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Title: Data analysis for European transition to Green Energy. Holistic approach for Waste to Energy, Recycling and Landfilling.

Abstract

In this thesis, we tested 3 different hypotheses to identify how financial factors such as GDP and environmental taxes affect, positive or negative, the green energy sector such as waste treatment methods and Wte plants. The data is collected on an annual basis and covers the period from 2003 to 2019. The main purpose is to investigate possible correlations between these factors applying the multivariate model. There is no anyone similar published report until now. For hypothesis 1 we use Time Series analysis and for 2,3 we use Panel Data analysis. OLS model and Fixed effects OLS are the statistical model for the hypothesis 2 and 3. The results reveal some interesting facts. Firstly, developed economies in Europe do not follow an uptrend Wte plants in contrast with emerging economies which chose a political and social swift to green energy with more Wte plants, especially after the 2009-2010 crisis. After, GDP and Wte plants express a tiny negative correlation under this analysis which presents a disorder for growth in this sector of renewables. Furthermore, waste generation is unstoppable rising trouble for most countries, when at the same time incineration supports the increase of waste generation. Also, green taxes have a negative effect on recycling. The most highlighted part is the flat growth for Wte plants and green taxes in Europe after 2010. A policy transformation is essential immediately if the EU plans to achieve a clean energy transition. The renewable uptrend was not correlated with the flat trend of Wte plants which disclose that recycling is the dominant waste treatment. After 2010, European countries focus on renewables without increasing Wte plants, especially in developed economies. In the end, GDP's growth expresses a higher positive impact in Wte plants than renewables' energy consumption which is based on the distinction between developed and emerging economies.

Keywords

Waste to Energy, Finance sector, Europe, Panel Data.

Περίληψη

Σε αυτή τη διπλωματική, έγιναν 3 διαφορετικές υποθέσεις για να εξεταστεί πώς οι οικονομικοί παράγοντες (ΑΕΠ και περιβαλλοντικοί φόροι) επηρεάζουν θετικά ή αρνητικά παράγοντες του τομέα της πράσινης ενέργειας όπως οι μέθοδοι επεξεργασίας αποβλήτων και οι εγκαταστάσεις WtE. Τα δεδομένα συλλέχθηκαν σε ετήσια βάση και καλύπτουν την περίοδο από το 2003 έως το 2019. Ο κύριος σκοπός είναι η διερεύνηση πιθανών συσχετίσεων μεταξύ αυτών των παραγόντων. Δεν υπάρχει καμία παρόμοια δημοσιευμένη αναφορά μέχρι τώρα. Η υπόθεση 1 χρησιμοποιεί ανάλυση Time Series και για 2,3 ανάλυση Data Panel. Τα στατιστικά μοντέλα για την υπόθεση 2 και 3 ήταν το Μοντέλο OLS και το Fixed effects OLS. Τα αποτελέσματα αποκαλύπτουν μερικά ενδιαφέροντα ευρήματα. Πρώτον, οι ανεπτυγμένες οικονομίες στην Ευρώπη δεν ακολουθούν μια ανοδική τάση μονάδων WtE σε αντίθεση με τις αναδυόμενες οικονομίες που επέλεξαν πολιτικές ταχείας ανάπτυξης της πράσινης ενέργειας με περισσότερα εργοστάσια WtE, ειδικά μετά την κρίση 2009-2010. Επίσης, η ανάλυση παρουσιάζει μια μικρή αρνητική συσχέτιση μεταξύ του GDP και των WtE εγκαταστάσεων που αποκαλύπτει μια αναντιστοιχία των 2 παραγόντων. Επιπλέον, η παραγωγή αποβλήτων είναι ένα ασταμάτητο αυξανόμενο πρόβλημα για τις περισσότερες χώρες, ενώ ταυτόχρονα η αποτέφρωση υποστηρίζει την αύξηση της παραγωγής αποβλήτων. Επίσης, οι πράσινοι φόροι έχουν αρνητική επίδραση στην ανακύκλωση. Το πιο ενδιαφέρον μέρος είναι η ελάχιστη ανάπτυξη των εργοστασίων WtE και των πράσινων φόρων στην Ευρώπη μετά το 2010. Ένας μετασχηματισμός πολιτικής είναι απαραίτητος εάν η ΕΕ θέλει να επιτύχει μετάβαση σε καθαρή ενέργεια. Η ανανεώσιμη ανοδική τάση δεν συσχετίστηκε με την επίπεδη τάση των εργοστασίων WtE που αποκαλύπτουν ότι η ανακύκλωση είναι η κυρίαρχη επεξεργασία αποβλήτων. Μετά το 2010, οι ευρωπαϊκές χώρες επικεντρώνονται στις ανανεώσιμες πηγές ενέργειας χωρίς να αυξάνουν τα εργοστάσια Wte, ιδίως οι ανεπτυγμένες οικονομίες. Στο τέλος, η αύξηση του ΑΕΠ εκφράζει υψηλότερο θετικό αντίκτυπο στα εργοστάσια Wte από την κατανάλωση ενέργειας από ανανεώσιμες πηγές, η οποία βασίζεται στη διαφορά μεταξύ των ανεπτυγμένων και των αναδυόμενων οικονομιών.

Λέξεις-κλειδιά

Απόβλητα για ενέργεια, οικονομικός τομέας, Ευρώπη, Δεδομένα πίνακα.

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List of Abbreviations

GDP	Gross Domestic Product.
EU	European Union.
WtE/WTE	Waste to Energy.
US EPA	United States Environmental Protection Agency.
FAO	Food and Agriculture Organization.
FLW	Food loss waste.
MSW	Municipal Solid Waste.
OECD	Organization for Economic Co-operation and Development.
RDF	Refuse-derived fuel.
GEM	Global Emerging Market.
WFD	Water Framework Directive.
GHG	Greenhouse gas.
SDG	Sustainable Development Goals.
EIA	Energy Information Administration.
LCA	Life Cycle Assessment.

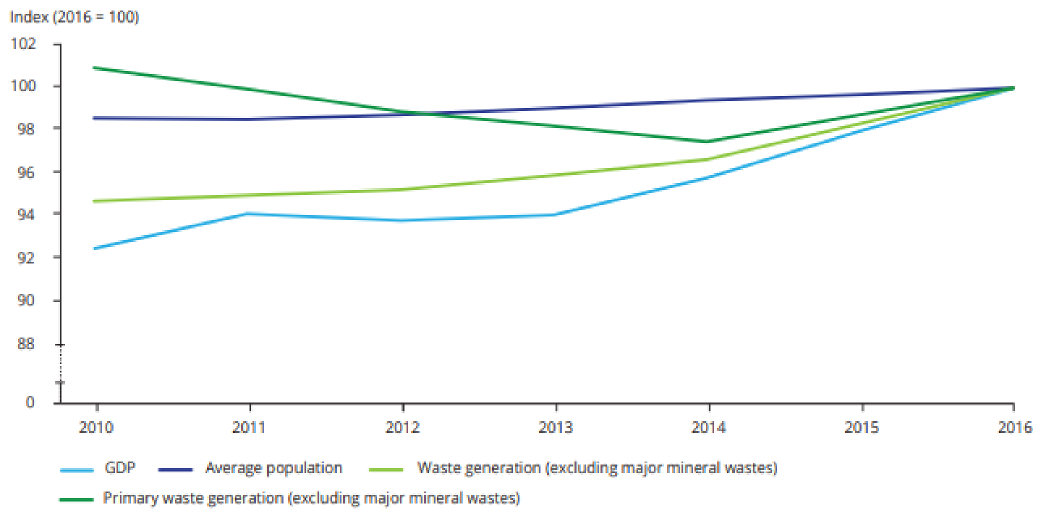
CONTENTS

1. Introduction

Nowadays, the humanity moves towards urbanization with a massive population that demands higher consumption of products and energy which means that waste management becomes mandatory for future sustainable development *(World Energy Council, 2016).* Firstly, the correlation between increased income and increased energy consumption is highlighted from reports. Then, increased consumption leads to more waste generation *(Mazzanti and Zoboli, 2008)*. Furthermore, waste generation continues to rise in proportion to the GDP growth *(fig.1) (European Environment Agency, 2013).*

In *figure 1*, it is displayed the evolution of 4 factors for the period 2010-2016. These factors are GDP, average population, waste generation and primary waste generation. Despite the initial small decline of primary waste generation, there is a constant increase for the other 3 factors as expected, based on the existing data.

Figure 1: Trend analysis for GDP, the average population of countries, waste generation and primary waste generation.



Source: (EEA, 2019).

According to this huge increase in waste generation, waste management is a social requirement. Waste management is one of the biggest challenges due to the environmental footprint, causing issues that contribute to climate change. On average, each of the approximately 500 million people living in the Europe produce half a ton of household waste every year (*European Commission, 2010).* This fact leads to the discussion on the need to trim the existing framework, which is in coordination with the Commission's overarching Regulatory Fitness and Performance Programme that aims at simplifying EU regulation *(European Commission, 2010).*

In this way, most favorable waste management methods are recycling and waste to energy. Turning waste into energy can be a game-changer to a circular economy enabling the value of products and resources to be maintained on the market, eliminating high levels of waste production. WtE has been pinpointed in the context of environmental policy in connection to the unequal distribution of environmental pollution and the environmental risks associated with them. EU calls for waste management to be transformed into sustainable material management which inserts the principles of the circular economy, increases energy efficiency, reduces the dependence of the Europe and provides long-term competitiveness (*European Waste Framework Directives)*. The insertion of the organic portion of MSW as a potential source of renewable energy has enabled the Europeans countries to meet their national renewable energy goals through the WtE incineration industry. Biomass and waste are the largest sources of renewable energy in Europe amounting to the majority of the total pool of renewable energy sources.

The recovery of energy and materials from waste based on modern WtE is ranked above landfilling in waste management hierarchies (*US EPA, European Waste Framework Directives).* The long-term vision for the waste sector is to establish a circular global economy. In 2015, the European Commission presented a Circular Economy Package which includes legislative suggestions on waste to stimulate Europe's green transition.

1.1. Historical facts

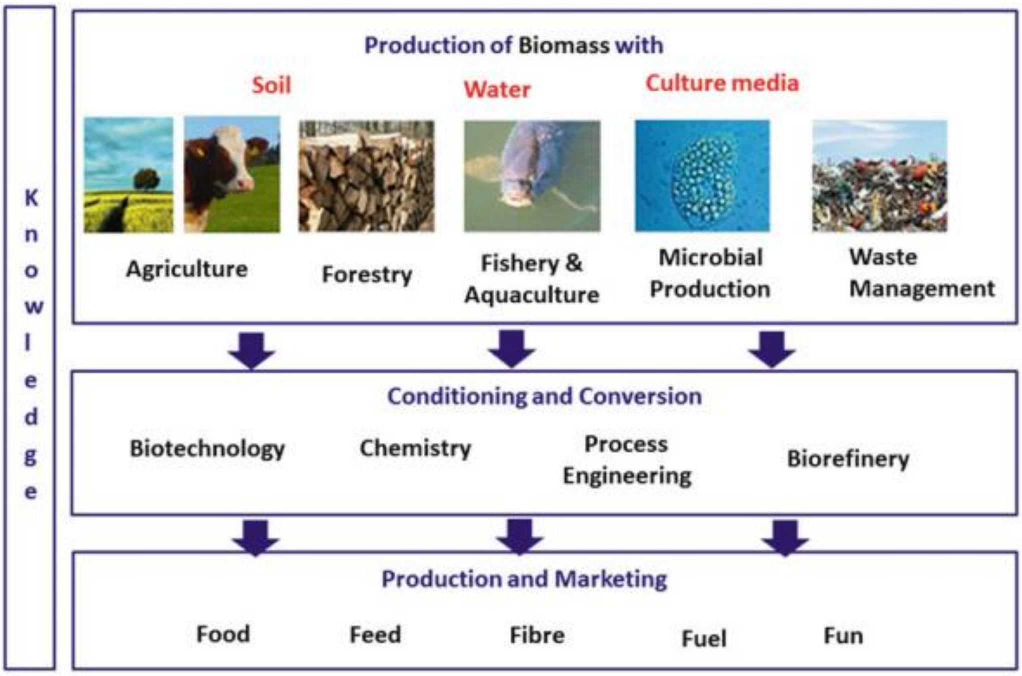
To begin with time order, the Industrial Revolution was fundamentally an energy transition. America was dependent on energy from biomass, while China and India remained biomass powered until the 1950s. The first incinerator was built in Nottingham UK in 1874 by Manlove, Alliott & Co. Ltd. *(Heribert, 2007).* The first US incinerator was built in 1885 on Governors Island in New York *(epa.gov).* The first waste incinerator in Denmark was built in 1903 in Frederiksberg and in the Czech Republic was built in 1905 *(Lapčík; et al., 2012).* Many countries remain highly dependent on energy from biomass. This transition from burning biomass to burning coal occurred first in Europe. By mid-eighteenth-century England was energy-based on coal, and by the mid-nineteenth century biomass was in long-term decline in Western Europe.

Since the crisis of the 1970s, many countries express interest to develop biomass as a fuel source. However, the interest in biomass energy has dropped due to the technological breakthrough that makes fossil energy slightly cheaper. Factors such as high greenhouse emissions, toxic air pollution and growth of transportation fuel demand have boosted extensive efforts in developing bioenergy. Modern incineration plants are different from old types. Modern incinerators are capable of reducing the volume of the waste by 97%, depending on the composition and degree of recovery of materials such as metals.

However, this long-term trend has been reversed, and biomass is now meeting form of interest in Europe because we need to reach the renewable energy targets. In 2007 the *European Union* decided that it should get 20% of its final energy consumption from renewables by 2020. However, looking at the available selections, countries quite clearly decided that wind and solar were not ready to be scaled up to the desired level that immediately. In this way, they decided to return to the oldest form: biomass *(EU).* Biomass is about the wide variety of resources containing non-fossil, organic carbon, derived from living plants, such as animals and microorganisms. These are summarized in the word "biomass". Bioenergy is energy derived from any fuel that is originated from biomass. Biomass is a renewable resource which has been considered as an alternative source of energy *(eia.gov).*

Scientific studies have demonstrated that it is possible to generate a wide variety of bioenergy from biomass *(fig.2).* However, the cost is not competitive compared to other sources. On-going efforts are continued to improve conversion technologies in order to reduce costs. Differing from first-generation biofuels that derived from food crops (sugarcane, wheat, corn), second-generation biofuels are generated from lignocellulosic materials (switchgrass, wood, straw) and biomass residues *(eia.gov).* In *figure 2,* there is a presentation of knowledge about the whole biomass sources like agriculture and waste, the conversion approaches leading to the final production of goods like feed and fuel.

Figure 2: From Biomass through conversion to Production.



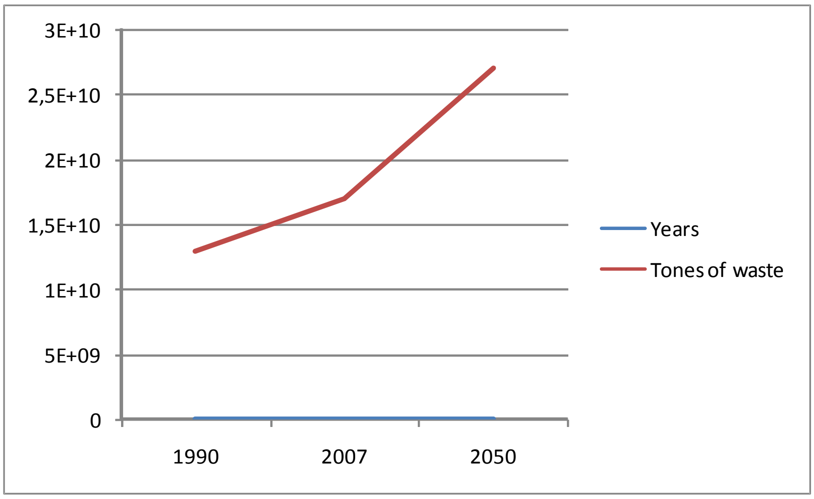
Source: (Bör, 2010).

Bio-based resources can be classified and characterized according to their origin and the sector in which they are produced. For the integration into bio-based product chains, the most relevant classification of biomass is according to its major components, such as sugar, oil or protein *(britannica.com).* Biomass has been identified as a fuel source since humanity learned to make fire and served as the primary source of energy before fossil fuels became the dominant trend. Biomass is still the dominant source of energy for billions of people who live in the poorest areas around the world.

1.2. Global waste data

One main part of biomass is referring to waste. According to statistics, waste generated per person per day is approximately 0,7 kg. Waste generated in the EU per capita in 2016 was 1,7 kg *(theworldcounts.com).* This massive amount of waste is because 90 percent of the products we buy, is trashed immediately *(theworldcounts.com).* For example, *the Food and Agriculture Organization (FAO) of the United Nations* estimated that roughly 30% of food produced for human consumption was transformed into waste, all over the world. The carbon and water footprints of this significant amount of FLW were estimated to be 4 gigatonnes (8% of the whole) of CO2 equivalent.

Table 1: Global waste generation.



Source: (Beede and Bloom, 1995), (Statista).

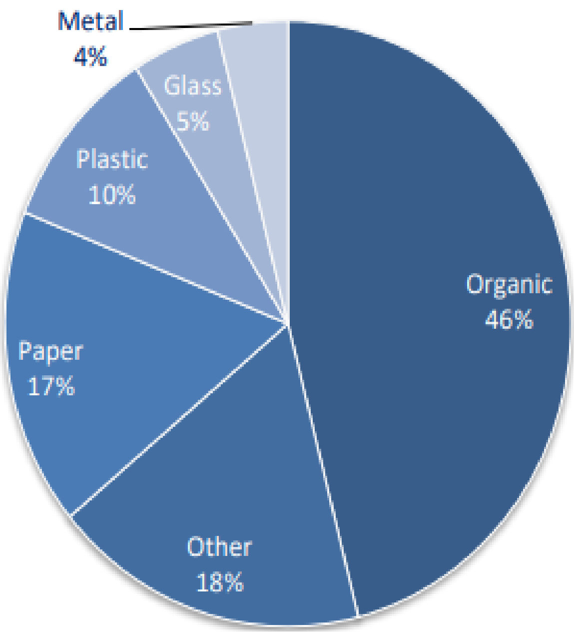
Focused on sectoral basis, farm FLW in agricultural production in low-income countries is higher than in high-income countries, because these countries usually have less advanced technology and infrastructure. Manufacturing and retailing are the crucial stages of food loss for products indicating that fresh products and bakery make up the largest share of retailing FLW due to factors such as expired sell-by dates, product damage and quality issues. For these tremendous amounts of loss waste, waste management strategy is absolutely essential. The methane produced by an average municipal landfill site, if was converted to energy, could provide electricity to approximately 20,000 households for 12 months. It is estimated that the whole materials sent to landfill could have an annual value of around €5 billion *(European Commission).*

Management of municipal solid waste continues to be one of the top priorities for all the countries around the world. The model of solid waste management is summarized in reduction of waste right before it enters the stream chain, reuse of waste for recovery by recycling and disposal through certain facilities. Solid waste management is known to be a significant factor in various environmental problems *(Eurostat, 2012).*

Municipal Solid Waste *(fig.4)* is classified and defined in various ways depending on the country. For example, *Eurostat* identifies MSW as “produced by households or by other sources such as commerce, offices and public institutions”. The waste is collected by local authorities and is disposed of through the waste management system. The differences in definitions create uncertainty in assessing management performance, but also inconsistency in data collection *(Eurostat, 2012).* Moreover, some countries include only waste from households in contrast to others which include wastes from commercial activities. Some countries have changed the definition of municipal waste over time, and recycled amounts can also be calculated differently, depending on whether they contain the weight of materials collected but discarded during the recycling process. Different definitions lead to mismanagement and misunderstandings for each country and corporation. In this way, there is a need of further clarification.

Firstly, we have to identify which materials are tracked in the whole waste system. These materials mainly are organic items, paper, plastic, metal and glass. Moreover, in *figure 3*, there is the global waste composition in 2010. Organic and paper are the main findings, followed by plastic, glass and metal.

Figure 3: Global waste composition 2010.



Source: (Hoornweg, 2012).

After identifying materials, we could separate wastes based on origin of use. In *figure 4*, we divide waste according to main groups like municipal solid waste (MSW), process waste, medical waste and agricultural waste.

Figure 4: Types of waste.

Source	***Type***	***Composition***
MSW	Residential	Food, paper, textiles, leather, plastics, wood, glass, metals, household, e-waste.
MSW	Industrial	Housekeeping, packaging, wood, concrete, steel, bricks, hazardous.
MSW	Commercial	Paper, cardboard, plastics, wood, glass,

		hazardous, e-waste.
MSW	Construction	Wood, steel, concrete, soil, bricks, tiles, glass, plastics, insulation, hazardous.
MSW	Services	Street sweepings, landscape &tree trimmings, sludge.
Process waste		Scrap materials, slag, tailings, top soil, waste rock, process water & chemicals.
Medical waste		Bandages, gloves, cultures, swabs, blood, hazardous, radioactive and pharmaceutical wastes.
Agricultural waste		Spoiled food wastes, rice husks, cotton stalks, coconut shells, pesticides, animal excreta, soiled water, silage effluent, plastic, scrap machinery, veterinary medicines.

Source: (Hoornweg et al., 2012).

In addition to, there are other types of waste such as e-waste.

The amount of electronic waste (or e-waste) has been exploding along with technological progress. Approximately 100 million tons of e-waste is being produced every year and the majority of that is shipped to poor countries in Asia and Africa. Of course, e-waste is highly toxic and not treated properly. Sadly, this is the reason why is dumped in these areas. Heavy metals and toxic chemicals pollute surrounding communities and poison the local population including children. Guiyu, China, may be the world's largest e-waste dump with tons of e-waste per year *(World Bank).*

Except e-waste, plastic is also a well-known threat. Burying of these materials in agricultural land represents an imminent threat for soil contamination, degradation of soil characteristics and for the safety of the products which are produced in these fields (*Briassoulis et al., 2010).*
Furthermore, accumulated plastic film in the soil can cause significant decreases in yield. The consequences of the disposal of plastic waste in landfills threats to domestic and wild animals, blocking of water flow, causing water pollution, and overload of landfills with an environmental and financial impact (*Briassoulis et al., 2010).*

Taking under consideration these data, there is an urgent call for a holistic transition to environmental-friendly framework such as circular economy and sustainable development.

2. Circular Green Economy

The ecosystem where human actions take place could be characterized as an organism with inputs and outputs. In this framework, materials are imported from the earth's surface or synthesized and are utilized through time. Like any living organism, this ecosystem exports materials, such as emissions to water, air, soil and waste products. If wastes are recycled and secondary materials are used, less primary materials have to be produced and mined from the ground. In addition to, mining requires more energy, water, land, and materials, which leads to the conclusion that recycling of products represents a massive contribution to environmental protection *(European Commission, 2015).* WtE process contain reduction of landfill volume, environmental usage, improvement on air quality, surface and groundwater, social impacts, programs for enhanced community benefits and integration with other waste management options. WtE (waste to energy) refers to any waste treatment that transforms waste resources into electricity, steam, or heat energy. These include anaerobic digestion, incineration, pyrolysis, gasification, plasma arc, and RDF. Basically, WtE reduce the volume of the waste by 90%, depending on the waste composition and the type of energy derived *(European Commission, 2015).*

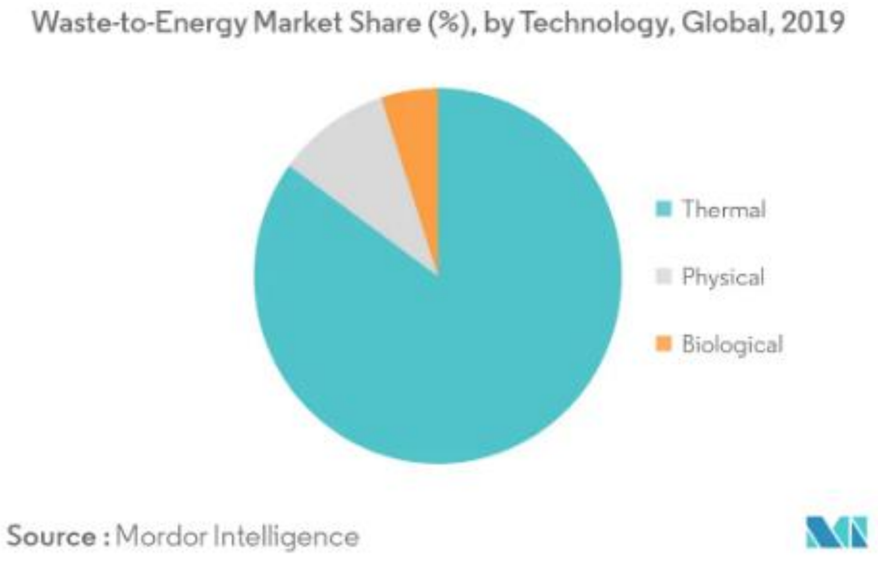
2.1. Criteria for WtE

To start with, the main reasons for choosing WtE strategy are due to climate change, production of low emissions, clean green energy, material recovery and implementation of circular value chain. In addition to that, the main advantages of using an energy recovery are that reduce the volume of waste up to 90%, boost production of heat and electricity, induce better sanitation, contain lower risk of contamination and high emission control. Moreover, it has a positive impact as producing energy from waste avoids potential emissions from landfilling. WtE also generates a ripple effect for the local economy. Furthermore, it is a proven and reliable base source of electrical energy.

Essential criteria which define the circumstances for a Wte plants are state of technology, technical proficiency, technical resources, public opinion, environmental emissions, financial resources and overall project risks. From investor side, choosing WtE is not an easy decision because there many obstacles which repel them due to lack of “know-how” and the extensive depreciation period.

According to *Mordor Intelligence*, WtE market share is dominated from thermal technologies, as we observe in *figure 5*. Close to 80% of the total market share is mainly based on thermal technology, then physical technology with more than 10%. Finally, biological approaches are implemented with a portion less than 10%.

Figure 5: Waste to Energy Market Share.



Source: (Mordor Intelligence).

In *table 2*, there is a whole presentation how to convert waste biomass to energy through different approaches. As we could observe, biochemical approaches such as anaerobic digestion and fermentation produce ethanol and biogas. Then, thermochemical approaches like pyrolysis, gasification, plasma techno, torrefaction and liquefaction produce syngas as liquid fuel for combustion and char as solid fuel. Moreover, thermal technology *(fig.5)* such as incineration directly leads to thermal energy when mechanical technology leads to RDF and solid fuel.

Table 2: Total Chain Analysis from Waste to Energy through different approaches.

WtE category	***Approach-Technology***	***1st Product***	***Final Product***
Biochemical	*Anaerobic digestion*	*Biogas*	*Thermal energy (combustion)*
	Fermentation	*Ethanol*	*Thermal energy (combustion)*
Thermo-chemical	*Liquefaction*	*Syngas*	*Thermal energy (combustion)*
	Pyrolysis	*Pyrolysis oil*	*Thermal energy (combustion)*
	Gasification	*Syngas*	*Thermal energy (combustion)*
	Plasma technology	*Syngas*	*Thermal energy (combustion)*

	Torrefaction	*Char*	*Thermal energy (combustion)*
Mechanical	*Pulverization & drying*	*RDF*	*Thermal energy (combustion)*
Thermal	*Incineration*		*Thermal energy*

Source: (Gumisiriza et al., 2017).

More details about these approaches. Thermal technologies:

Gasification: produces combustible gas, hydrogen, synthetic fuels. The resulting gas mixture is named syngas due to the flammability of the H_2 and CO of which the gas is largely composed. Power can be derived from the combustion of the gas and is considered to be a source of renewable energy *(NNFCC project, 2009).*

Thermal depolymerization: produces synthetic crude oil, which can be further refined. **Pyrolysis:** produces combustible tar and chars. Pyrolysis is most commonly used in the treatment of organic materials. In general, pyrolysis of organic substances produces volatile products and leaves a solid scrap. Pyrolysis is considered as the first level in the processes of gasification and combustion *(Hui Zhou, 2017).*

Plasma arc gasification or plasma gasification process: produces rich syngas including hydrogen and carbon monoxide usable for fuel cells or generating electricity.

Non-thermal technologies:

Anaerobic digestion: is a process by which bacteria break down biodegradable material in the absence of oxygen. The process is used for industrial and domestic reasons to manage waste. Anaerobic digestion is widely implemented across the world. The process produces a biogas, consisting of methane, carbon dioxide, and traces of by-products. This biogas can be used directly as fuel, in combined heat and power gas engines *(clarke-energy.com).*

Fermentation production: is a metabolic process that trigger changes in organic substrates because of the enzymes. Defined as the extraction of energy from carbohydrates in the absence of oxygen *(Y. H. Hui, 2004).*

Direct thermal treatment:

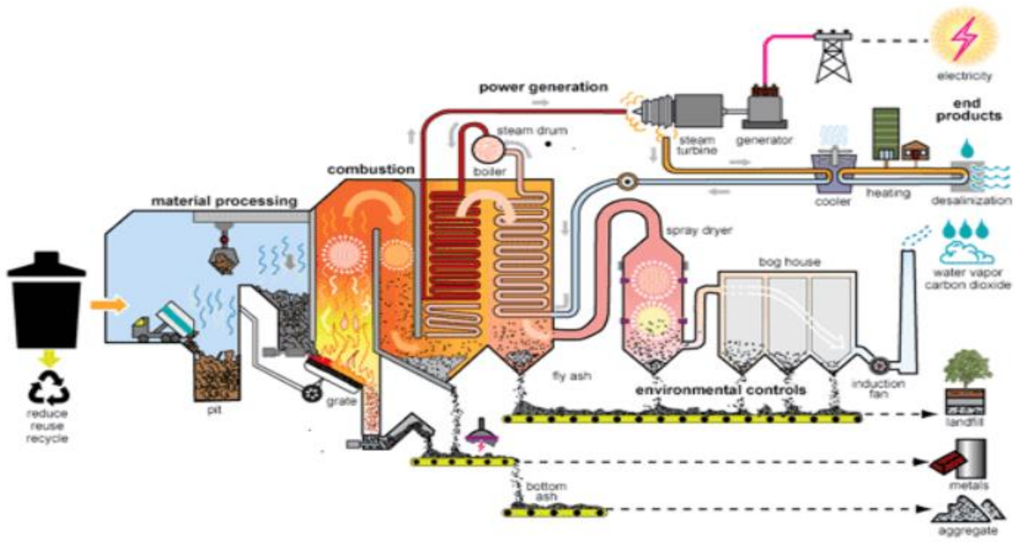
Incineration: The method of incineration which convert municipal solid waste (MSW) is a relatively old method. Incineration generally implies burning waste to boil water which powers steam generators. That generates electric energy and heat which will be used in homes, businesses and industries *(eia.gov).*

Incineration Process

The process of generating electricity in a mass-burn waste-to-energy plant (*fig.6)* has seven stages:

1. Waste is collected from garbage trucks into a large pit.
2. A giant claw grabs waste and puts that in a chamber.
3. The waste is burned causing heat release.
4. The heat change water into steam in a boiler.
5. The high-pressure steam turns on the turbine generator to produce electricity.
6. An air pollution control system removes pollutants from the combustion gas before it is released.
7. Ash is collected from the air control system.

Figure 6: Waste to Energy plant.



A mass-burn waste-to-energy plant

Source: (eia.gov).

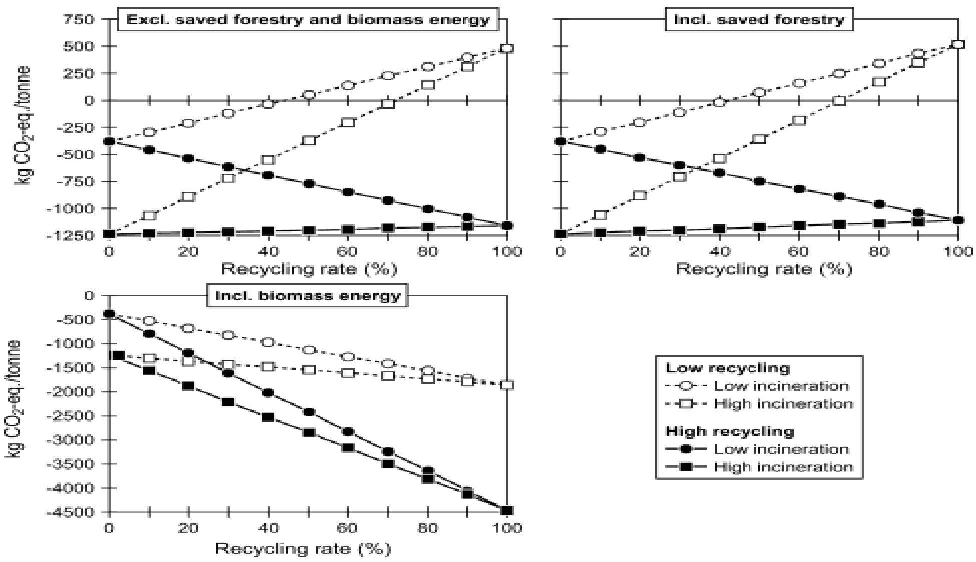
Upgraded WtE plant-model

After recent technological upgrades, metals such as zinc, iron, lead, copper, aluminum are recoverable from fly ashes, either by wet-chemical or thermo-chemical processes. For example, a full-scale plant is in operation in Switzerland recovering zinc by extraction and electrolysis. In addition, a mixture of cadmium, lead, and copper is recovered in the same way. It remains to be seen how economically and environmentally profitable these new concepts will be when implemented on a commercial scale.

In modern societies, energy from MSW amounts to over 5% of the total energy demand. The effective utilization of this energy could possibly reduce the demand of other energy carriers such as fossil fuels *(Waste and Resource Action Programme, 2006).* To reach the maximum efficiency and accomplish the green transition, we have to identify which method is preferable for each material.

Searching for the best way to implement green energy, recent review studying nine studies concluded that recycling of waste paper was preferable to landfilling and favorable to the current mix of land filling and incineration (20–30% incineration and 70–80% landfilling), while the comparisons between recycling and incineration of paper showed mixed results depending on what issues were studied *(table 3).*

Table 3: Results of mix strategy incineration-recycling.



Source: (Hanna Merrild, 2008).

Comparing recycling and incineration, our choice is highly dependent on both the level of recycling technology or the level of incineration technology. The combination with an increased benefit *(table 3)* is the one of a high-level recycling technology combined with low-level incineration technology for paper waste *(Hanna Merrild, 2008).* The results from the modeling of several reprocessing technologies show that the choice of technologies for waste paper can have a positive impact on the result of an LCA *(Hanna Merrild, 2008).*

2.2. Boundaries for WtE sector

On a technical level, many factors influence the adoption of waste heat streams. Besides inappropriate temperature levels, there is often a discord between supply and demand by time and location. Moreover, financial barriers like high capital investment and economic volatility could affect the waste heat utilization. The major target is to supply the energy demand at an appropriate level. Taking the example of household heating, content is burnt to heat water and space to temperatures of up to 70 °C and 80 °C. Such heat demand could be provided by a waste heat source below 100 °C. These power densities of energy production have to be compared with the power density of energy consumption. At the most populated areas, such as the UK, Germany and Japan, this is above 1 watt per square meter. To explain that, powering these economies exclusively with biomass will require two times more land than they have.

A similar example with bioethanol in the US. Moving to 100% bioethanol would require a land mass of roughly the size of the US to be converted over to bioethanol, sounds very unlikely. These barriers mean that it is no feasible that bioenergy can provide anywhere close to the majority of the global energy needs. Also, more obstacles exist for MSW treatment. Especially, some main negatives for MSW treatment are: relatively low energy content (If the calorific value is < 7 MJ/kg due to humidity, for all combustion technologies the minimum acceptable humidity should be clarified), high moisture content, diverse elemental composition, competitiveness of electricity markets, public education, limitations, and need for stable long-term flow.

2.3. European Union's instructions

The recent plan presented that the transition to a circular economy requires action throughout a life-cycle assessment: from production to the creation of markets. Waste management is one of the main areas where further steps must be done. Achieving these objectives can create opportunities, jobs, improve raw materials industry and reassure European leadership in the green sector *(EC, 2015).* A circular economy should lead to lower energy consumption, lower emissions and lower use of fossil fuels. This means that the circular economy has strong synergies with the EU's objectives on climate policy. More than 2000 million tons of non-hazardous waste have been generated in the EU from various economic activities, with additional 100 million tons of hazardous waste in 2015. These tremendous amounts have to be recycled or combusted.

On the other hand, biomass availability, competition between the alternative uses of biomass, as well as sustainability issues are major concerns for bioenergy which derived from WtE method. Despite these concerns, waste incineration is a mainstream option in Norway, Denmark, Sweden and Germany, as a significant share of the waste treatment selections *(Eurostat).* Although municipal waste represents only around 10% of total waste generated in the EU *(Eurostat),* it is feasible that prevention of this waste has the potential to reduce the environmental footprint not only during the consumption and the waste phases but also throughout the life-cycle assessment (LCA). Countries which have developed efficient municipal waste management systems generally perform better in overall waste management *(EC, 2015).*

One of the success stories in Europe is the increase in the recycling rates of municipal waste. European countries achieved an average total recycling rate of 33% in 2014, compared with 23% in 2004 *(EC, 2015)*. The output of environmental goods and services per unit of gross domestic product has grown by 50 % over the last decade and the employment linked to this production has risen to more than 4 million full-time equivalents. In 2015, the European

Commission proposed new targets for the municipal waste of 60% recycling and preparing for reuse by 2025 and 65% by 2030 *(EEA, 2017).*

On a global scale, the *World Bank* has estimated that over the next 10 years, 6 trillion euros will be invested in clean technologies in developing countries. Although, they only account for a small percent of the world's population, high-income countries generate about 30%, of the world's waste. In Japan, South Korea, Turkey and the EU-27 more than half of all energy needs were met by imports in 2017. Opposite results in the US, China and Brazil. Before going forward to the analysis, we have to explore and compare data and facts from similar reports and publications.

3. Literature review

Similar reports

Study	**Period**	**Source**	**Sample**	**Findings**
Assessment of waste incineration capacity and waste shipments in Europe.	2017	*Eurostat, EEA.*	*EU-28*	2010 - 2014, the incineration capacity in the EU-28 countries increased by 6%. Incineration capacity for municipal waste is unevenly spread. Germany, France, the Netherlands, Sweden, Italy and the UK account for the majority of the EU's incineration capacity. Sweden and Denmark have the highest per capita incineration capacity, followed by the Netherlands, Austria and Belgium**.** In contrast, the southern and eastern parts of the EU are highly dependent on landfill.
Municipal solid waste management and waste-to-energy in the context of a circular economy and energy recycling in Europe.	2017	*Eurostat, EEA, governments.*	*Estonia, Greece, Italy, Latvia, Lithuania, Norway, Poland, Slovenia, Spain, and the UK.*	Biggest proportion of waste (above the EU average) was generated in Italy, Greece, and the UK. Landfilling is still a problem in most countries, especially in Greece and Latvia, followed by Spain. Intensive recent progress in Lithuania and Poland with new WtE plants underway.
Waste-to-energy status in Serbia.	2015	*Ministry of Education, Science and Technological Development*	*Serbia*	Serbia has a total energy dependence of 40% which is considered average when compared to other EU countries. Waste-to-energy processes have been attempted at

		of the Republic of Serbia.		various Serbian cities numerous times but with no success. Negative public opinion about incineration sector. No incineration in Serbia, similar with the most eastern European countries.
A life cycle approach to the management of household food waste – A Swedish full-scale case study.	2011	*Malmö Municipal Housing Company (MKB), Malmö Waste Department (VA SYD) and Southern Scania Waste Management (SYSAV).*	*Sweden*	Use of produced biogas as car fuel has shown to be more beneficial than if used for production of electricity and heat. Participation of households is crucial to a successful system of waste for biological treatment. Incorrect sorting can reduce process efficiency. Acidification and enrichment are significant for footprint.
Status and Opportunities for Energy Recovery from Municipal Solid Waste in Europe	2018	*Eurostat's Environmental Data Centre on Waste.*	*EU-28*	More than 2000 million tons of non-hazardous waste have been generated in the EU from various economic activities in 2015. Among different treatment options, waste recycling has become the first treatment option at EU level with 69 million tons, followed by incineration with 64 million tons and landfilling with 62 million tons. Major MSW producers are Germany, France, UK and Italy. In incineration sector, Germany is the leading country with, followed by France and UK. Large amounts of waste with no other uses are landfilled every year in most of European countries.
Integrated assessment of a new Waste-to-Energy facility in Central Greece in the context of regional perspectives	2010	*Multi criteria assessment of Regional Management Scenarios.*	*Greece*	From 4 different scenarios it can deduced that the transportation of MSW via TS is more cost effective than direct transportation and moreover it is demonstrated that TS system could offer more cost reduction. TS=Transfer station

Municipal waste management across European countries.	2016	*EEA*	*32 EEA countries: EU-28 Member States, Iceland, Norway, Switzerland and Turkey.*	In 2014, municipal waste generation per person was highest in Denmark and Switzerland and lowest in Romania, Poland and Serbia. Germany, Austria, Belgium, Switzerland, the Netherlands and Sweden recycled at least half of their municipal waste. The highest increase in recycling rates between 2004 and 2014 was reported in Lithuania, Poland, Italy, the United Kingdom and the Czech Republic. In Austria, Belgium, Denmark, Germany, the Netherlands, Norway, Sweden and Switzerland, virtually no municipal waste is sent to landfill. On the other hand, Cyprus, Croatia, Greece, Latvia, Malta and Turkey. All the countries that show landfill rates lower than the average of 28 % have either banned landfill of municipal waste, or implemented a ban combined with a tax.

Positive green examples

Country	**Period**	**Sources**	**Findings**
Estonia	2012-2015	*(European Commission, 2017b).*	By introducing a landfill tax Estonia has moved from landfilling almost all its MSW to only 5% in 2015, whereas WtE treatment has increased from 16% up to 56% only in 2 years period.
Estonia	2008	*(EEA, 2016) (J. Malinauskaite et al., 2017a)*	Introduced a ban on the landfill of municipal waste with basic requirements to the municipalities for organizing source separation of paper and cardboard, green garden waste and hazardous waste, as well as packaging waste.
Norway	2015	*(EEA, 2016) (J. Malinauskaite et al., 2017a)*	Abolished landfill taxes in 2015, since the amount of waste being landfilled was so low that the costs for governments and businesses to implement the tax was greater than the net income.

Sweden	2016-2017	*(EEA, EC)*	Landfill tax that was imposed on 2000 and was raised in 2002, 2003 and 2006 played a crucial role in the reduction of the amount of the wastes in landfills. Crucial step in the reduction of the landfilling was the landfill ban on combustible waste on 2002 which on 2005 was expanded to include all the organic waste.
Slovenia	2001	*(EEA, 2016) (J. Malinauskaite et al., 2017a)*	Landfill tax in 2001, when the environmental tax for environmental pollution caused by waste disposal was adopted. On a positive note, many municipalities introduced a door-to-door collection system.

European Programs

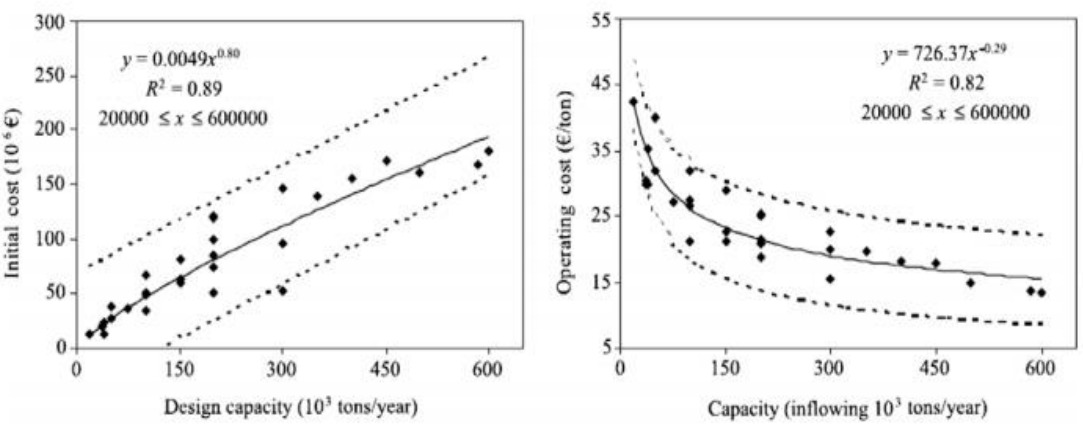
Country	**Program**	**Information**
United Kingdom	National Industrial Symbiosis Programme.	Created a market which brings together producers and users of waste. By turning pastry waste into electricity, converting fatty acids into biodiesel, they estimate that the whole program has boosted the UK economy by €3 billion.
Italy	Eco-point initiative.	Dry food sold through dispensers at Italian supermarkets reduces packaging and allows customers to buy the amount they want. Not only for environment but also for reduction cost – between 10 and 70% compared to the price of packaged goods.
Austria	Vienna waste prevention program.	Helping small firms become more eco-efficient, the promotion of re-use and repair of goods, and awareness-raising for every service. As a result, citizens can buy and sell used appliances through an online market, preventing tons of waste annually.
Portugal	Menu Dose Certa.	The pioneering Menu Dose Certa or Right-Sized Menu project aims to support

		restaurants in creating menus that generate less food waste. Porto's waste management organization LIPOR aims to reduce food waste by 50 kilos per year per restaurant client by 2011 by promoting a balanced diet.
France	Stop-Pub.	French households receive an average of 15 kg of junk mail each year, adding up to almost a million tons of waste. Operation 'Stop Pub' was launched as part of France's national waste prevention plan.
Belgium	Kringloop Re-use Centres.	*E*xtend the useful life of discarded clothes, appliances, kitchenware, furniture and bicycles. Almost 50,000 tons of discarded items were collected in 2008.

Greece

Thermal technologies of MSW, such as incineration, could treat the energy content of waste for electricity generation or combined heat and power production, where the heat is recovered and exported to industrial premises, heating, water supply and other services *(Bilitewski et al., 1997).* Usually, these processes are defined by the general term Waste-to-Energy. In *table 4,* there is a linear correlation between initial *(left)* and operating *(right)* costs with the capacity of WtE plant. Moving to higher capacity, initial cost for WtE plant is increasing in contrast to operating cost which is sharply decreasing according to this analysis.

Table 4: Operating costs for Wte plant.



Source: (Perkoulidis, 2010).

Serbia

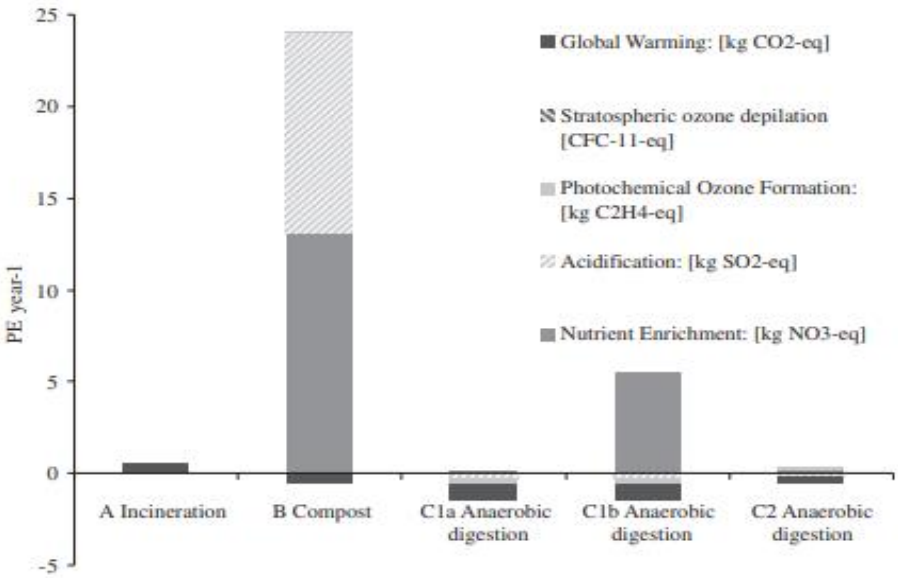
Serbia has a total energy dependence of 40% which is considered average compared to other European countries. The energy sector is a hot-issue in Serbia, mainly due to the use of domestic lignite, which is burned using old-style technology. Waste-to-energy processes have been attempted at various Serbian cities plenty of time, but without success. Several failures over the decades lead to a negative public opinion of the process as well as for the investors. The main reasons of this lack of success are the absence of a strong policy framework for waste-to-energy process and no financial planning. Recycling and landfilling are over than 90% of waste treatment in Serbia for 2011-2013 *(Bojana 2015).*

Sweden

For this analysis, 5 different scenarios were tested *(Bernstad, 2011).*
A. Food waste and organic waste are not separated and are incinerated together with residual waste in a waste incineration plant with energy recovery. Energy recovered is utilized for electricity and heat.
B. Food waste and organic waste are separated by households and treated in decentralized compost reactors. Compost produced is used to substitute garden soil.
C1. Food waste separated in bags by households. Produced biogas is upgraded and used as fuel in light vehicles (a). Digestate is used to replace commercial fertilizers (b).
C2. Analogous to C1 but the biogas produced is not upgraded.

The greatest avoidance of aggregated negative environmental impact is seen in scenario C1a *(table 5).*

Table 5: 5 different scenarios to identify best environmental treatment.



Source: (Bernstad, 2011).

The best energy balance is definitely scenario C2 while the lowest energy balance is in scenario B. The low balance in scenario B is triggered by the fact that no energy is produced in this situation. Emissions of NH_3, NH NO_x and SO_2 retain a higher weight in the overall environmental impact compared to emissions of CO_2, N_2O and CH_4. Meaning that, acidification and enrichment are significant for environmental footprint. The use of produced biogas as car fuel has shown to be more beneficial than if used for production of electricity and heat. Participation of households is crucial to a successful separation system of food waste for each treatment which means that incorrect sorting can reduce process efficiency *(Sysav, 2008).*

3.1. From landfilling to Green transition

Based on the literature review previously, the least favorable waste management method is landfilling not only for the environment but also for financial reasons. In fact, landfills were responsible for five times more GHG emissions than analysts expected. For these specific data, WtE and recycling are the most preferable methods compared to landfilling. This leads data-driven governments and corporations to create a robust plan and climate policy with the purpose to handle this fatal issue. Countries with a certain environmental strategy display a different profile not only for green targets but also for competitiveness and innovation *(fig.7).*

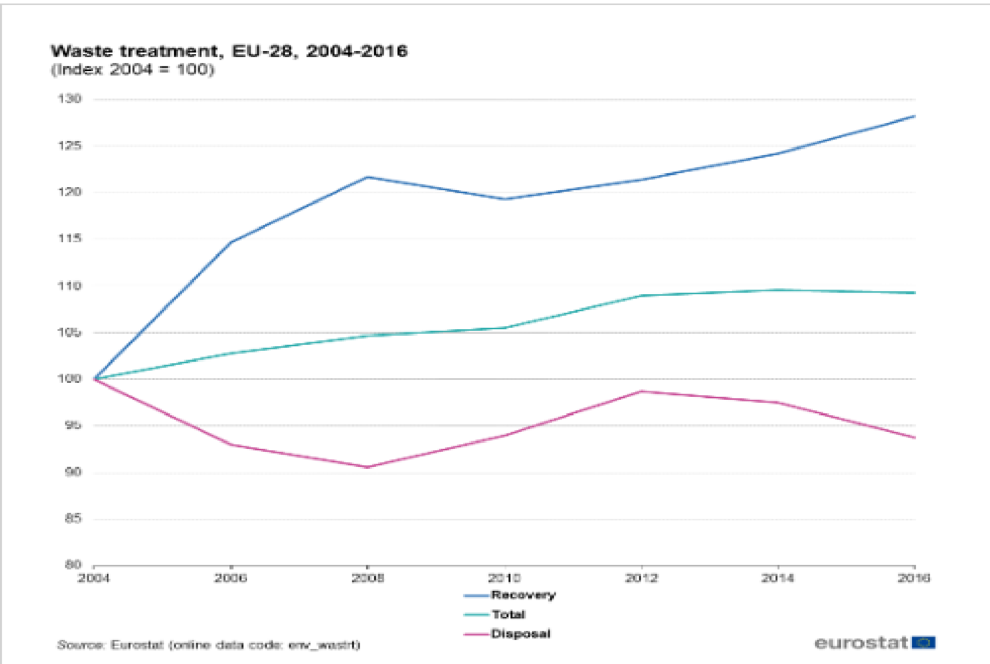
In figure 7, according to EEA's analysis, there is a high association between competitiveness and robust environmental policies which is in coordination with the literature review previously. Denmark, Sweden, Norway, Germany, Finland, UK and the Netherlands with core strategy for environment present a totally different profile compared to Slovakia, Hungary and Greece.

Figure 7: Environmental policy is associated with competitiveness and more eco-innovation.

Source: (EEA, 2016).

Having a strict environmental policy, leads to the fact that recycling and WtE inevitably will reach higher marks than landfilling through time. In addition to that, recycling is declared several times as the most preferable method in Europe. In *figure 8*, there is a trend analysis which express the massive increase of recycling especially after 2004, when at the same time, there is a huge drop in disposal.

Figure 8: EU Waste treatment.



Source: (Eurostat).

3.2. Sustainable Development Goals (SDG)

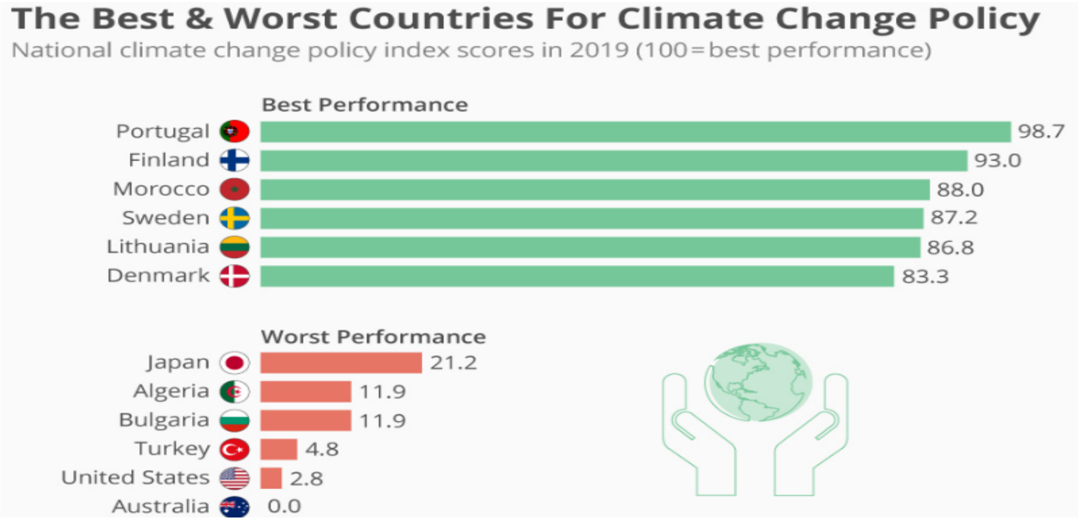
European union and United Nations are two of the main ambassadors who strongly believe in SDG goals *(fig.9).* SDG are 17 common goals for everyone with the aim to eliminate and decrease some basic problems such as poverty, hunger, inequalities, climate change and clean sustainable energy. For example, recycling *(fig.8)* was boosted because of the establishment of renewable targets. In contrast to this, SDG Index reveals that OECD countries face major challenges in meeting several SDGs, mostly on sustainable consumption and production (12), climate change (13), clean energy (7) and ecosystem conservation (14,15). Recent results display that high-income countries tend to generate negative SDG spillover effects for poorer developing countries.

Figure 9: SDG goals.

Source: (europa.eu).

For achieving green targets, governments should follow a certain well-organized climate policy. Especially, in *figure 10,* there is a supporting evidence that countries like Finland, Sweden, Denmark and Lithuania are the highlighted green examples related to environmental issues.

Figure 10: Climate Change Policy.



Source: (Statista).

According to estimates, about 30% of the EU's target for renewable energy in transport could be attained by using biogas produced from waste, while around 2% of the EU's overall renewable energy target could be achieved if whole waste was turned into energy. Compost from waste can also improve the soil's quality, replacing chemical fertilizers. In 1995, more than 13 million tons of municipal waste were composted in Europe. By 2008, this had reached over 40 million tones, accounting for 17% of municipal waste.

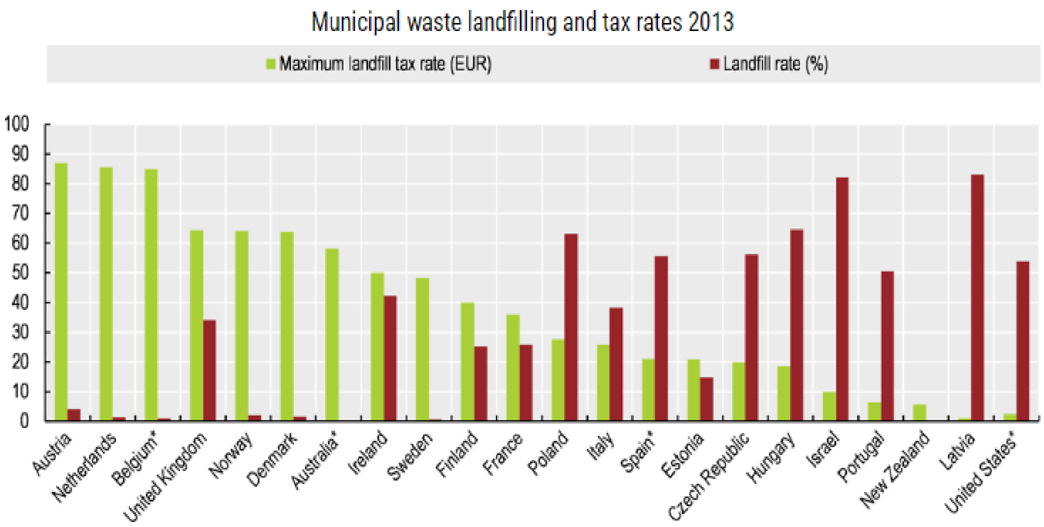
For accomplishing SDG goals and implement effective environmental policy, governments and corporations have to use financial tools such as environmental (green) taxes, incentives and redefined strategy. To specify, environmental taxes contain a wide spectrum which consists of landfilling taxes *(fig.11,12),* incineration taxes, Co2 taxes, recycling deductive and more.

3.3. Green taxes' data

To achieve SDG and attain a robust green policy, we have to implement certain financial measures. The most common measure is to carry out taxes. Basically, the implementation of landfilling taxes has been decided by governments and not by a certain core European consortium. This fact triggered two different pathways for countries which applied taxes and countries which did not apply. In *figure 11 and 12*, there is a distinction between countries which chose high landfill taxes having as a result lower landfill rates and the other group of countries which have the opposite results. From 2013 to 2017 top-listed are the same group of 5-6 countries which bring us to the conclusion that other countries, despite the fact that they should, do not implement higher environmental taxes to eliminate landfilling *(Statista).*

In *figure 11*, there is a clear distinction between countries based on landfill tax rate. Austria, the Netherlands, Belgium and northern European countries follow a strict tax plan against landfilling in comparison with east Europe and southern countries in 2013.

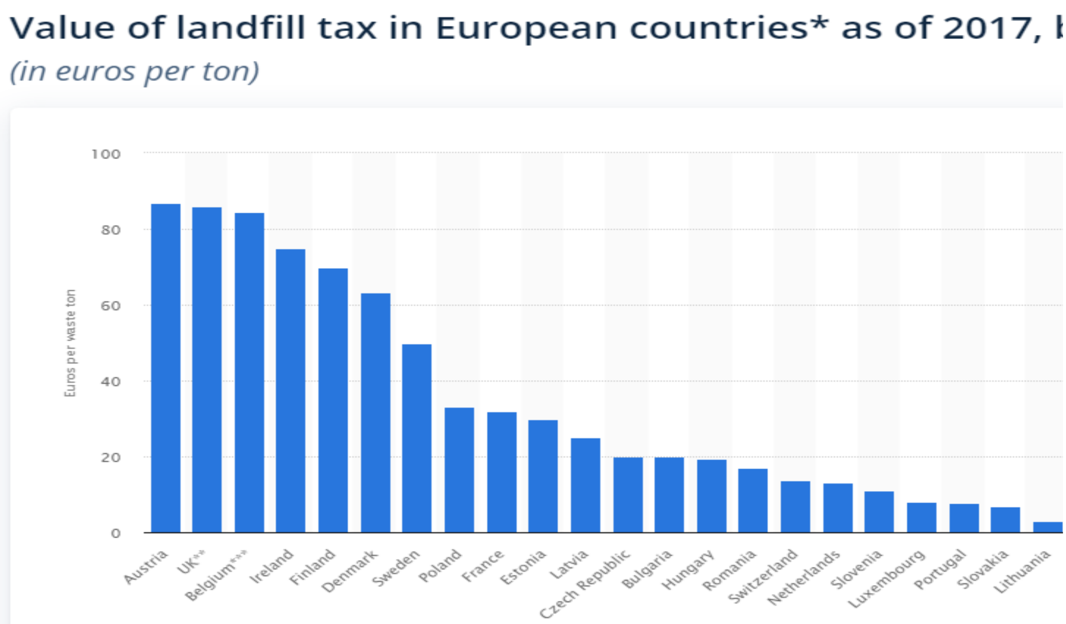
Figure 11: Landfilling taxes in 2013 for European countries.



Source: (Statista).

Furthermore, in *figure 12*, we can observe the value of landfill taxes in European countries in 2017. Countries such as Austria, Belgium, Denmark and Sweden remain at the top of this list with the passing of the years.

Figure 12: Landfilling taxes (value) in 2017 for European countries.



Source: (Statista).

There is a straight-forward distinction between European countries based primarily on country's financial status and secondly on location. Scandinavian countries along with UK and Germany were the early adopters of green transition before 2010. Recently, small countries with emerging economy like Estonia, Lithuania and Poland followed this pattern, improving their previous status *(fig.11,12).*

On the other hand, no-taxes policy is adopted by many European countries. For instance, Malta, Greece and Croatia still landfill the majority of their generated waste. Croatia, Greece, Iceland, Malta, Romania, and Turkey are the main countries with no WtE and recycling plan. Based on the current literature review, we have to clarify and justify the reasons which trigger this distinction between countries. This leads us to made 3 different hypotheses in purpose to find answers to certain financial questions.

4. Research hypotheses

In this thesis, we tested 3 different hypotheses to find out how financial factors such as GDP and environmental taxes affect, positive or negative, the green energy sector such as waste treatment methods and Wte plants. The data is collected on an annual basis *(for hyp.2-3)* and covers the periods 2003-2019 *(hyp.1)*, 2010-2018 *(hyp.2)* and 2010-2015 *(hyp.3)*. The main purpose is to investigate possible correlations between these factors applying the multivariate model. Our purpose was to identify the basic financial clue which boost the green transition. Also, which reasons lead each country to follow each pathway either recycling or incineration.

This analysis examines data and facts about waste management and bioenergy. Our research is mainly based on Panel Data and Time Series analysis with descriptive statistics. The econometrical data analysis was executed on a sectoral basis and comparative study for European countries, at first, and for US secondly. Different hypotheses about crucial financial factors such as waste treatment methods and GDP per capita so as to examine the impact on the whole renewable sector especially for waste to energy methods.

The scope of this analysis is to clarify which factors contribute to the green transition in the Europe. The main contribution is to clearly present the relationship between waste treatment methods, the Wte sector and the renewable sector. The well-known necessity for an energy transition to a green sustainable framework especially for Europe was the motivation which led to this analysis. This correlation was underestimated and not properly examined from previous reports so we decided to deep dive into the interactions of these sectors.

3 hypotheses so as to find answers in the following questions:

Hypothesis 1: Does GDP's change affect Wte sector's growth? GDP's change has a positive or negative effect on Wte plants?

Hypothesis 2: Do green taxes and waste generation affect the main waste treatment methods?

Hypothesis 3: Do green taxes and GDP affect Wte plants and renewables' energy consumption?

Hypothesis 1. We examine the change in Wte Plants in certain years such as 2003, 2010, 2012, 2017 and 2019. Also, we examine the whole GDP change (%) from 2003 to 2019 for 22 countries. Countries: *Austria, Belgium, Czechia, Denmark, Estonia, France, Germany, Hungary, Italy, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Slovakia, Spain, United Kingdom, United States of America, Norway, Finland, Sweden and Switzerland.*

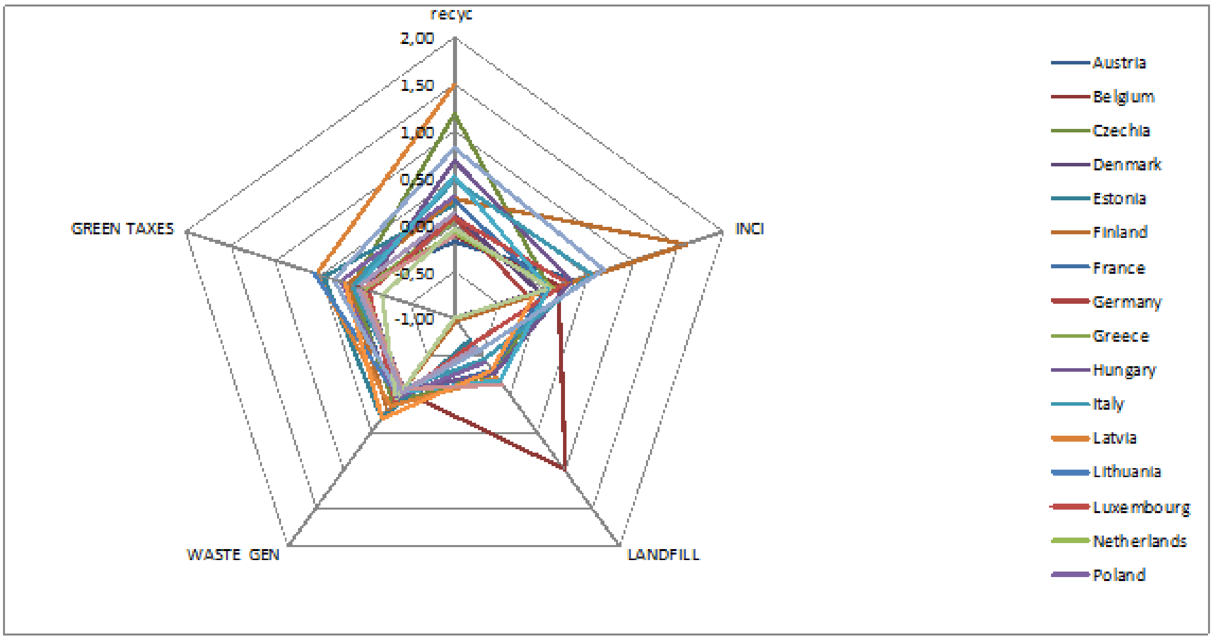
Sources*: (gebi2010/psomopoulos2009), (isa bioenergy), (Waste to Energy/ ISWA / 2012), (cewep), (Sandbox Climate change) and (world bank).* These were related with 2003 plants, 2010 plants, 2012 plants, 2017 plants, 2019 plants and GDP per capita(pc).

Hypothesis 2. We examine 5 different factors such as recycling, landfilling, incineration, waste generation and environmental green taxes for every year between 2010 to 2018 for 19 European countries. Countries: *Austria, Belgium, Czechia, Denmark, Estonia, France, Germany, Hungary, Italy, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden and United Kingdom.*

Sources: *Eurostat, cewep and OECD.*

In *table 6*, we identify countries' profile based on 5 factors which are waste generation, green taxes, incineration, landfilling and recycling for each country. Most countries follow the same pattern in green taxes and waste generation *(both negatives on average)*, although follow different strategies in recycling and incineration.

Table 6: European countries' profiles according to 5 factors.



Sources: (Eurostat, cewep and OECD).

Hypothesis 3. We examine 4 factors: Wte plants, GDP per capita, green environmental taxes and renewables' energy consumption {% of total} for every year between 2010 to 2015 for 19 European countries. Countries: *Austria, Belgium, Czechia, Denmark, Estonia, Finland, France, Germany, Hungary, Italy, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Slovakia, Spain, Sweden and the United Kingdom.*

Sources: *World Bank, OECD and cewep.*

Data uncertainties

One main problem in this analysis was the missing data. Countries and governments do not implement a robust plan about waste management as well as the renewable sector are under constant modification and evolvement.

As a result, when you decide to search about this sector, your study will be limited by barriers and obstacles. Our biggest problem was the missing data from OECD after 2015 and a small portion of uncertainties from the World bank for specific countries.

4.1. Methodology

For this holistic analysis, we made 3 different hypotheses to determine the effects and correlation between factors around the green economy. We collect data across the Europe including the most countries in 3 hypotheses and the USA for Hypothesis 1. Using STATA Programme and Microsoft Excel to find the necessary statistics and graphs.

The problem was to find out how GDP, renewable trend and waste management options influence or not the establishment of Wte plants in European countries. Our purpose is to examine the possible correlation between these factors and compare our results with other papers. Mathematical model: OLS model and fixed-effects OLS model.

Ordinary least squares (OLS) regression is a statistical method of analysis that estimates the relation between one or more independent variables and a dependent variable. The method estimates the connection by minimizing the sum of the squares in the difference between the observed and predicted values of the dependent variable configured as a straight line. The logic of OLS regression is easily extended to the multivariate model in which there are two or more independent variables *(Zdaniuk, 2014).*

Ordinary Least Squares regression (**OLS**) is well-known as linear regression (simple or multiple depending on the number of variables).

In the case of a model with p explanatory variables, the OLS regression model:

$Y = \beta_0 + \Sigma_{j=1..p} \beta_j X_j + \varepsilon$

where Y is the dependent variable,

β_0, is the intercept of the model,

X_j corresponds to the j^{th} explanatory variable of the model (j= 1 to p)

and e is the random error with expectation 0 and variance σ^2.

In the case where there are n observations, the estimation of the predicted value of the dependent variable Y for the i^{th} observation is given by:

$y_i = \beta_0 + \Sigma_{j=1..p} \beta_j X_{ij}$

The OLS method corresponds to minimizing the sum of square differences between the observed and predicted values. This minimization leads to the following estimators of the parameters of the model:

[$\beta = (X'DX)^{-1} X' Dy$ $\sigma^2 = 1/(W - p^*) \Sigma_{i=1..n} w_i(y_i - y_i)$] where β is the vector of the estimators of the β_i parameters, X is the matrix of the explanatory variables preceded by a vector of 1s, y is the vector of the n observed values of the dependent variable, p* is the number of explanatory variables to which we add 1 if the intercept is not fixed, w_i is the weight of the i^{th} observation, and W is the sum of the w_i weights, and D is a matrix with the w_i weights on its diagonal *(xlstat).*

The vector of the predicted values can be written as follows: $y = X (X' DX)^{-1} X'Dy$.

Fixed Effects Regression.

Panel regression model.

Yit=β0+β1Xit+β2Zi+uitYit=β0+β1Xit+β2Zi+uit

where the Z_i are unobserved time-invariant heterogeneities across the entities $i=1,\dots,n i=1,\dots,n$.
We aim to estimate $\beta_1\beta_1$, the effect on Y_i of a change in X_i holding constant Z_i. Letting $\alpha_i=\beta_0+\beta_2Z_i\alpha_i=\beta_0+\beta_2Z_i$ we obtain the model $Y_{it}=\alpha_i+\beta_1X_{it}+u_{it}$. (a)

(a) $Y_{it}=\alpha_i+\beta_1X_{it}+u_{it}$. Having individual-specific intercepts $\alpha_i\alpha_i$, $i=1,\dots, n i=1,\dots, n$, where each of these can be understood as the fixed effect of entity $i i$, this model is called the *fixed effects model*. The variation in the $\alpha_i\alpha_i$, $i=1,\dots, n i=1,\dots, n$ comes from the Z_i.
(a) can be rewritten as a regression model containing $n-1$ dummy regressors and a constant:
$Y_{it}=\beta_0+\beta_1X_{it}+\gamma_2D2_i+\gamma_3D3_i+\cdots+\gamma_nDn_i+u_{it}$. (10.2)

(b) $Y_{it}=\beta_0+\beta_1X_{it}+\gamma_2D2_i+\gamma_3D3_i+\cdots+\gamma_nDn_i+u_{it}$. Model (b) has $n n$ different intercepts — one for every entity. (a) and (b) are equivalent representations of the same model.
The fixed effects model can be generalized to contain more than just one determinant of $Y Y$ that is correlated with $X X$ and changes over time. Key Concept 10.2 presents the generalized fixed effects regression model *(econometrics-with-r).*

The multivariate model is a well-known statistical tool that uses multiple variables to forecast possible results. Research analysts use multivariate models to forecast investment outcomes in different scenarios in order to understand the risk exposure which they handle. For example, this allows portfolio managers to mitigate efficiently the risks identified through the multivariate modeling analysis.

4.2 Main findings

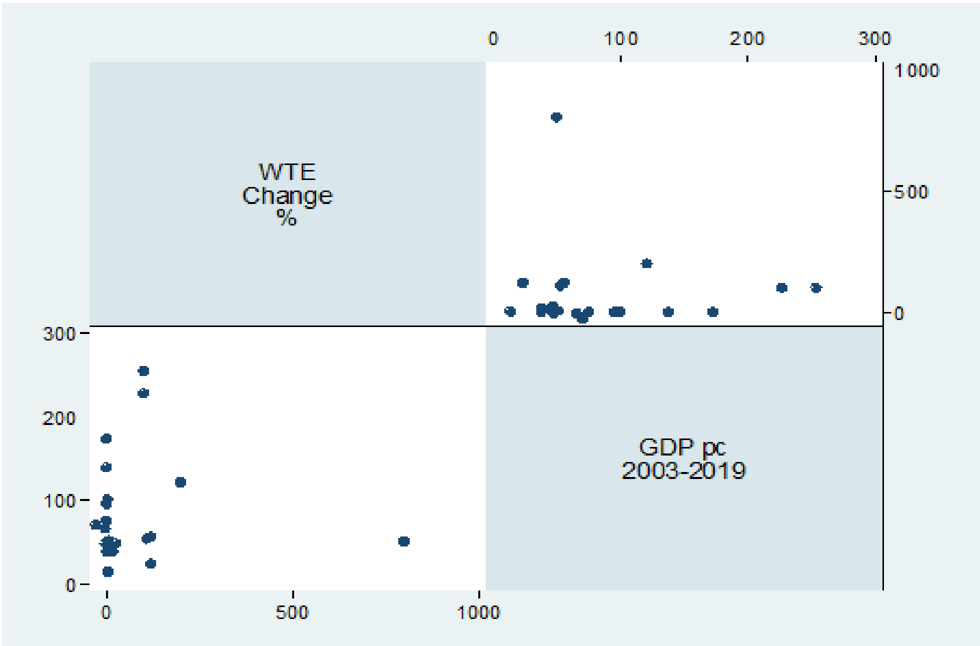
First of all, according to this analysis, developed economies in Europe do not follow an uptrend on Wte plants in contrast with emerging economies which chose a political and social swift to green energy with more Wte plants, especially after 2009-2010 crisis. GDP and Wte plants express a tiny negative correlation under this analysis which express a discord in this sector of renewables. Waste generation is an unstoppable rising trouble for most countries when at the same time incineration support the increase of waste generation. Also, green taxes have a negative effect on recycling. The most highlighted part is the flat growth for Wte plants and green taxes in Europe after 2010. A policy transformation is essential immediately if EU want to achieve clean energy transition. Renewable uptrend was not correlated with the flat trend of Wte plants which disclose that recycling is the dominant waste treatment. After 2010, European countries focus on renewables without increasing Wte plants, especially developed economies. GDP’s growth expresses a higher positive impact in Wte plants than renewables’ energy consumption which is based on the distinct between developed and emerging economies. Finally, Estonia, Lithuania and Poland are the most improved emerging countries in green energy sector.

4.3. Results

Hypothesis 1: The results reveal that European countries could be listed in 4 different groups *(fig15a-d)* according to their Wte plants' change and GDP's change. Developed economies in Europe do not follow an uptrend in contrast with emerging economies which chose a political and social swift to green energy with more Wte plants. Also, one highlighted and remarkable output is that GDP and Wte plants express a tiny negative correlation *(table8)* under this analysis which expresses a disorder for growth in renewable sector.

Despite what we expected, there is no significant signal between these 2 factors in *fig.13.*

Figure 13: Scatterplot GDP/Wte.



In *table 8*, there is a tiny negative correlation between these 2 factors. This means that WtE plants' change have not been heavily affected by any GDP's fluctuation.

Table 7: Negative correlation WtE/GDP.

	WTE	**GDP**
WTE	1	
GDP	-0.0131	1

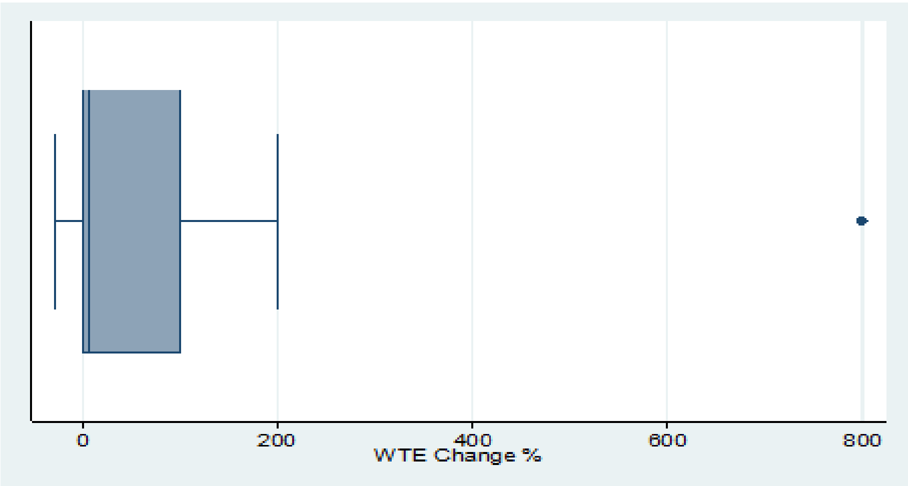
In *table 8*, there are mean, standard deviation, range, values and percentiles about GDP and WtE for hyp.1. Standard deviation and range are slightly smaller in GDP than WtE.

Table 8: Summary statistics for GDP's and Wte plants' change.

GDP	**mean**	82.85		**Unique values**	22
	Std dev	63.78		**missing**	0
	range	{13.7, 254}			
percentiles	10%	25%	50%	75%	90%
	37.9	47.1	54.5	100	173
WtE	**mean**	72.16		**Unique values**	17
	Std dev	172.91		**missing**	0
	range	{-28.5, 800}			
percentiles	10%	25%	50%	75%	90%
	-3	0	7.05	100	120

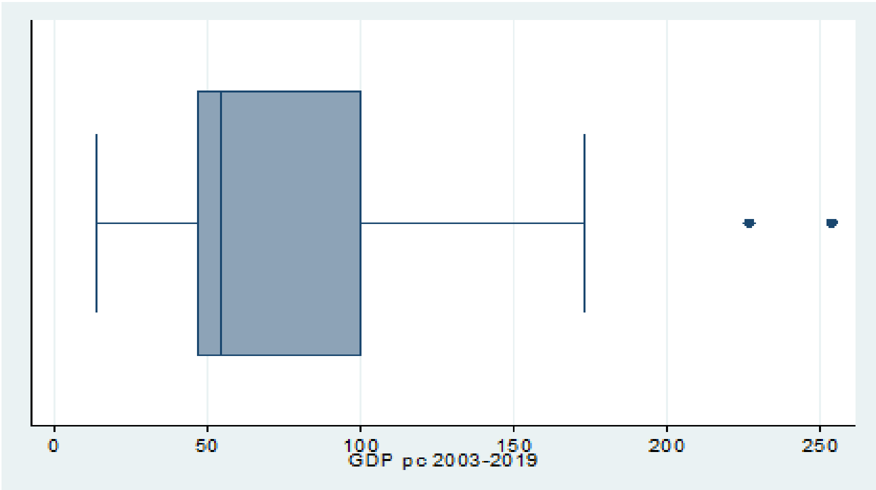
In *figure 14a*, the majority of countries move from small negative to 200% WtE change, with only one exemption. 0-100% more Wte plants at the most countries for the same period.

Figure 14a: WtE plants' change, 2003-2019.



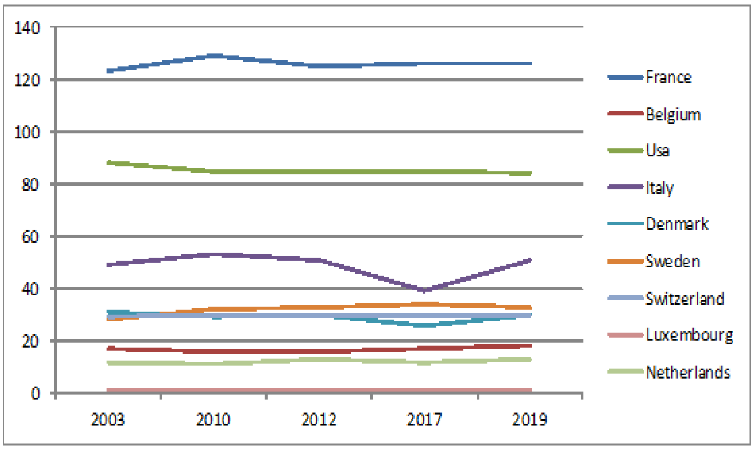
Based on the analysis, we expected to pinpoint a correlation between these 2 factors because they presented the same percentage increase, but in reality, these 2 factors did not express a positive correlation. In fact, 50-100% GDP per capita *(fig.14b)* increased at the majority of European countries. GDP in European countries display an increase for 2010-2013 and then a huge drop.

Figure 14b: GDP's change, 2003-2019.

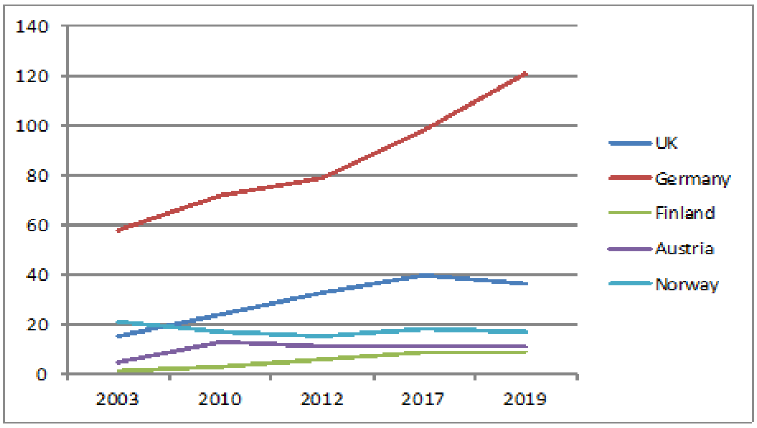


Based on WtE plants and GDP, there are 4 main different groups. According to results, countries with high GDP *(15a)* do not express higher interest in Wte plants except UK, Germany, Finland, Austria and Norway *(15b).* Countries with lower GDP express higher interest in Wte plants *(15c)* which was combined with increase in GDP over the past 17 years *(15d: 3 exceptions).*

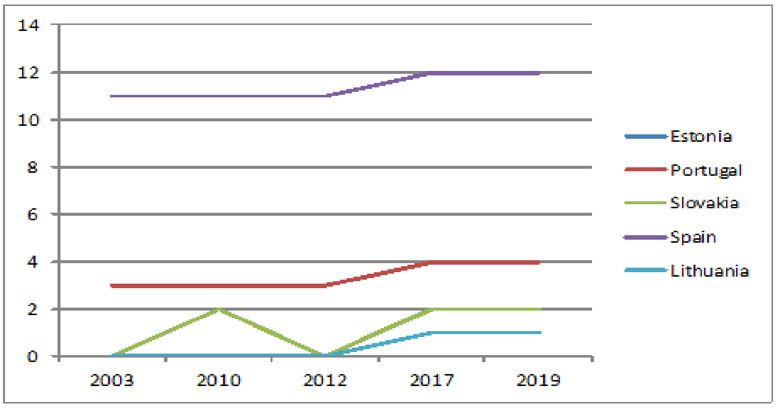
Figure 15d: Exemptions.



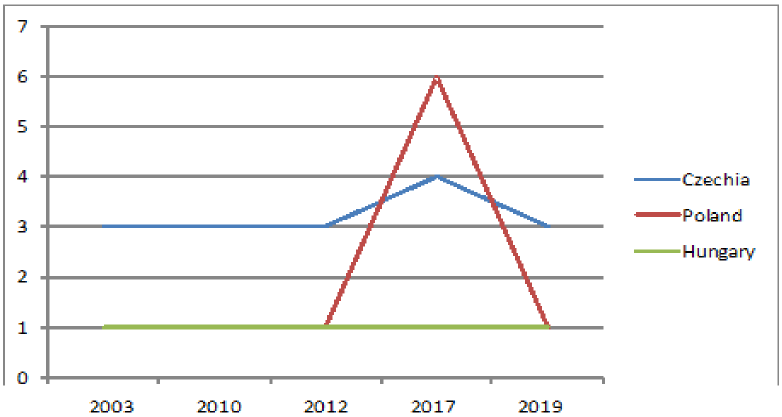
a



b



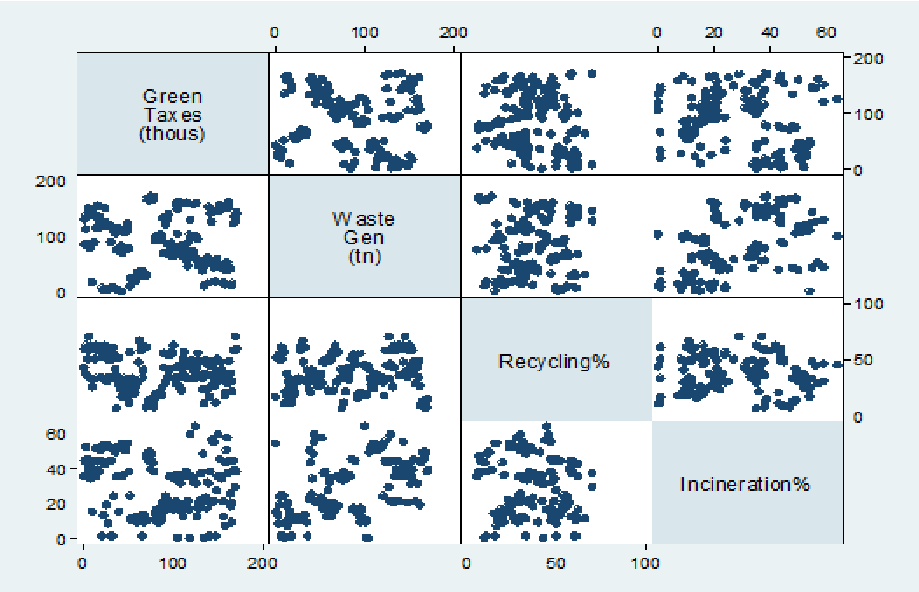
c



Hypothesis 2: Waste generation is an unstoppable rising trouble *(fig.16d)* for most countries when at the same time incineration supports the increase of waste generation *(table 11a,12b).* Also, green taxes do not have a positive effect on recycling. We examine separately countries with the aim to highlight the best overall performances in this period.

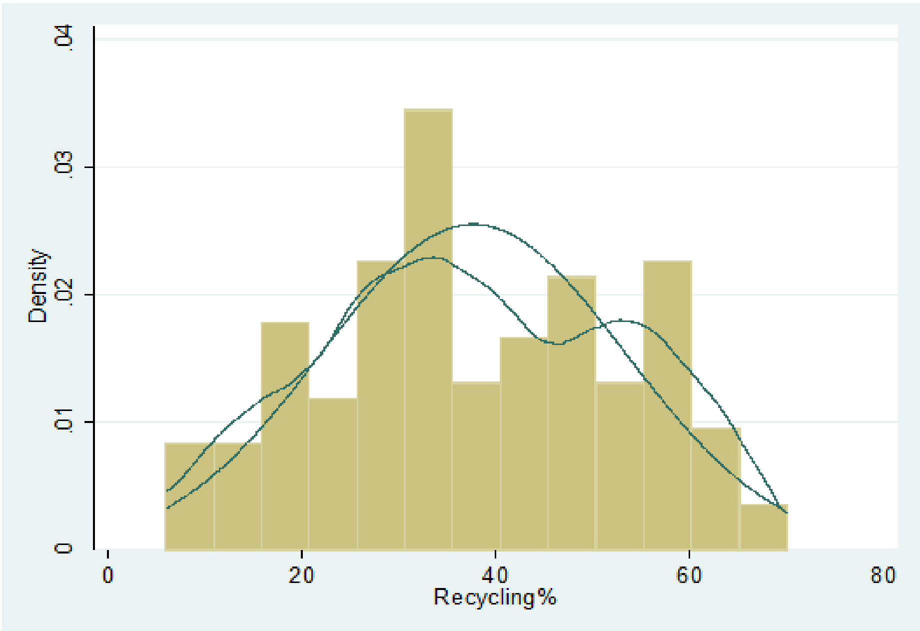
In figure *16a*, we can't extract any significant result from scatterplot.

Figure 16a: Scatter plot for green taxes, waste generation, recycling and incineration.



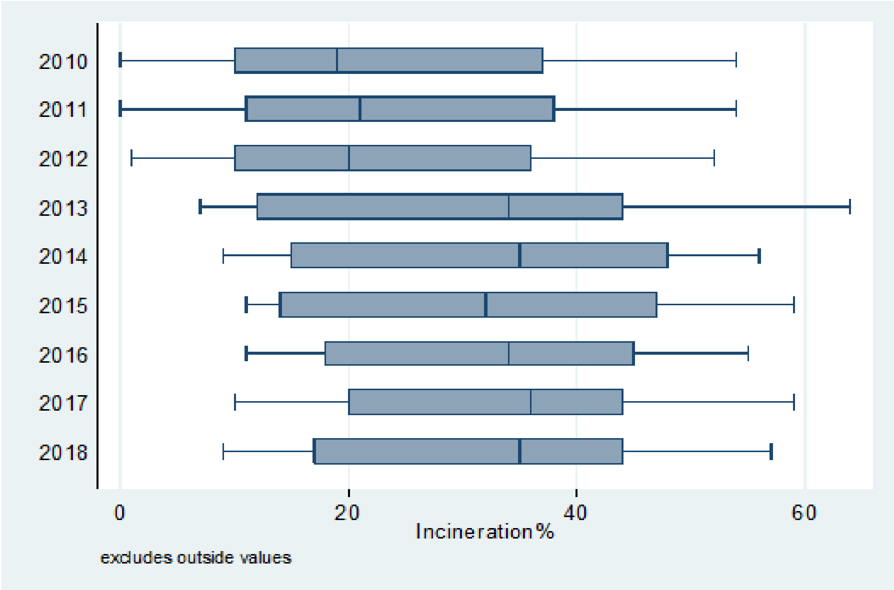
In *fig.16*, there is a 20-60% recycling rate for the majority of European countries with a peak close to 30%. In this sector, as a whole Union we have accomplished our recycling goals.

Figure 16b: Recycling (%) as a waste treatment in European countries.



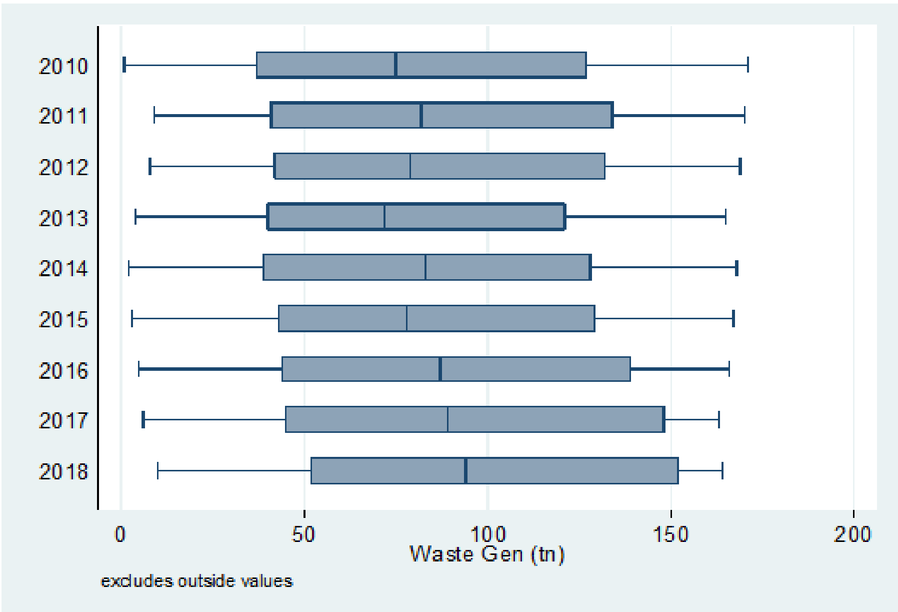
Now, let's examine Europe as a whole to understand the general trend. In *fig.16c,* there is a huge increase in incineration over this period, especially in 2013-2014.

Figure 16c: Incineration (%) as a waste treatment in European countries.



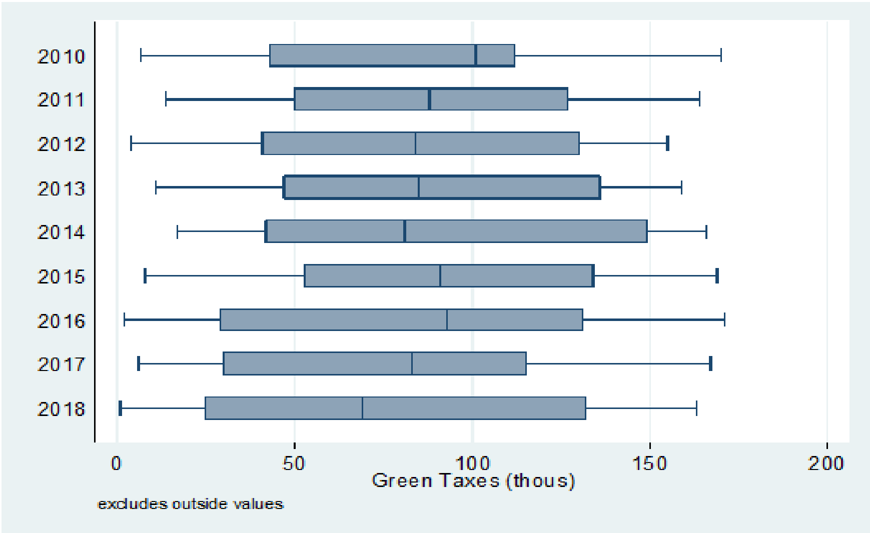
In *fig.16d*, there is a disappointing upside trend for waste generation. The imminent threat of waste is a constant issue without solving, worldwide. Few countries are the exemptions.

Figure 16d: Waste generation in European countries.



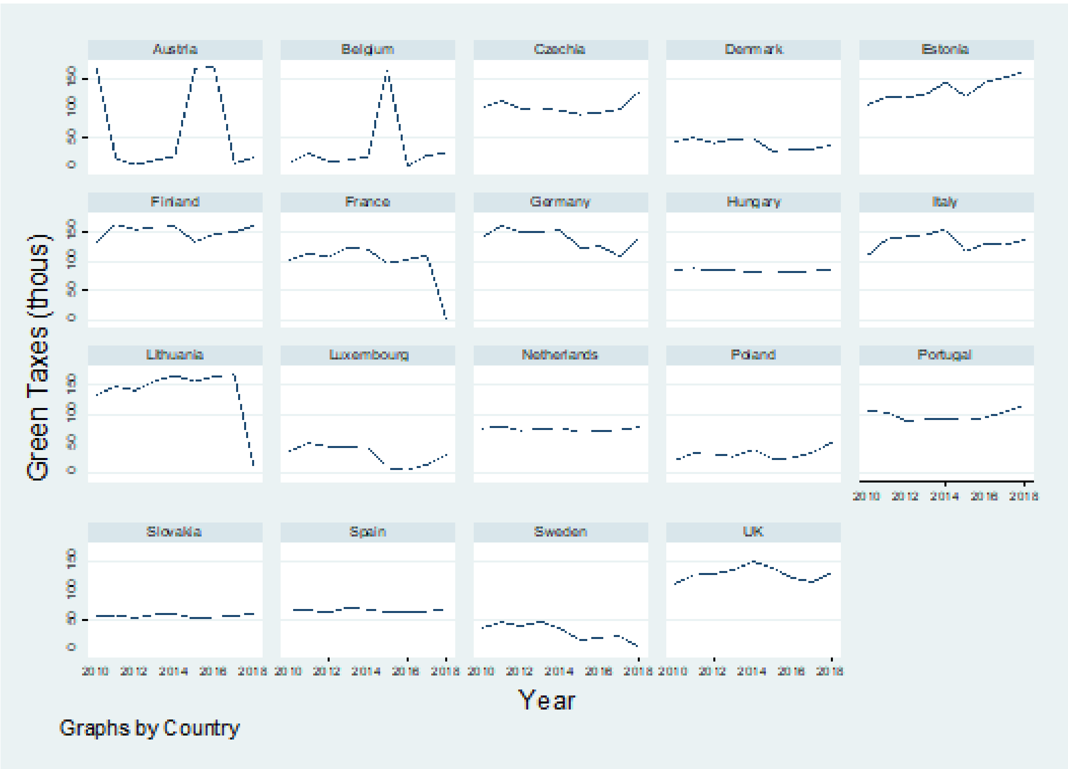
In *fig.16e*, there is a remarkable loss for Green taxes. Governments and corporations should examine alternative financial tools to accomplish the green mission because green taxes are not efficient across every community, country and mindset. New regulations have to be considered.

Figure 16e: Green taxes in European countries.



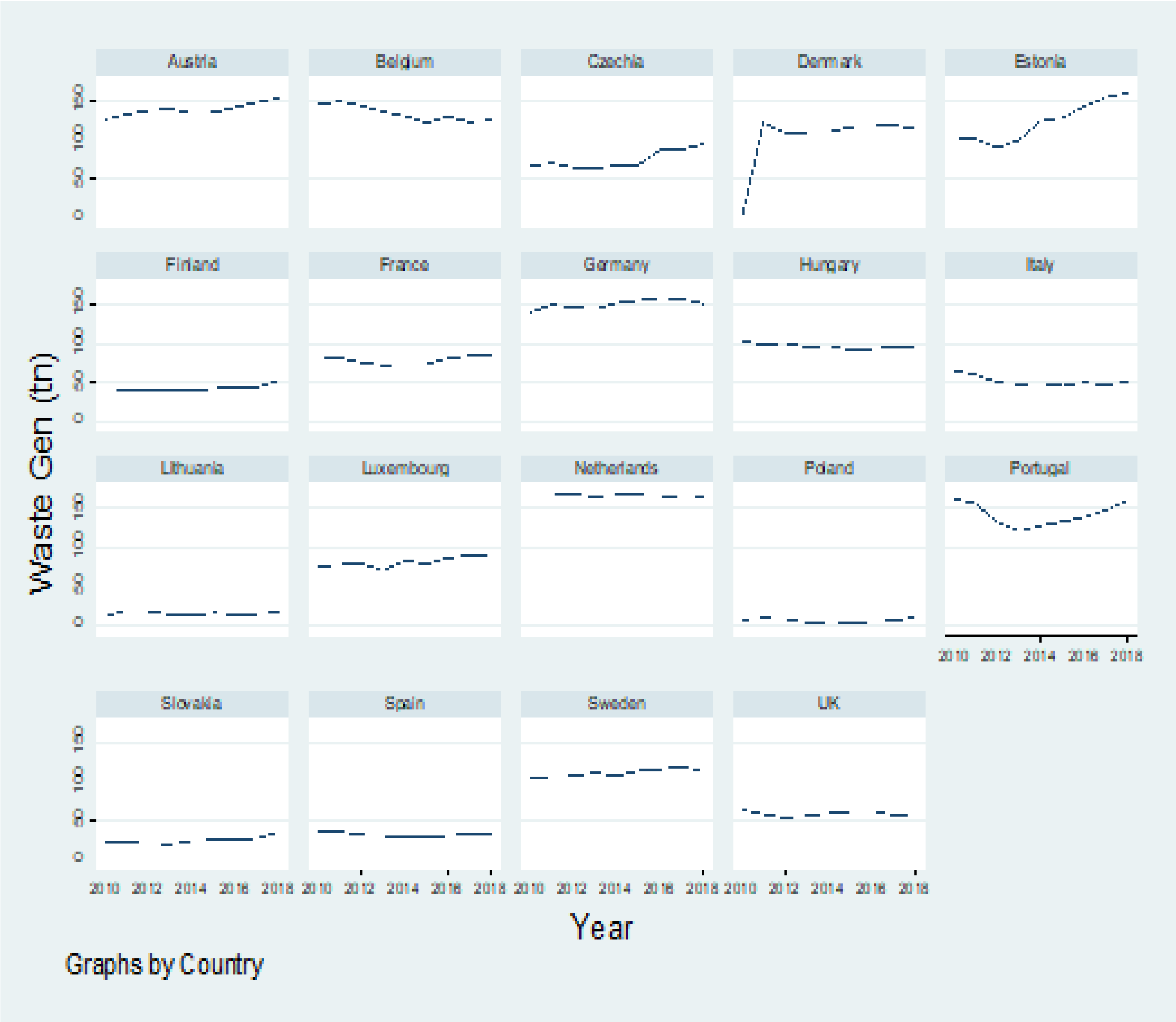
In *fig.17a*, Estonia, Finland, Germany, Czechia and UK are the top highlighted countries. Austria, Sweden, Lithuania and France are negative examples. Neutral trend for the majority of Europe in taxes' sector.

Figure 17a: Trend analysis for green taxes in Europe for 2010-2018.



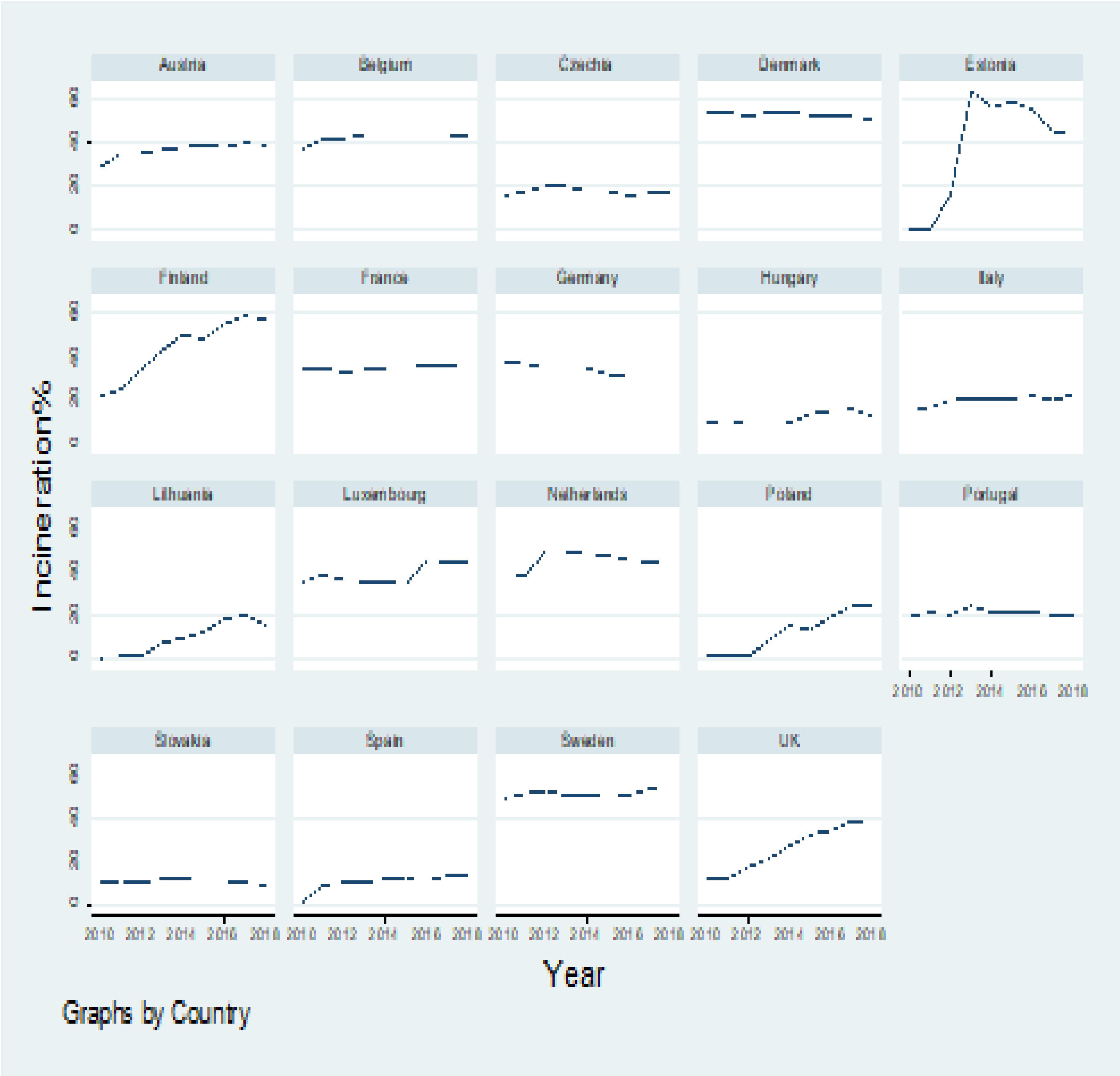
In *fig.17b,* Belgium, Hungary, Poland, Slovakia, Lithuania, UK and Spain are the top countries in reducing waste generation. UK is the only country being on positive examples for waste generation and green taxes. Most countries with high waste generation present high marks in incineration.

Figure 17b: Trend analysis for waste generation in this period in Europe for 2010-2018.



In *fig. 17c*, Estonia, Finland, Lithuania, Poland, Netherlands and UK are the top six countries in WtE sector. Estonia, Finland and UK were on top list for green taxes when Lithuania and Poland were positive examples for waste generation. Denmark, Sweden, Luxemburg and Netherlands were already at the top before 2010.

Figure 17c: Trend analysis for incineration sector in Europe for 2010-2018.



In *fig. 17d*, it is slightly difficult to find any negative trend for recycling sector. The only exemptions are countries which, were before 2010, already on the top level like Austria and Belgium.

Figure 17d: Trend analysis for recycling in Europe for 2010-2018.

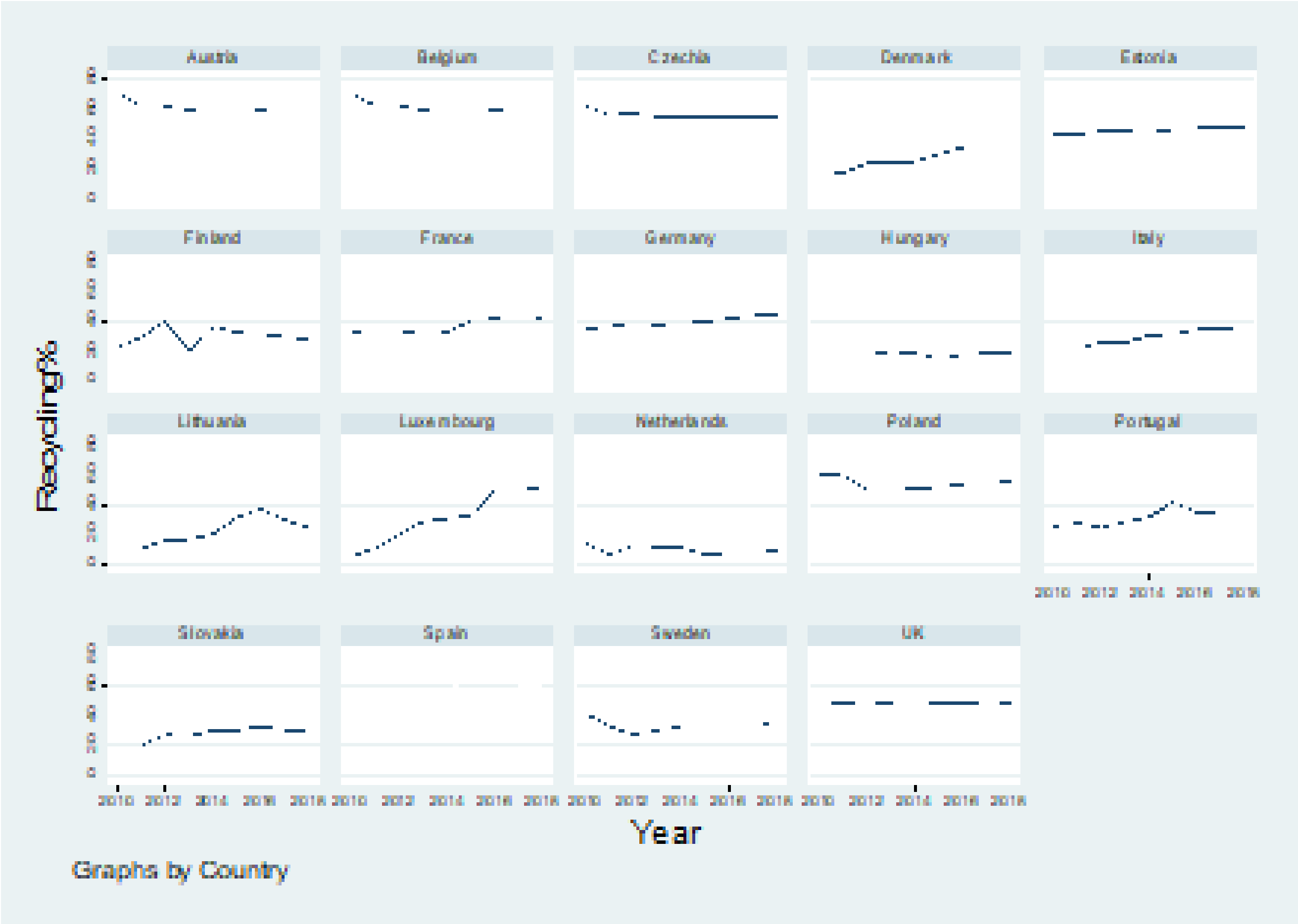


Table 9a: Summary statistics for waste genaration.

	mean	82.85		**Unique values**	171
	Std dev	49.50		**missing**	0
	range	{1, 171}			
examples	34	68	102	136	
	222221	3334	399	4836	
		Percentiles		**Small/Large**	
1%		2		1	
5%		9		2	
10%		16		2	
25%		42		4	
75%		129		165	
90%		154		169	
99%		170		171	

Table 9b: Summary statistics for recycling.

	mean	37.68		**Unique values**	57
	Std dev	15.63		**missing**	0
	range	{6, 70}			
percentiles	10%	25%	50%	75%	90%
	17	26	35	50	59

	Percentiles	**Small/Large**
1%	7	6
5%	11	7
10%	17	7
25%	26	8
75%	50	66
90%	59	70
99%	70	70

Table 9c: Summary statistics for incineration.

	mean	29.15		**Unique values**	50
	Std dev	16.26		**missing**	0
	range	{0, 64}			
percentiles	10%	25%	50%	75%	90%
	10	15	31	44	52

	Percentiles	**Small/Large**
1%	0	0
5%	1	0
10%	10	0
25%	15	1
75%	44	57
90%	52	59
99%	59	64

Table 9d: Summary statistics for green taxes.

	mean	86		**Observations**	50171
	Std dev	49.5		**missing**	0
	variance	2451		**Kurtosis**	1.79

	Percentiles	**Small/Large**
1%	2	1

5%	9	2
10%	16	3
25%	43	4
75%	129	165
90%	154	169
99%	170	171

In *table 10a*, based on linear regression, we could suppose as a possible result that 10% increase in incineration leads to 16% increase in Waste generation in 1% (high) confidence.

In other words, countries which chose incineration as a method is inevitably possible that they would count an increase also in waste generation.

Table 10a: Linear Regression with y=waste generation and x1=green taxes, x2=recycling and x3= incineration.

GEN1	**COEF.**	**STD. ERROR**	**T**	**P>T**	**CONF. INTERVAL**
Tax1	-.0008014	.068	-0.01	0.991	-.1358 .1342
Rec	-0.0453568	.204	-0.22	-.825	-.4497 .3590
Inc	1.653091	.207	7.97	0.000	1.2437 2.0624
cons	39.5774	12.776	3.10	0.002	14.3527 64.8022

In *table 10b,* based on linear regression, we could suppose as a possible result that 10% increase in green taxes leads to -0.4% decrease in Recycling in 10% confidence. This confidence level is not trusted for a statistical conclusion. Although, the increasing trend for recycling is not supported from green taxes based on these results.

Table 10b: Linear Regression with y= recycling and x1=green taxes, x2= waste generation and x3= incineration.

REC	**COEF.**	**STD. ERROR**	**T**	**P>T**	**CONF. INTERVAL**
Tax1	-.0447325	.0236	-1.80	0.061	-0.0914 0.0020
Gen1	-.006292	.0284	-0.22	0.825	-0.0624 0.0499
Inc	-.034405	.0749	-0.46	0.647	-0.1824 0.1136
cons	43.0755	3.678	11.71	0.000	35.8128 50.3382

In *table 11a*, Vif is equal to 1.03. A variance inflation factor(VIF) detects multicollinearity in regression analysis. Multicollinearity is when there's correlation between predictors in a model which can adversely affect your results. The VIF estimates how much the variance of a regression coefficient is inflated due to multicollinearity in the model. Close to vif=1 means there is no multicollinearity.

Table 11a: Multicollinearity detected with Vif.

Variable	VIF	1/VIF
tax	1.04	0.96
inc	1.02	0.97
rec	1.02	0.97
MEAN VIF	1.03	

In *table 11b*, there is only one strong positive correlation between incineration and waste generation as mentioned in *table 11a*, again. The other correlations are slightly negative, with the highest between taxes-incineration and taxes-recycling.

Table 11b: Correlation between waste generation, incineration, green taxes and recycling.

	wasteGen	Incineration	Taxes	recycl
wasteGen	1			
Incineration	0.54	1		
Taxes	-0.07	-0.13	1	
recycl	-0.02	-0.02	-0.13	1

In *table 12,* based on fixed-effects OLS model, we could suppose as a possible result that 10% increase in waste generation leads to 0.8% increase in recycling which seems a relevant conclusion (10% confidence).

Table 12: Fixed effects OLS model.

(Ln)Recycling	COEF.	STD. ERROR	T	P>T	CONF. INTERVAL
Inc	0.0332446	0.0371	0.90	0.372	-0.0401 0.1066
Tax1	-0.0427258	0.0282	-1.51	0.133	-0.0985 0.0131
Gen1	0.0812382	0.0484	1.68	0.096	-0.0146 0.1771
cons	3.326552	0.2784	11.94	0.000	2.7759 3.8771

Hypothesis 3: The most significant output was that renewable uptrend was not correlated with the flat trend of Wte plants *(fig. 19,20)* which present that recycling is the dominant waste treatment. After 2010, European countries focus on renewables without increasing Wte plants especially developed economies with the majority of European citizens.

Table 13a: Summary statistics for green taxes.

	mean	21704.8		**Unique values**	114
	Std dev	25367.2		**missing**	0
	range	{573, 81695}			
percentiles	10%	25%	50%	75%	90%
	862.55	3694.11	10990	27409.7	68264.3

	Percentiles	**Small/Large**
1%	630.9	573
5%	681.88	630.9
10%	862.5	634.3
25%	3694.1	634.8
75%	27409.6	76960.4
90%	68264.2	77438.33
99%	77764.1	81695.2

13b: *Summary statistics for renewables' energy consumption.*

	mean	19.37		**Unique values**	114
	Std dev	11.89		**missing**	0
	range	{3.63, 53.24}			
percentiles	10%	25%	50%	75%	90%
	5.72	10.91	16.27	27.21	35.25

	Percentiles	**Small/Large**
1%	3.65	3.63
5%	4.40	3.65
10%	5.72	3.73
25%	10.91	3.87
75%	27.21	48.82
90%	35.25	49.69
99%	49.94	53.24

13c: *Summary statistics for Wte plants.*

	mean	21.27		**Unique values**	36
	Std dev	32.91		**missing**	0
	range	{0, 129}			
percentiles	10%	25%	50%	75%	90%
	1	1	11	25	72

	Percentiles	**Small/Large**
1%	0	0
5%	0	0
10%	1	0
25%	1	0
75%	25	127
90%	72	128
99%	129	129

13d: Summary statistics for GDPpc.

	mean	38497		**Unique values**	114
	Std dev	22994		**missing**	0
	range	{11957, 118823}			
percentiles	10%	25%	50%	75%	90%
	14246	18670	40756	49878	60020

	Percentiles	**Small/Large**
1%	12572	11957
5%	13113	12572
10%	14246	12599
25%	18670	12651
75%	49878	106749
90%	60020	113625
99%	115761	118823

In *table 14*, there is a strong positive correlation for WTE/tax. This is due to the common stagnant progress in these 2 areas in Europe for the last 10 years. Renewables' factor presents a slightly negative correlation with taxes and GDP, mainly triggered from taxes and GDP's stagnation for this period of time.

Table 14: Correlation between green taxes, renewables' energy consumption, Wte plants and GDPpc.

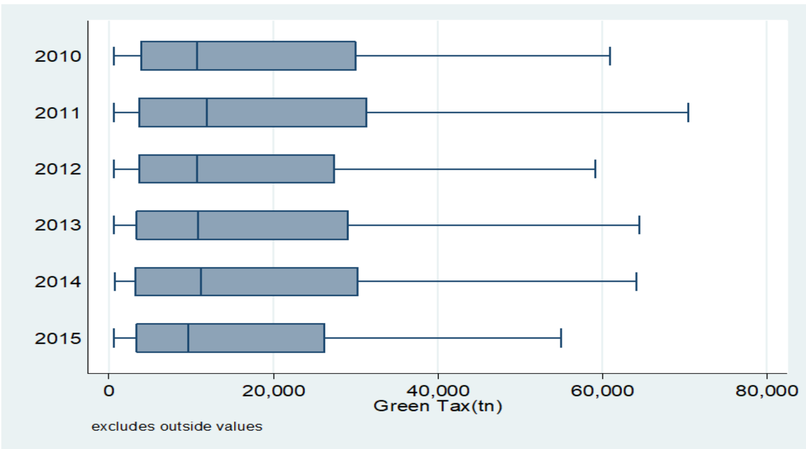
	taxes	WTE	Renewable	GDP
taxes	1			
WTE	0.76	1		
Renewable	-0.28	-0.17	1	
GDP	0.10	0.12	-0.23	1

From a political and social perspective, we should re-examine immediately the laws and regulations for green taxes and the waste to energy sector if we are planning not only reaching our goals but also accomplishing a green energy transition. The main focus of the governments was recycling but at the same time all the over green sectors were set aside.

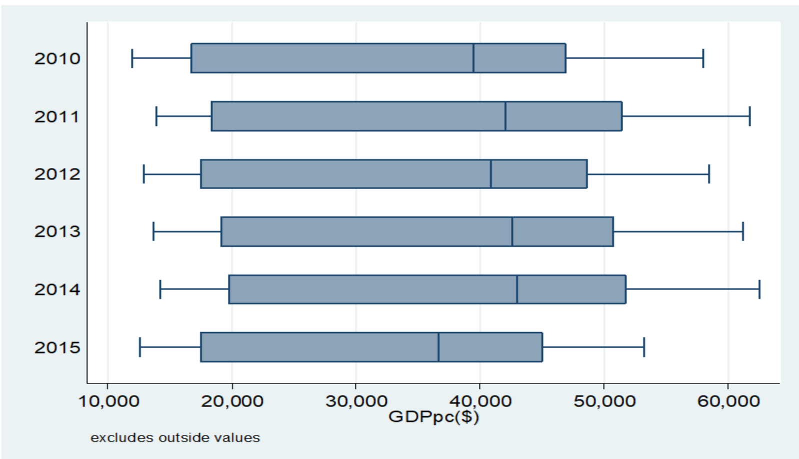
The most highlighted part of this hypothesis is the flat growth for Wte plants and green taxes in Europe after 2010.

In *fig. 18a-b,* there is a clear presentation of immobility for green taxes' sector and GDP's sector. To explain that, these are frustrating results for financial and green sector which demand regulation, as soon as possible.

Figure 18a-b: Decrease in Green taxes and GDP over the 5 years period, especially in 2015.



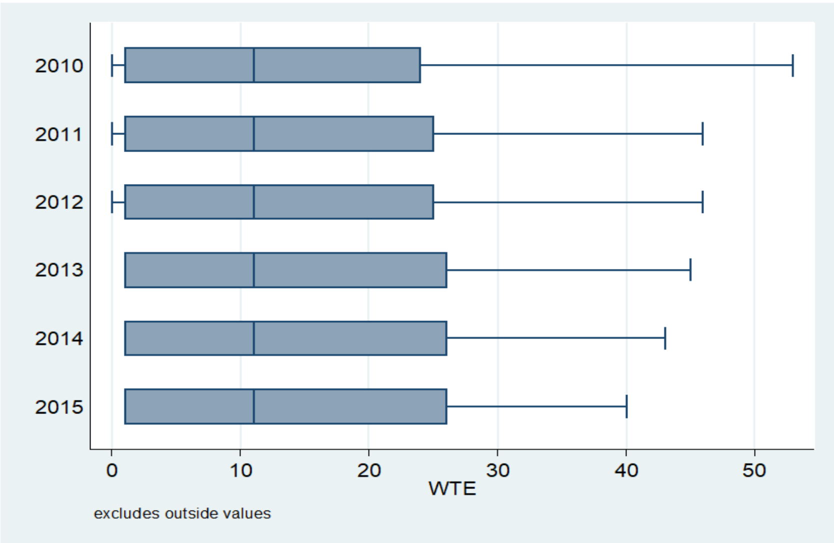
a



b

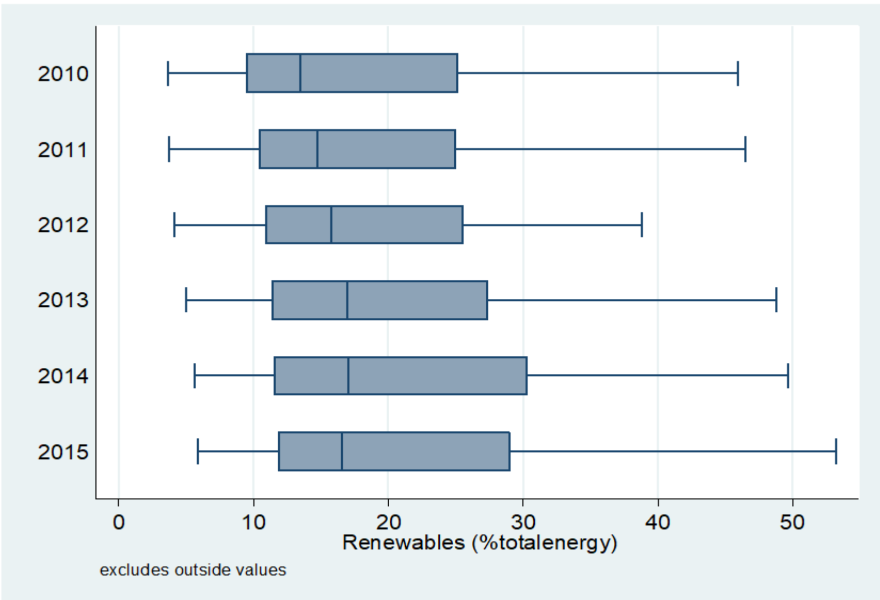
In *figure 19,* most of European countries choose recycling as a strategy and not incineration, based on this trend analysis. This is another evidence of different strategies between European countries, with recycling being priority for developed economies.

Figure 19: Flat progress for Wte sector.



In *figure 20,* there is an absolutely expected result due to several action plans for many years related to renewable energy.

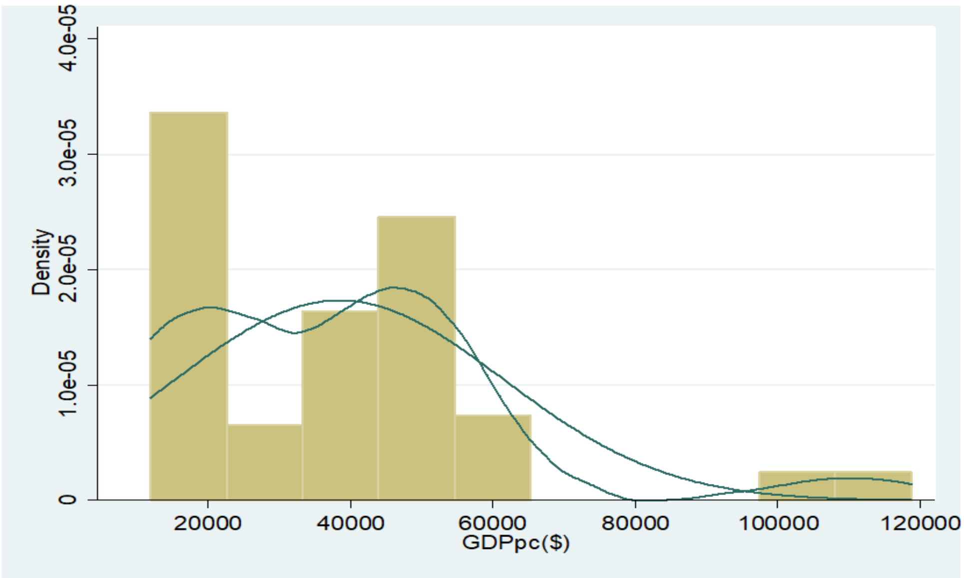
Figure 20: Significant increase in renewables.



In *figure 21a,* GDP's main density is close to 20 thousand and between 40-50 thousand in European countries. A clear distinction between poorer and richer countries in Europe.

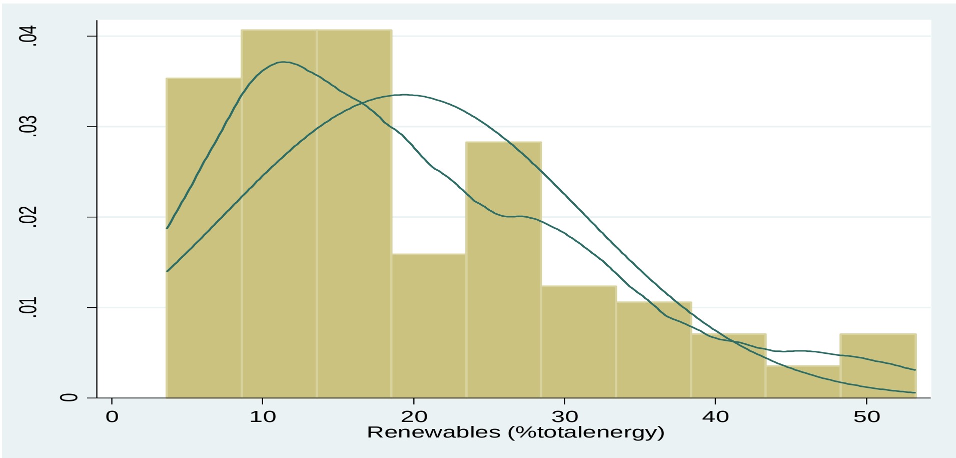
There are 3 main groups (20, 40, 50 thousand) with 4 smaller groups based on GDP per capita. Only 10% of European's population are listed in GDPpc with more than 60 thousand dollars.

Figure 21a: Main density GDPpc.



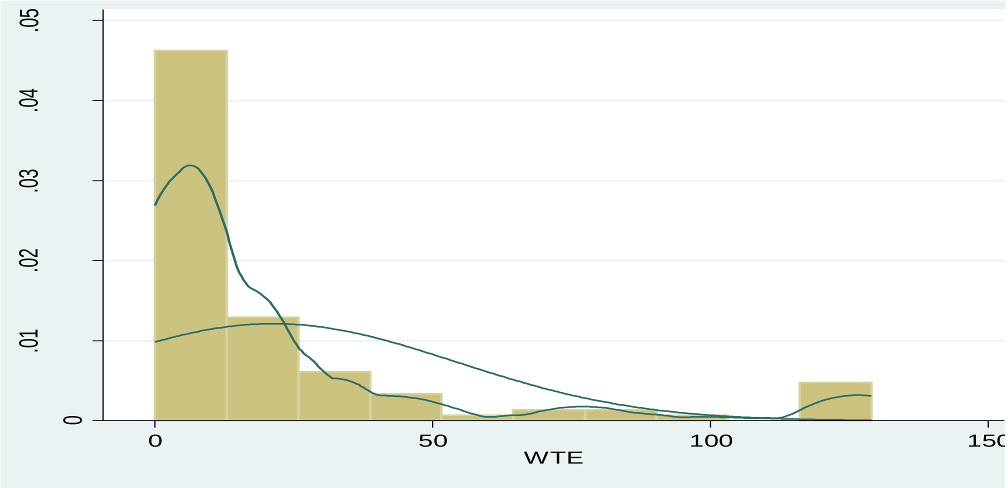
In *figure 21b,* renewables' main density is between 10-20% for renewables (% total energy consumption). Despite the massive increase in recent years, most countries consume less than 30% of total energy consumption based on renewables. This trend could and should be continued to achieve common green targets.

Figure 21b: Main density for renewables.



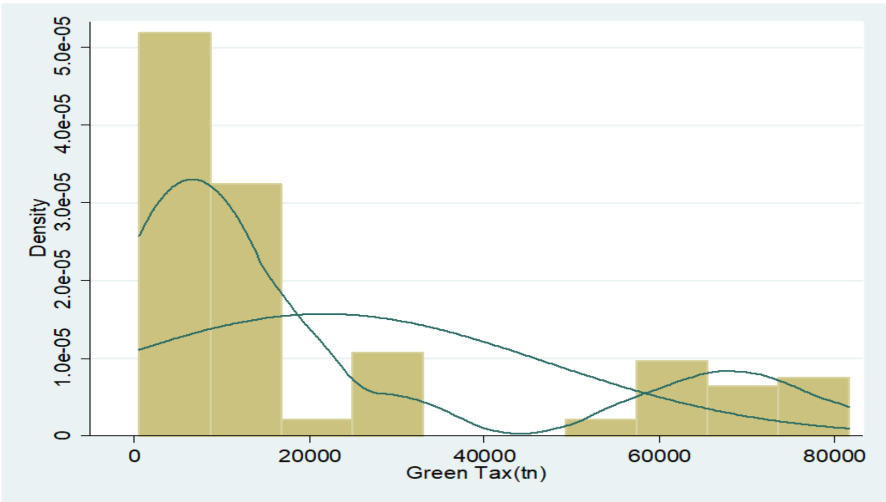
In *figure 21c,* WtE plants' main density is lower than 10. Big-in shape countries with well-established emerged economies are the exceptions of this graph. This is another evidence which states that recycling is more favorable compared to incineration in Europe when at the same time, the majority prefers to retain active 30-40 Wte plants, at maximum.

Figure 21c: Main density for WtE plants.



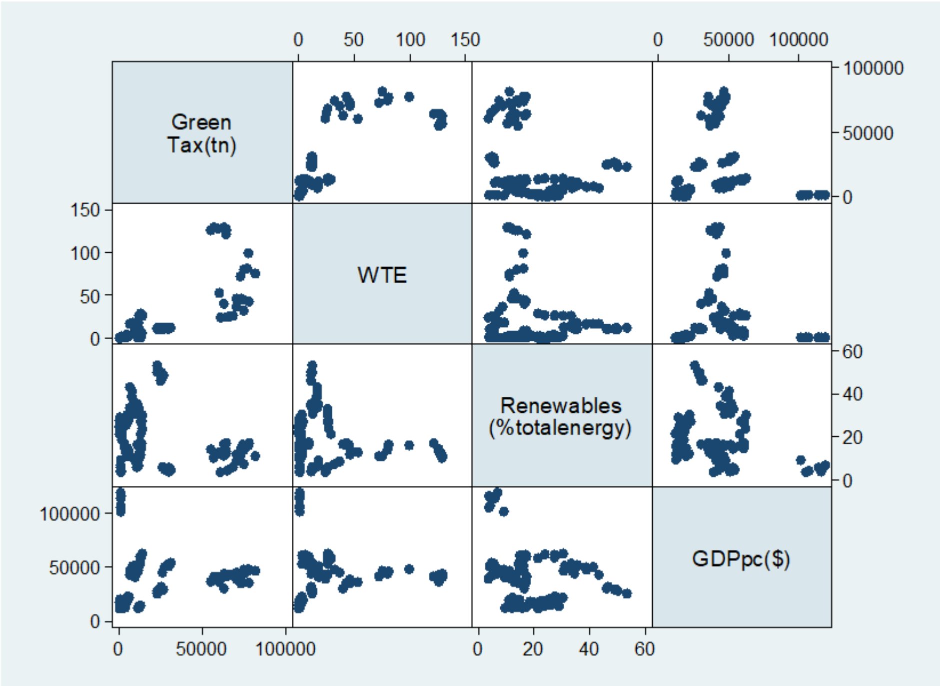
In *figure 21d*, taxes' main density is lower than 20 thousand which is obviously a disappointing result for green economy in Europe. There are some exemptions over than 60 thousand, however the majority of governments did not increase environmental green taxes in recent years.

Figure 21d: Main density for Green taxes.



In *fig.22,* between Wte plants and green taxes, we could pinpoint a possible combined linear increase from 0-50 plants. However, after that we could obviously justify a flat progress for green taxes for countries with more than 50 Wte plants. To make that clear, emerged economies with more than 50 WtE plants do not achieve better results in taxes' issue compared to others.

Figure 22: Scatter plot for 4 factors.



In *table 15a*, the calculation of Vif<5 means moderate collinearity. Vif in this hypothesis is way higher than Vif in *hypothesis 2.*

Table 15a: Multicollinearity detected by Vif.

Variable	VIF	1/VIF
tax	2.46	0.40
inc	2.44	0.40
rec	1.02	0.98
MEAN VIF	1.97	

In *table 15b*, based on fixed-effects OLS model, we could suppose as a possible result that 10% increase in Wte plants leads to -1,4% decrease for Renewables in 10%confidence. Also, 10% increase in GDPpc leads to 8% increase for Renewables in 5% confidence.

This means that, a percentage increase in income per inhabitant may proportionally cause an increase in renewables' energy consumption.

Table 15b: Fixed effects OLS model with y= renewables' energy consumption.

(Ln)Ren	**COEF.**	**STD. ERROR**	**T**	**P>T**	**CONF. INTERVAL**
Wte	-.1404153	.0813	-1.73	0.088	-.3021 .0213

Tax	-.2668778	.2172	-1.23	0.223	-.6987 .1650
GDP	.8034439	.3451	2.33	0.022	.1175 1.4893
cons	-2.635411	2.9876	-0.88	0.380	-8.5736 3.3028
R-sq	0.6265				
Prob>F	0	**Obs**	6		

In *table 15c,* we chose Hausman test with the purpose to find out which model is the best in our case, fixed or random effects. Based on outcome, the best is with fixed effects because P value is less than 0,05 in Hausman test.

Table 15c: Hausman test.

	Fixed	**Random**	**Difference**	**S.E.**
lnWte	-.1404153	-.0314108	-.1090045	0.0336093
lntax	-.2668778	-.0868901	-.1799876	.1892492
lnGDP	.8034439	.1114506	.6919933	.2665868
Prob>chi2	0.0229			
Test Ho	Not systematic	difference		

In *table 15d*, based on fixed-effects OLS model, we could suppose as a possible result that 10% increase in GDPpc leads to 22% increase in Wte plants in 1% confidence. Another evidence that emerging economies with high growth rates chose WtE pathway.

Table 15d: Fixed effects OLS model with y= lnWte.

(Ln)WtE	**COEF.**	**STD. ERROR**	**T**	**P>T**	**CONF. INTERVAL**
Tax	-.3465559	.2814	-1.23	0.22	-.9059 .2128
GDP	2.399448	.3822	6.28	0	1.6397 3.1591
Ren	-.2355	.1365	-1.73	0.088	-.5070 .0358
cons	-18.61045	3.3360	-5.58	0	-25.2411 -11.9797
R-sq	0.4657				
Prob>F	0	**Obs**	6		

In *table 16e,* we chose Hausman test with the purpose to find out which model is the best in our case, fixed or random effects. Based on outcome, the best is with fixed effects because P value is less than 0,05 in Hausman test.

Table 15e: Hausman test.

	Fixed	Random	Difference	S.E.
lntax	-.3465559	.5945125	-.9410654	.259639
lnGDP	2.399448	1.039864	1.359585	.304313
lnRen	-.2355918	.0094997	-.2480912	.0828935
Prob>chi2	0.0003			
Test Ho	Not systematic	difference		

5. Comparison with relative data

There are several reports of similar analysis and in this section, we attempt to compare the results of this thesis with the existing data.

2001-2010

Only four countries *(Austria, Belgium, Germany and the Netherlands)* managed to attain the top recycling rates for the period 2001-2010. Landfill treatment remains high around the world until 2008. After this period, governments have decided and slightly enacted to drop these levels of landfilling, focusing mainly on recycling and WtE. A low level of waste reuse is associated with structural problems in the basic collection system. *Reviewing that in 2021, we face a green transition due to higher recycling and lower landfilling. These 4 countries are on the top list until now.*

2010-2015

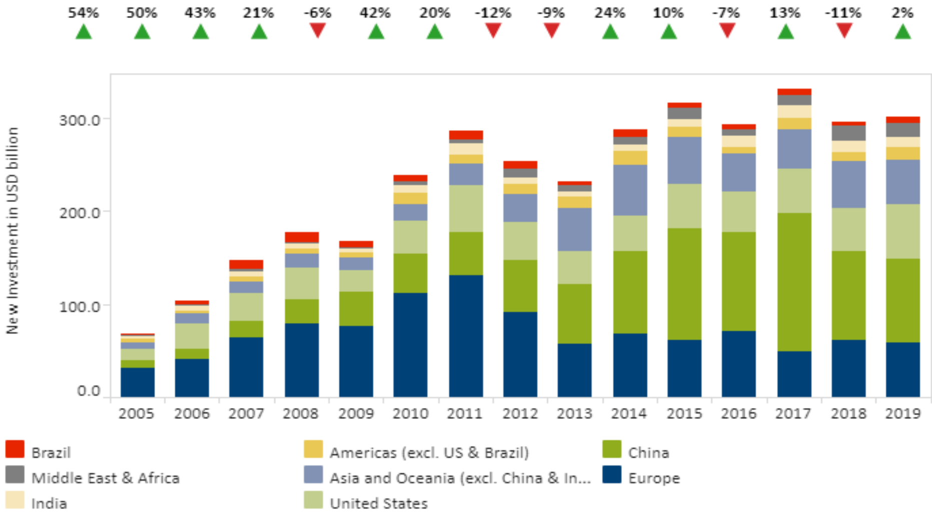
Europe is the largest market for WtE technologies, accounting for over than 40% of total market revenue in 2013.

The Asia-Pacific market is dominated by Japan, which uses up to 60% of its solid waste for incineration. However, the fastest market growth has been highlighted in China *(fig.23a-b),* which has more than doubled its WtE capacity in the period 2011-2015.

From a regional perspective, the Asia-Pacific region will register the fastest growth over this period *(Frankfurt UNEP Centre)*. *Reviewing that today, China and East countries are facing tremendous growth until 2021.*

Figure 23a: Comparison between continents. Source: (Frankfurt UNEP Centre).

Figure 23b: Investments in incineration. Source: (Frankfurt UNEP Centre).



Source Frankfurt School-UNEP Centre/BNEF. 2020.Global Trends in Renewable Energy Investment 2020,

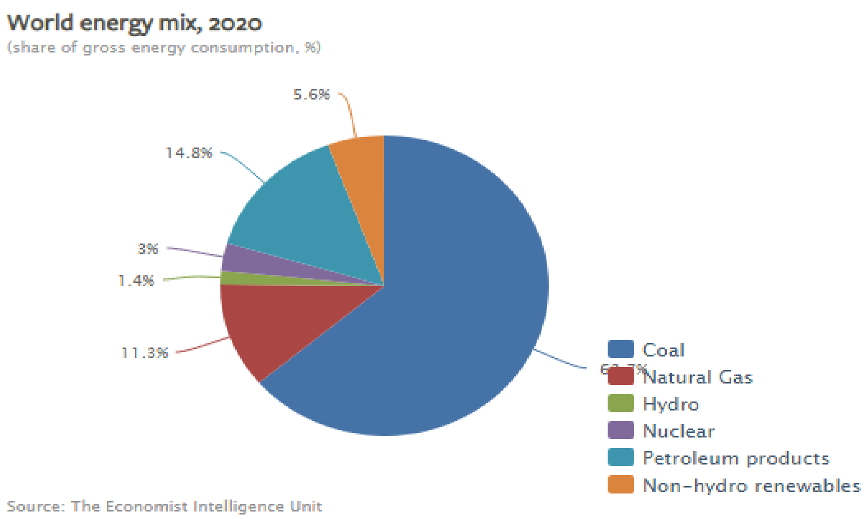
Biological WtE technologies will experience faster growth at an average of 10% per year, as new technologies become commercially viable. Until 2012 countries such as Denmark, Finland, Sweden, Luxembourg, Austria and Belgium produced the lowest Co2 emissions among the European countries. In the case of Cyprus, Estonia, Greece, Hungary, Malta, Poland and Portugal, there is a need to boost the annual recycling rate by between 2 and 4% annually through to 2020. *Reviewing this goal today, Estonia, Hungary and Poland are the most improved countries in the recycling and incineration sectors, not only from this thesis but also from literature review.*

A study *(EEA, 2017)* maps existing dedicated incineration capacity for municipal waste in the EU-28 countries and the flows of municipal waste between European countries. The study shows that for the period 2010-2014, the incineration capacity in the EU-28 countries increased by 6 %. The study also confirms that dedicated incineration capacity for municipal waste is unevenly spread in the EU. Germany, France, the Netherlands, Sweden, Italy and the UK account for the majority of EU's incineration capacity. Sweden and Denmark have the highest per capita incineration capacity with 591 kg/cap and 587 kg/cap respectively, followed by the Netherlands, Austria and Belgium. In contrast, the southern and eastern parts of the EU are highly reliant on landfills. This data is in line with Eurostat statistics on the incineration rates of municipal waste which also show great variation across the Europe. *In recent years, some eastern countries are changing their previous profiles about this sector.*

2020-2021

In *figure 24*, there is a pie graph which represent the worldwide total energy mix in 2020. Our planet energy power is based 64% on coal, until now. Moreover, petroleum products, natural gas and non-hydro renewables together reach 30% of total mix. There is a need of huge steps and massive improvements in order to achieve green transition globally in the future.

Figure 24: World energy mix 2020. Source: (Economist Intelligence unit).



Today, approximately exist more than 2,430 waste treatment plants with more than 4,800 incineration units worldwide.

According to similar reports and our analysis, countries like Estonia, Slovenia, Lithuania, Italy, Poland and the UK follow a certain and robust plan about the waste treatment which is correlated to the overall traits around Green Energy and material recovery, especially in the last years following the examples of Sweden, Denmark, Norway, Germany and the

Netherlands. Landfilling is the cheapest option for waste but now, countries with low income and GDP prefer another way like incineration. Yet, if the government introduces a high landfilling tax, that could be a financial signal to reuse the waste for energy production than depositing it in landfills as the example of Estonia proves.

Slovenia and Estonia are two great examples for sustainability and material recovery according to existing data. Firstly, Lithuania and Hungary, with Finland, Italy and the UK secondly are the most improved countries in this sector according to the factors which have been analyzed. In the EU vocabulary re-use, recycling, and recovery are the key words that a new framework is created to promote sustainability, innovation, and competitiveness. In contrast to that, there is an existing insufficient planning in certain tasks.

Insufficient planning

To start with, sometimes regulatory barriers may prevent the commercialization of new technologies. Equally, there has to be a vibrant business case for the industry to get involved.
A possible solution could be the introduction of a new term of 'prosumer' which has emerged attributing to the role of active consumers. Active consumers with the potential to be energy producers, particularly through self-generation of renewable energy, storage, energy conservation and participation in demand response across value chain *(fig.25).*

Figure 25: New technology approach. S*ource: (Estimates of European food waste levels, FUSIONS, European Commission, 2016).*

Comparing different markets, the immature WtE market in Greece *(table 16a)* leaves significant margins for action and investments, in contrast with Italy *(table 16b)* where actions have already been executed.

Greece is one of the few European countries that still has not incorporated WtE in its waste management practices. The main reasons for this can be found in failures to properly implement the legislation, administrative issues, poor quality of environmental information and problems with public acceptance in terms of site selection. Until 2020, Greece did not achieve any significant progress.

Table 16a: Waste trend in Greece. Source: (J. Malinauskaite et al., 2017a).

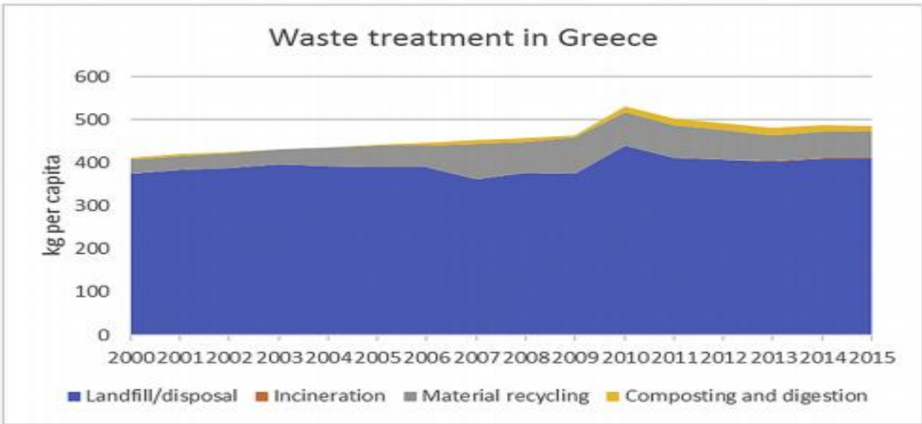
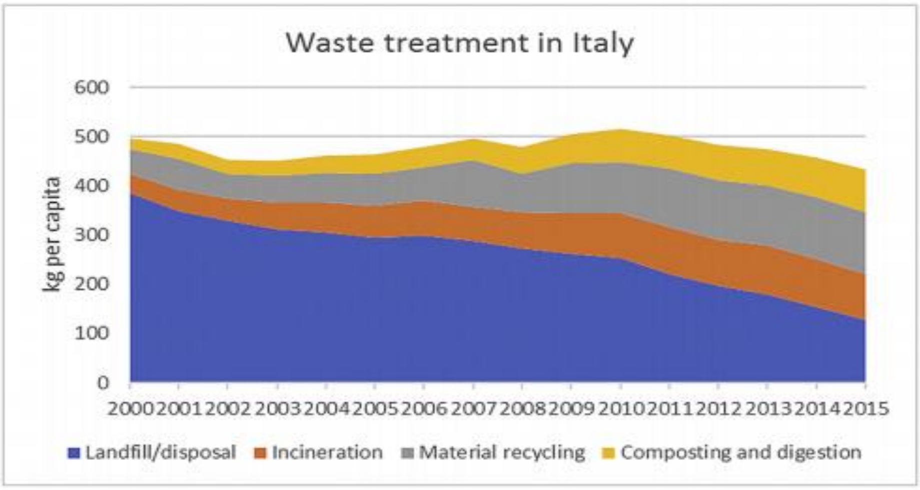


Table 16b: Waste trend in Italy. Source: (J. Malinauskaite et al., 2017a).



In *table 16a and 16b*, different strategies and approaches to waste management have been adopted in different areas due to the lack of a concrete holistic implementation in the whole of Europe. Outside Europe, other countries such USA have experienced similar problems.

5.1. USA example

During the 1990s, the WtE industry experienced several failures which resulted in no new facility being constructed for a long period of time. Expiration of tax incentives, significant public discord and the US Supreme Court decision in Carbone dealing forced many communities in the US to opt for transport of their solid waste to regional landfills.

A recent Supreme Court decision on flow control has reinstated the ability of communities to enact flow-control agenda and enable them to direct their wastes to WtE plants. Combustion plants are no longer a significant source of emissions due to the implementation of regulations, reducing the dioxin emissions by 99%.

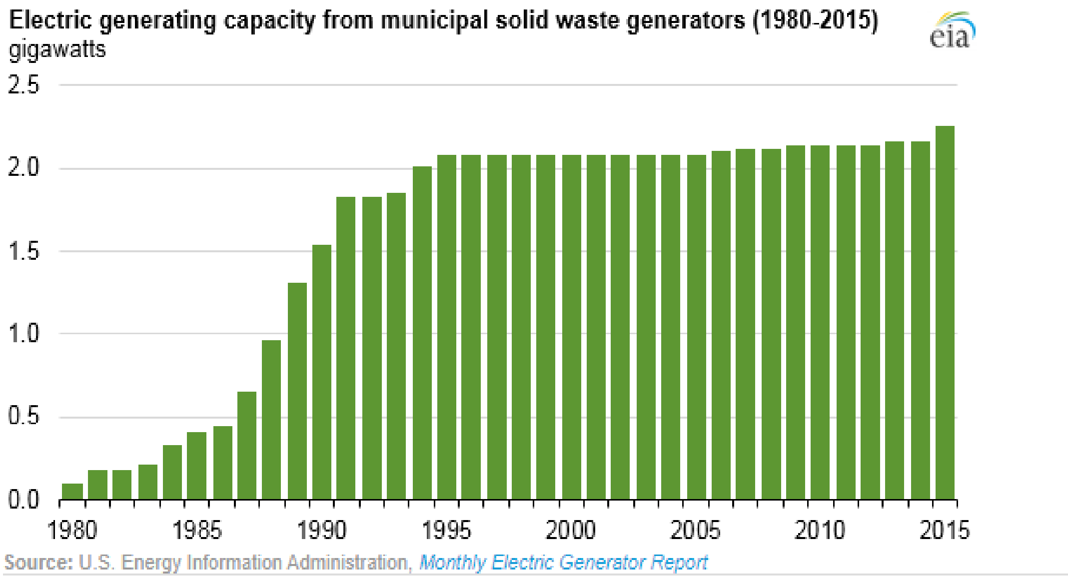
Incineration and anaerobic digestion represent two existing types of WtE plants in the United States. Both require prior separation to achieve maximum recovery and produce electricity, and heat. However, high operating costs and high level of competition from alternative sources make the production of heat and power from MSW economically challenging.

In 2015, the United States had 71 WtE plants that generated electricity in 20 U.S. states, with a total generating capacity of 2.3 gigawatts *(fig.26).* Florida contains more than one-fifth of the nation's WtE electricity generation capacity. Florida's Palm Beach Renewable Energy Facility Number 2 became the first new WtE plant to be active since 1995.

WtE plants account for a relatively small portion of the total U.S. electric capacity and generation, providing less from 1% of total U.S. electricity generation in 2015. WtE power plants convert the combustible content of municipal solid waste to energy.

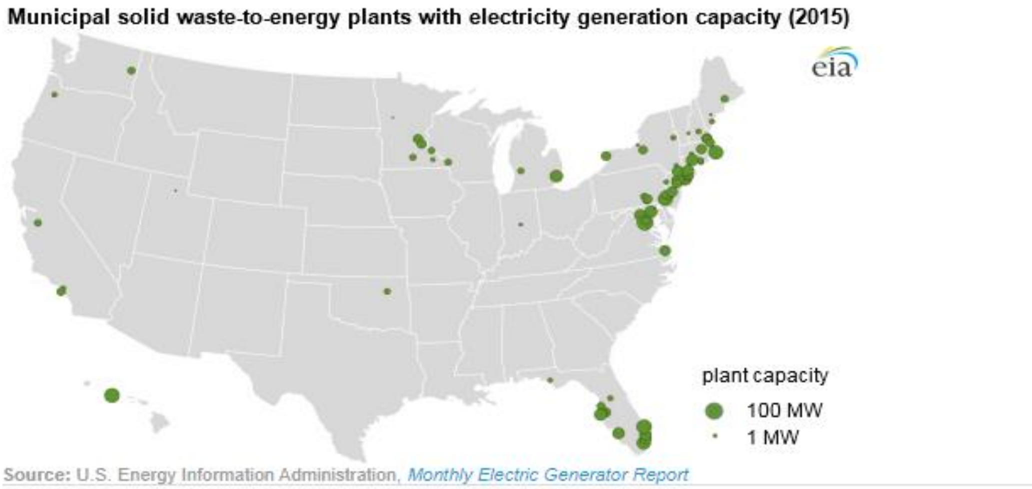
In 2015, Florida and four states in the Northeast accounted for 60% of the total WtE power plant capacity in the United States, and they were responsible for the majority of total U.S. WtE electricity generation *(fig.27).*

Figure 26: Electric generating capacity from MSW in the USA.



Source: (EIA).

Figure 27: Wte plants' mapping across USA.



Source: (EIA).

Based on the most recent estimates from the *U.S. Environmental Protection Agency*, the United States produced about 250 million tons of MSW. *EIA* estimates that WtE plants burned about 29 million tons of MSW, of which 26 million tons were used to generate electricity. The remaining amount of MSW was recycled, composted, or disposed of in a landfill. If the 171 million tons of unrecycled MSW was converted to liquid fuel, the estimated yield would be 10 billion gallons. Until nowadays, incineration plant it is not the best choice from an investor perspective.

In *figure 28,* capital cost and nominal capacity are clearly presented for the whole energy sector, like photovoltaic, wind, natural gas combustion, nuclear, coal and incineration plant.

Figure 28: Capital costs on the whole renewable spectrum.

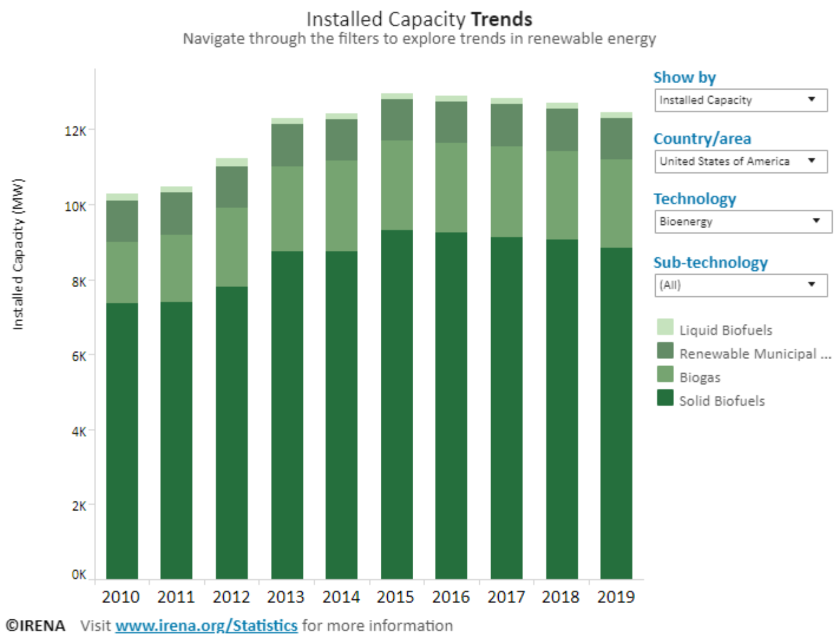
	Palm Beach MSW Incineration Plant(40)	Ultra-Supercritical Coal(41)	Advanced Nuclear(41)	Natural Gas Combined Cycle(41)	Natural Gas Combustion Turbine(41)	Onshore Wind(41)	Photovoltaic - Fixed(41)
Nominal Capacity (MW)	100	650	2,234	702	100	100	20
Capital Cost ($/kW)	$6,720	$3,636	$5,945	$978	$1,101	$1,877	$2,671

Source: (U.S. Department of Energy 2019).

USA versus Europe

The *EPA* has stated that WtE plants produce electricity with “less environmental impact than almost any other source of electricity”. Studies have displayed that we can avoid nearly 1 ton of CO2 emissions for every ton of waste.
The most recent data available from the *U.S. Environmental Protection Agency* shows that MSW incinerators released about 1% of the quantity of highly toxic dioxin compounds after 2000 compared to what they release many years ago.
According to *EPA and Eurostat figures*, Denmark recycles 42% of its waste and burns 54% in heat and power stations. The US, by comparison, recycles 33% while only 13% is used in waste-to-energy incinerators. The majority of US trash ends up in landfills, compared to only 4% in Denmark (*thinkglobalgreen).*
In *figure 29*, there is a trend analysis for installed capacity evolution of bioenergy’s plants in the USA. It is clear that USA reversed the previous negative situation.

Figure 29: USA capacity trends.



Source: irena.org

5.2. Developed or Emerging

Countries are separated into different groups mainly because their financial status, political strategy and their location. Moreover, there is a distinct between developed(A) and emerging(B) countries.

A. Developed nations have more advanced economies, developed infrastructure, mature capital markets and high standards of living. These are the most advanced countries. Most developed markets are located in North America, Europe and Asia. They include countries like the United States, Germany, the United Kingdom and Japan.
B. Emerging markets are in the process of rapid growth and development but they have lower household incomes and capital markets which are less mature than developed countries, characterized by fast economic growth.

In *2009, Dr. Kvint* published this definition: "an emerging market country is a society transitioning from a dictatorship to a free-market-oriented-economy, with increasing economic freedom, gradual integration with the Global Marketplace and with other members of the GEM *(Global Emerging Market)".* Julien Vercueil introduced a definition of the "emerging economies", as distinguished from "emerging markets" coined by an approach heavily influenced by financial criteria. According to his definition, an emerging economy displays the following characteristics:

1. Intermediate income: per capita income is comprised between 10% and 70% of the average EU per capita income.

2. Catching-up growth: during at least the last decade, it has experienced an economic growth that has narrowed the gap with advanced economies.

3. Institutional transformations: which contributed to integrate it into the world economy. Therefore, emerging economies appears to be a by-product of the current globalization *(Marois, 2012), (Vercueil, 2012).*

In *figure 30*, there is a cost estimate of MSW incineration both in industrialized and emerging countries. Obviously, the cost basis in developed countries is equal to 3-5 times more than emerging countries which is a basic argument for the distinction between these 2 groups, especially in our analysis. Developed economies like France, Italy and others may have based their neutral position for WtE sector on this cost analysis. In contrast, emerging countries such as Estonia and Lithuania experienced tremendous growth based on low cost and compared to the stagnant strategy of more advanced economies. This figure may be the crucial reason behind the clear distinction which is clearly highlighted in this thesis.

Figure 30: Different costs for Developed and Emerged countries.

Cost estimate of MSWI in industrialised and emerging countries – figures are a rough orientation only						
Incineration Capacity: 150'000 t/a	Initial Investment	Capital costs per ton of waste input	O&M costs per ton	Total cost per ton	Revenues from energy sales per ton	Cost to be covered per ton waste input
Cost Basis in the EU (advanced technical set-up, 2 furnace lines)	135 – 185 million EUR	80 – 115 EUR/t	180 EUR/t	260 – 295 EUR/t	60 EUR/t (heat and electricity) 27 EUR/t (electricity)	200 – 235 EUR/t
Emerging country cost basis (basic technical set-up, 1 furnace line)	30 – 75 million EUR	22 – 55 EUR/t	20 – 35 EUR/t	42 – 90 EUR/t	2 – 10 EUR/t (electricity)	40 – 80 EUR/t

Source: (EEA).

5.3. Upcoming improvements

There are few upcoming new WtE technologies:

- Hydrothermal Carbonization which fast-tracks the slow process of geothermal conversion of wet waste with an acid catalyst at high pressure and heat to simulate the production of 'hydro-char' that has properties close to fossil fuels. The main advantages are the lower processing period and similar operating conditions needed to generate the same amount of energy.
- Dendro Liquid Energy which is a nearly 'zero-waste' WtE innovation from Germany. It is pretty much, four times more efficient than other treatments.

Some further improvements in the upcoming years could be the development of pretreatment processes, the development of discrete process quality control parameter, more corporate partnerships to achieve WtE goals and a push to use organic waste *(blueandgreentomorrow.com).*

Thermal technology is expected to account for the highest market share in the global WtE market. This trend of dominance by the thermal approach is expected to continue in the coming years, owing to the increasing developments in the technologies of incineration and gasification. It is estimated that plants, with electricity generation, can reach optimum efficiencies of 80-90%.

Until now, incineration is the most well-known WtE technology for Municipal Solid Waste processing. However, WtE technologies, particularly incineration, produce pollution and carry potential health safety risks. In order to reduce gas phase emissions, incineration plant owners have adopted a series of process units for cleaning the flue gas stream, which as a result, induce a significant improvement in terms of environmental sustainability.

5.4. Policy implications

To sum up, until now, measures which have been implemented such as tax incentives, tax exemptions and tax deductions, are not sufficient enough according to the results. Moreover, soft loans such as Austria, Finland, Hungary and Lithuania policy, green certificates scheme such as Sweden policy. However, these are not enough. It's absolutely essential, individual and social actions, which have to be done with the purpose of establishing a long-term green mindset.

These measures should be implemented as obligations through European Union's legal actions so as to achieve common goals in the whole Union and not only in specific countries. Scientific results related to green energy and circular economy should be examined by EU so as to redefine the purpose and our common goals. As a result, WtE sector is under further expansion with crucial functional improvements when at the same time establishing robust tax plan is an effective measure for green transition policy.

My personal suggestion, based on the results, is to establish a holistic robust plan for emerging countries to increase WtE plants to the maximum and at the same time for developed countries to reach 100% recycling and reducing waste generation. In this way, each country according to its features, respond differently based on this 2-methods strategy.

6. Conclusion

In conclusion, WtE is a key to the circular economy and the waste management which has strong synergies with the goals on climate and energy, especially in the context of resources and energy efficiency. It is also crucial for supporting the worldwide commitments on sustainability *(SDG).*

The contribution of this analysis is to express that, most countries presented a stagnant trend without increasing green taxes and WtE plants, mainly developed economies. The positive massive upside for renewables, as a whole, was not combined with a relevant upside for taxes and the waste to energy sector. Also, countries which chose incineration as a method is inevitably possible that they would count an increase also in waste generation. 2-path strategy should list countries, based on financial status and infrastructure, in 2 different groups, if we would like to extract useful data from this analysis.

From a social perspective, we need political regulations and social implementations to achieve an energy swift in the whole spectrum such as more WtE plants and green taxes. Incentives and common goals could eliminate current boundaries and deficiencies at the majority of European countries. The amount of waste is constantly increasing and the nature of waste is changing due to the dramatic rise of hi-tech products. For sustainable environmental management, waste management is essential. The protection of public health and environmental quality leads to a reduction of landfill use. In a global framework, both recycling and WtE could contribute to reach our common goal.

Waste to energy systems can provide an incentive for revenue generation through energy production, and the revenue stream can positively affect the financial evaluation of waste handling. WtE systems are a part of waste management, and a catalyst for establishing waste collection and processing in some areas. For a long-term transition to green energy, the waste to energy systems can be designed to accommodate potential changes in the waste volume and composition. Most technologies until 2010 achieved levels of efficiency close to 60%. Nowadays after new improvements in waste to energy systems the efficiency of waste conversion into energy has reached 70-80%.

Going forward to the future, smart cities and green energy are two key parts for accomplishing our goal of building a sustainable society and the dawn of prosperity.

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