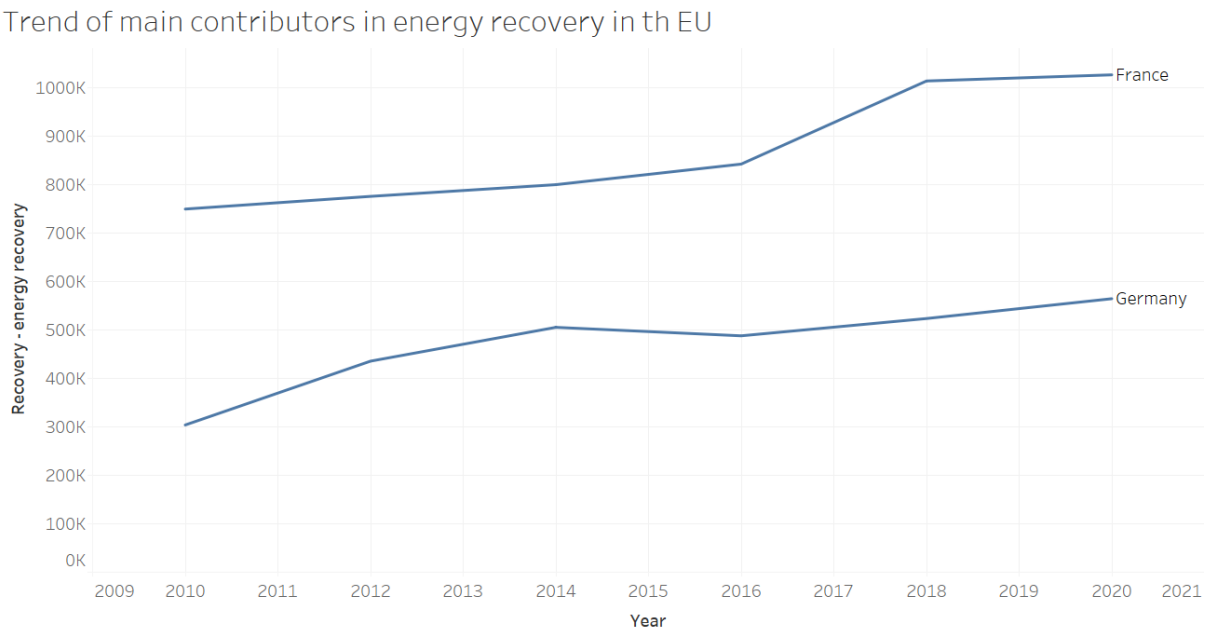
We will also check the trends for the bigger contributors of the other two operations just mentioned, starting with recycling.



Contribution: Margarita Hernández Casas

This plot shows the trend of the countries that have recycled more than 5M tonnes from 2010 to 2020. Italy and Germany are quite steady on their trends, the first decreasing with a peak in 2014, and the second slowly increasing. However, the highlight here is Türkiye, which has increased exponentially the tonnes of plastic waste recycled. This is in line with what was explained on page 7 about Türkiye importing plastic waste from other EU countries.

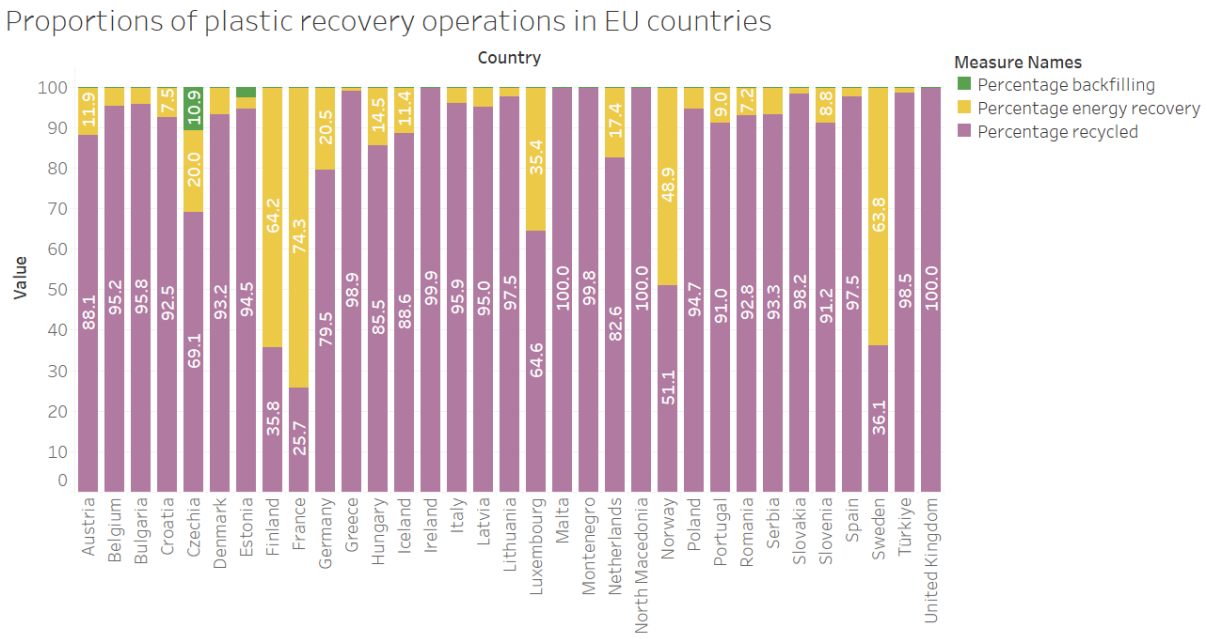
Finally, we will have a look at the trend of the main contributors to energy recovery in the EU from 2010 to 2020.



Contribution: Margarita Hernández Casas

We can only confirm our previous hypothesis of energy recovery and recycling increasing proportionately to plastic waste generation. It's still interesting to see that only Germany and France are strongly supporting this operation.

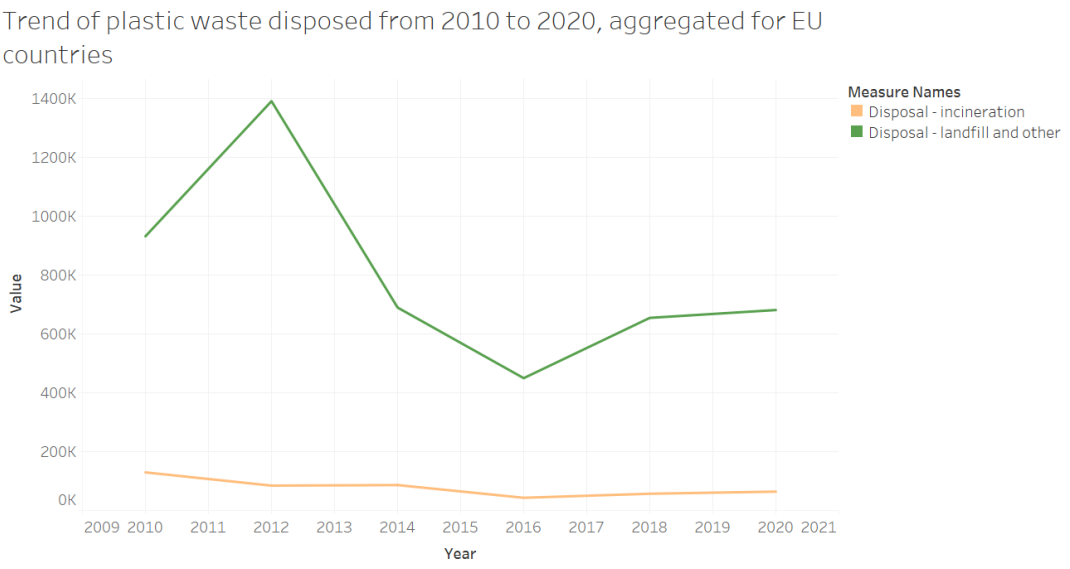
To finish with the analysis of trends of plastic waste recovery, we plot the percentages of the sum of tonnes in each operation from 2010 to 2020 for all EU countries.



Contribution: Margarita Hernández Casas

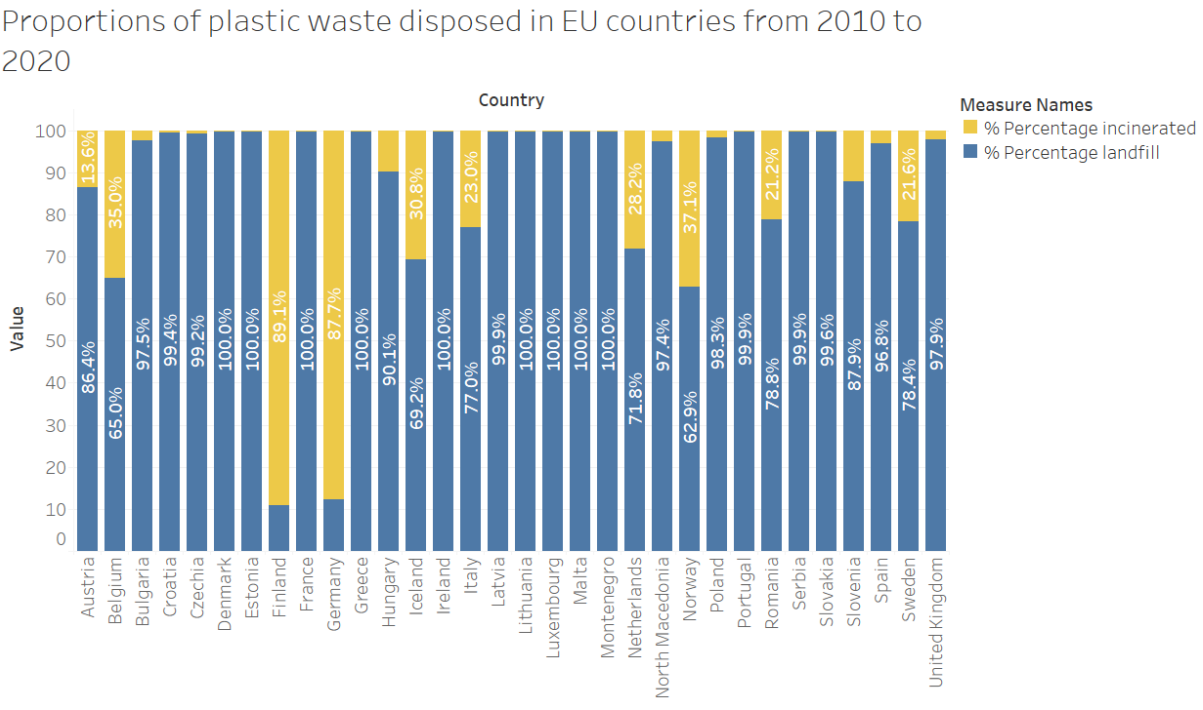
This plot shows the percentage of the different plastic waste recovery operations across the EU countries considered.
We observe again some of the previously mentioned remarks: Czechia and Estonia with a bigger percentage of backfilling, 10.9% and 2.6% respectively; France has the biggest percentage of energy recovery with almost 75%. We also see some new insights: UK, Türkiye, North Macedonia, Montenegro, Malta, Ireland and Greece seem to be only opting for recycling as a recovery operation; and Sweden, Norway, France and Finland perform energy recovery to over 50% of their plastic waste tonnes in recovery operations.

Following this analysis, we now look at the trends for plastic waste disposal in EU countries.



Contribution: Margarita Hernández Casas

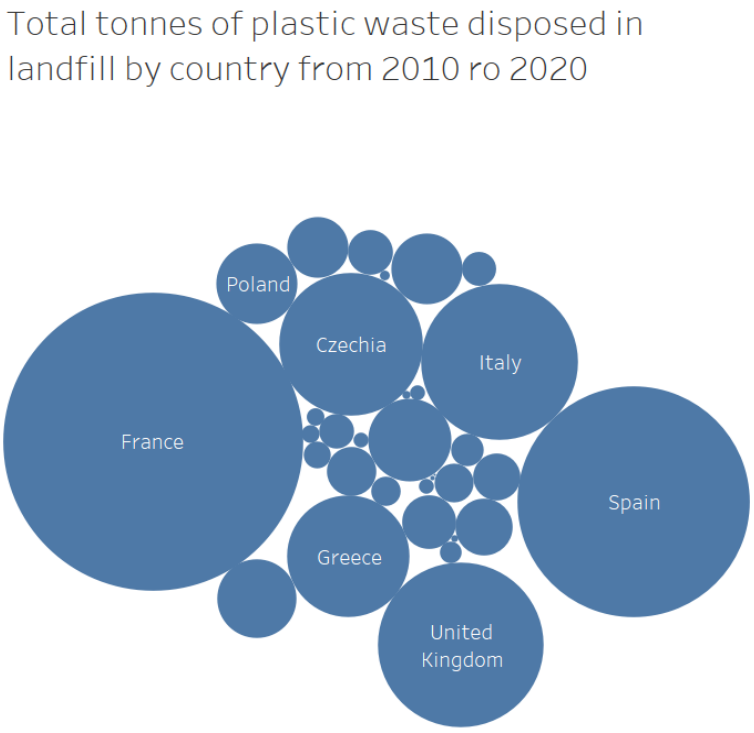
This figure shows how the trend of different plastic waste disposal operations has evolved in EU countries over the years. It seems that both trends are decreasing, although landfill disposal is more unstable. In order to look in detail at the management operations in different countries we get the following figure.



Contribution: Margarita Hernández Casas

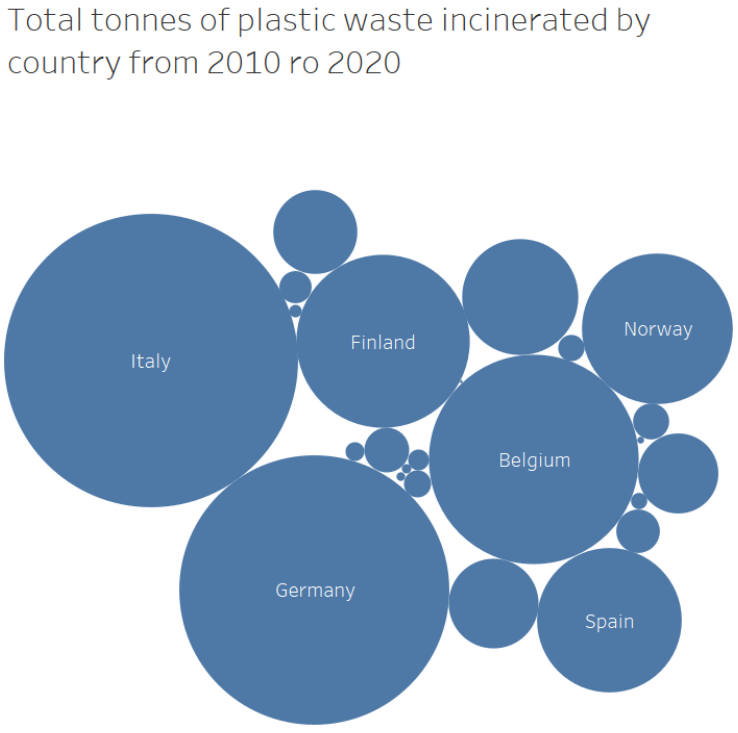
This plot shows the percentage of the different plastic waste disposal operations across the EU countries. The majority of them do not consider incineration as a way to dispose of plastic waste. On the contrary, Germany and Finland almost only use this over disposal in landfills.

Lastly, we will observe which countries contribute more to the overall disposal operations, each separately on a bubble plot.



Contribution: Margarita Hernández Casas

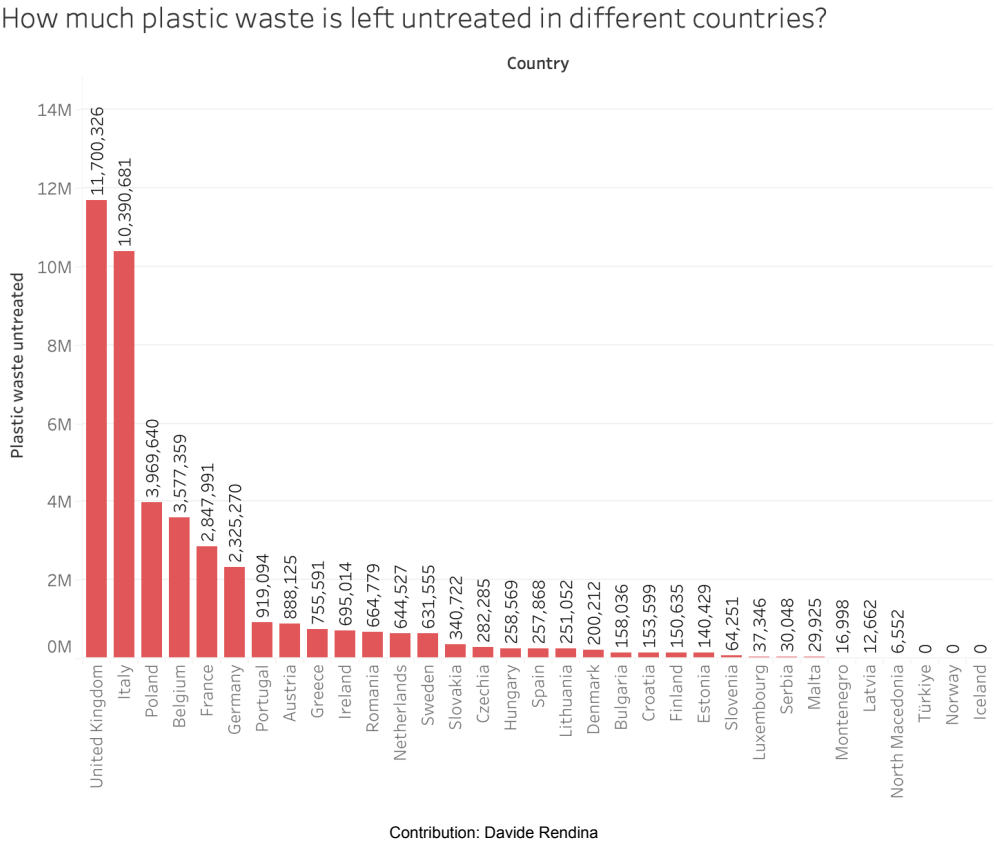
This figure shows the sum of plastic waste tonnes disposed of in landfill from 2010 to 2020 by country. The main contributors to this operation are France, Spain, the UK, Italy, Czechia and Greece. Similarly, we can now plot plastic waste incinerated.



Contribution: Margarita Hernández Casas

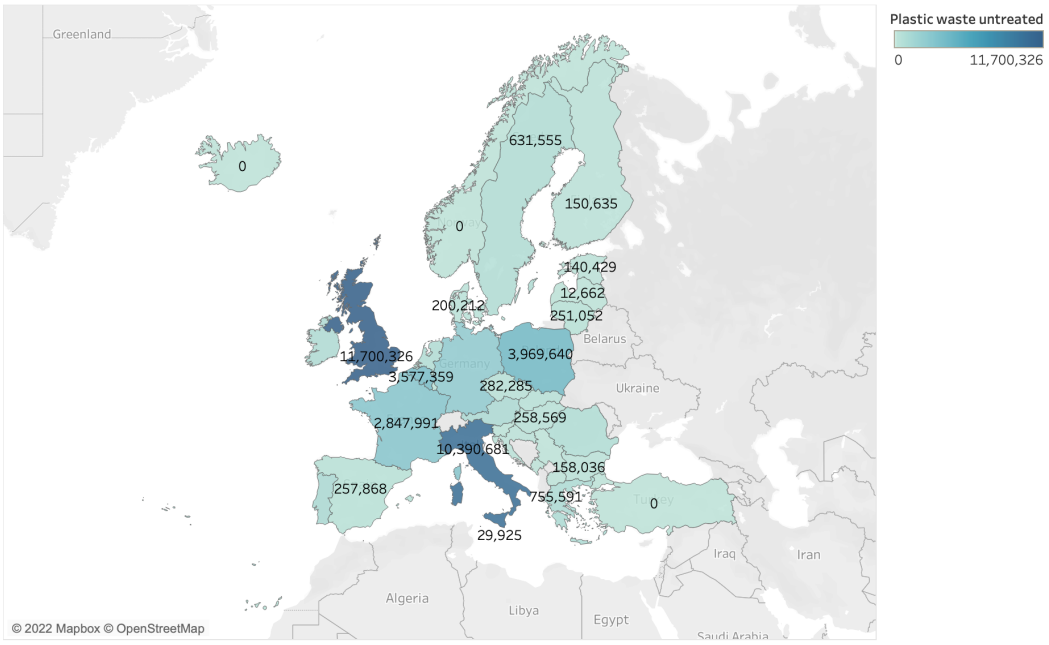
This figure shows the sum of plastic waste tonnes incinerated from 2010 to 2020 by country. The main contributors to this operation are Italy, Germany, Belgium, Finland, Spain and Norway.

Finally, we move to answer our question regarding how much plastic waste is left untreated. For doing this, we can create a Calculated field that detracts the plastic waste treated from the plastic waste generated.



This plot shows the total amount of plastic waste left untreated in each EU country considered. As we can see, the majority of countries have some amounts of plastic waste left untreated. Only Türkiye, Norway and Iceland have 0 tonnes of plastic waste untreated, which could be due to the fact that importing plastic, as seen in the previous analysis, leads to more plastic waste to treat compared to the waste generated by the country.
To have a visual representation we can plot this on a map.

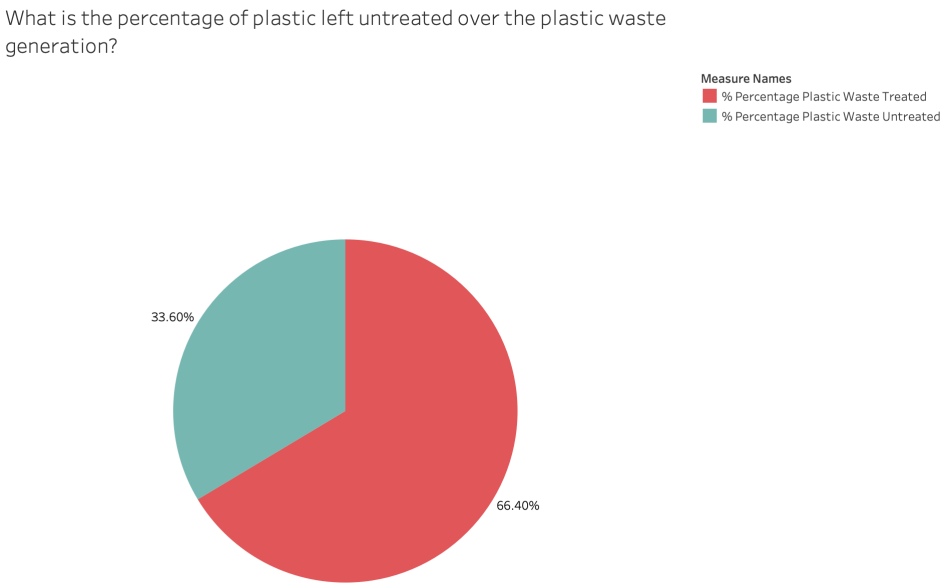
How much plastic waste is left untreated in different countries?



Contribution: Davide Rendina

This map shows an alternative representation of the previous chart, showing the quantity of plastic waste untreated in the EU countries. It is notable that some countries have also a great quantity of plastic waste left untreated, such as the UK or Italy, followed by Belgium and Poland.
At this point, we wanted to investigate what happens to this waste that is not treated in any way.
To answer this question we did some research and found out that there is a business behind plastic waste export. In particular, according to Exporting plastic waste for recycling, the United Kingdom *"currently exports plastic because there is not enough capacity within the UK to recycle it. In 2019, the UK exported 61% of its plastic packaging for recycling."*
Plastic waste export is an ongoing problem which poses a serious environmental and health threat for the receiving countries, as we have seen in Türkiye. The major importers of plastic according to the G7 include Vietnam, India, Malaysia and, in Europe, Türkiye.
In 2021, a waste trade manifesto was posed to the European Commission to regulate the shipping of plastic waste, as reported by Rubbish-spewing dragon in Brussels highlights EU waste export.

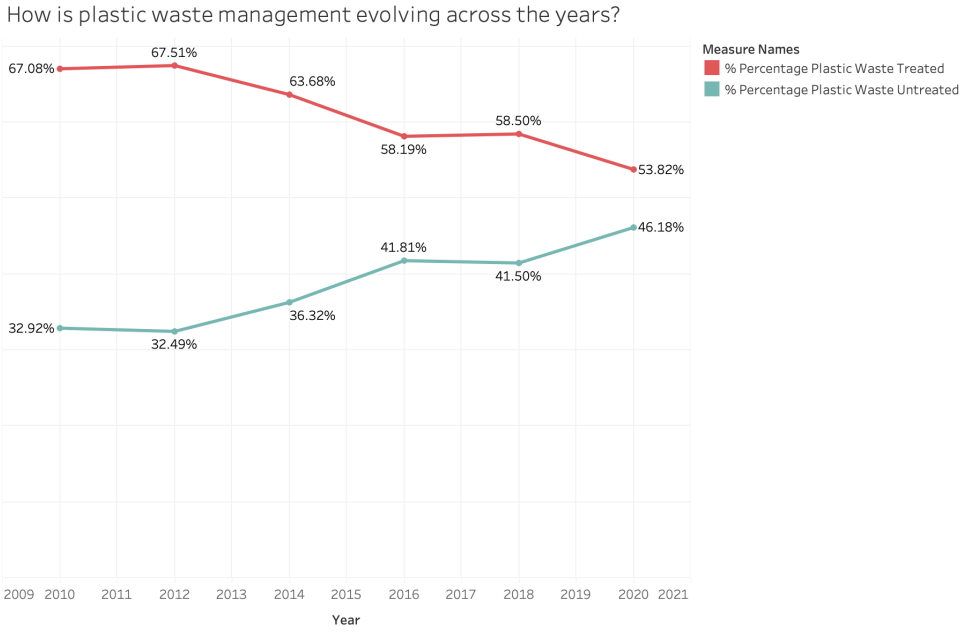
Given this new insight, we want to have a closer look at the relationship between plastic waste treated and plastic waste untreated in the EU. To do this, we created two calculated fields for the percentage of plastic waste treated and the percentage of plastic waste untreated.



Contribution: Davide Rendina

This chart shows the proportion of plastic waste untreated against the proportion of plastic waste treated in the EU countries considered. It is evident that the majority of plastic waste is treated, however, it is important to remember that some countries in the EU import plastic from other countries leading to more plastic waste treated which is not necessarily their own production. In addition, ⅓ of the plastic waste remains untreated.

At this point we would like to know: how has plastic waste management evolved over the years? What is the proportion to this day?

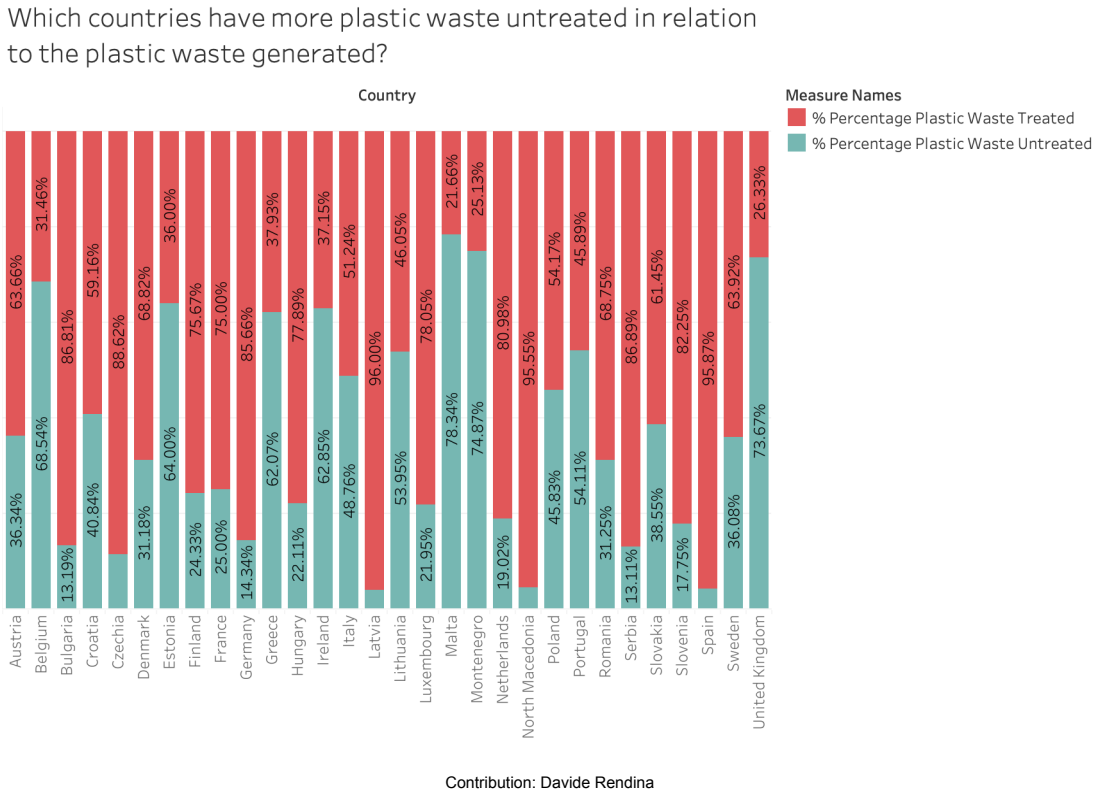


Contribution: Davide Rendina

This plot shows how plastic waste treated and plastic waste untreated in the EU have evolved over the years. It is immediately evident that, even if we have seen plastic waste

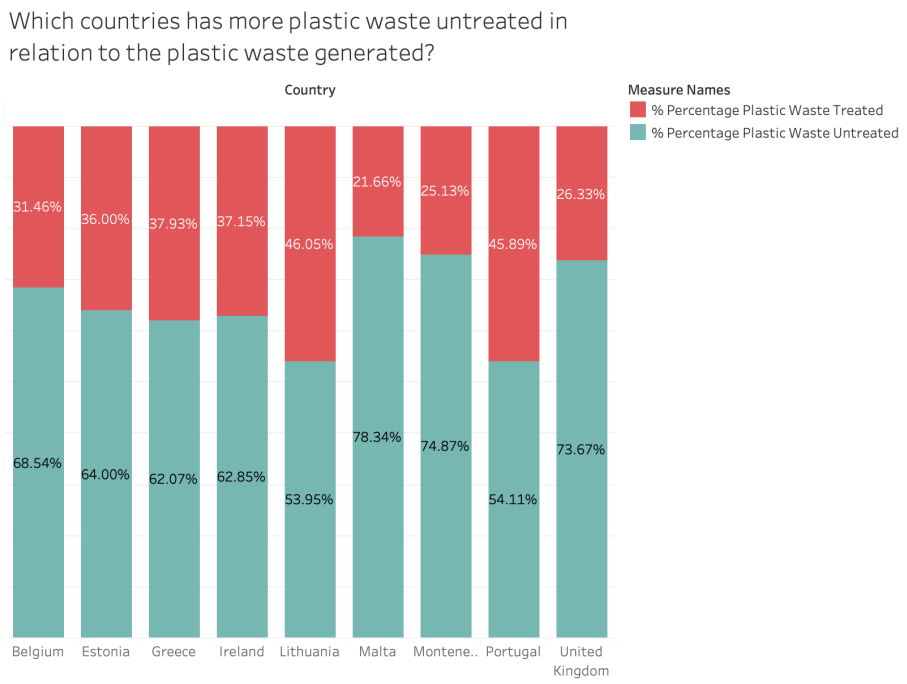
generation increasing, the percentage of plastic waste treated is decreasing reaching constantly reaching the lowest with only 53% of plastic waste treated in 2020. On the other hand, the percentage of plastic waste untreated is increasing, due to the aforementioned problem of plastic waste export.

Finally, It is worth investigating this further by looking at these proportions in individual countries. Türkiye, Norway and Iceland have been excluded from this analysis it was seen that the amount of plastic waste untreated was 0 in these countries.



Contribution: Davide Rendina

The chart illustrates the proportion of plastic waste treated and untreated in different countries. It is evident how some countries have a clear unbalance. In particular, it is worth noticing countries with a higher percentage of untreated plastic waste such as the United Kingdom, Belgium, Malta and Montenegro. This is more visible if we filter the countries with more than 50% of untreated plastic waste.



Contribution: Davide Rendina

This chart shows the countries whose majority (>50%) of plastic waste is left untreated. Among these countries, we can notice the United Kingdom and Belgium which were identified as one of the largest exporters of plastic waste in the World (Rubbish-spewing dragon in Brussels highlights EU waste export).

Summary

All in all, plastic waste generation is increasing over the last decade in the EU with the treatment of waste that struggles to keep up the pace. Some countries, in particular Türkiye in great quantity, have to deal not only with their own plastic waste generated but also with plastic waste imported from other countries.
Most of the plastic waste is recovered, with recycling being the most preferred operation followed by energy recovery, and only a few countries, such as Greece, Montenegro and North Macedonia have overall more plastic disposed, mostly via landfill. However, in recent years, recycling has gained ground across all the EU countries considered, including the aforementioned countries and recycling remains the main way to deal with plastic waste in the EU.
Nonetheless, due to the lack of recycling facilities and the inability to properly manage plastic wastes, the percentage of plastic remaining untreated is increasing over the last decade, leading to countries exporting their plastic abroad and posing a major threat to the environment (The plastic waste trade in the circular economy).

Link to Google Doc:
CleanData-Assignment3