DIPLOMA THESIS

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MUNICIPAL SOLID WASTE INCINERATION AS A SUSTAINABLE WAY OF ENGERGY PRODUCTION

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Content

List of Abbreviations:

MSW: Municipal Solid Waste

WTE: Waste-to-Energy

EU: European Union

GHG: Greenhouse Gases

CO2: Carbon Dioxide

WEEE: Waste Electrical and Electronic Equipment

PETE: Polyethylene Terephthalate

HDPE: High-Density Polyethylene

SUDs: Single-Use Devices

COP: Coefficient of Performance

ES: Energy Storage

GACERE: Global Alliance on Circular Economy and Resource Efficiency

WFD2008: Waste Framework Directive 2008/98/EC

CE: Circular Economy

PV: Photovoltaic

GWHP: Ground Water Heat Pump

GCHP: Ground-Coupled Heat Pump

SWHP: Surface Water Heat Pump

SCW: Standing Column Well

GNI: Gross National Income

HDPE: Polyethylene

PET: Bio-Based Polyethylene Terephthalate

EPS: Bio-Based Expanded Polystyrene

MSWI: Municipal Solid Waste Incineration

WFD2008: Waste Framework Directive 2008/98/EC

1. INTRODUCTION

The purpose of this thesis is to discuss some conditions and more novel green treatment methods for municipal solid waste incineration as a sustainable energy production mode, and to provide some ideas for future urban construction. The thesis covers the sources of sustainable energy, the treatment of municipal solid waste incineration, the case of sustainable treatment of solid waste incineration in Austria, the problems faced by municipal solid waste incineration in the current European energy crisis, and the response measures of Europe, Hungary, and China to the global energy crisis. Finally, in the form and method of questionnaire survey, the European people's perception of the construction of green and environmentally friendly solid waste incineration plant as the main energy supply system was investigated.

The central idea of this paper is that the state will listen to the voices of the people about the energy shortage. It is hoped that according to the general public's perception of new energy, the energy problem can be solved, and the important position of new energy for sustainable development in the future can be promoted.

At the heart of this exploration is a comparative lens that scrutinizes the EU and China's waste classification systems, unveiling the complexities and innovations within. By dissecting the technological breakthroughs in MSW incineration. The study further probes the attitudes of EU residents, a critical determinant in the trajectory of waste-to-energy incineration plants and addresses the underlying concerns impeding their acceptance.

In summary, the above is intended to address the following issues:

1.What delineates the waste classification systems between the EU and China, and how do they impact the efficacy of MSW incineration?

2.Are there discernible innovations in MSW incineration technology that propel its development forward?

3.Amidst the stringent environmental policies in the EU, can waste-to-energy incineration systems operate sustainably?

4.How do EU residents perceive the advent of waste-to-energy incineration plants, and what factors influence their stance?

5.What strategies could potentially alleviate the apprehensions of EU residents regarding the establishment of waste-to-energy incineration plants?

In pursuit of these questions, the thesis navigates through an extensive literature review, examining the EU's waste classification and treatment, and draws a parallel with China's framework. It scrutinizes the policy support structures, the attitudes towards solid waste combustion, and culminates in a multi-faceted methodology encompassing quantitative and qualitative analyses. The results and discussions are anchored in statistical evidence and cogent interpretations, steering towards a conclusion that envisages the role of MSW incineration within the grand tapestry of sustainable urban construction.

In essence, this thesis endeavors to unravel the complexities of MSW incineration as a sustainable energy source, its acceptance by the populace, and its position in the future of urban development.

2. LITERATURE

2.1. EU Waste Classification

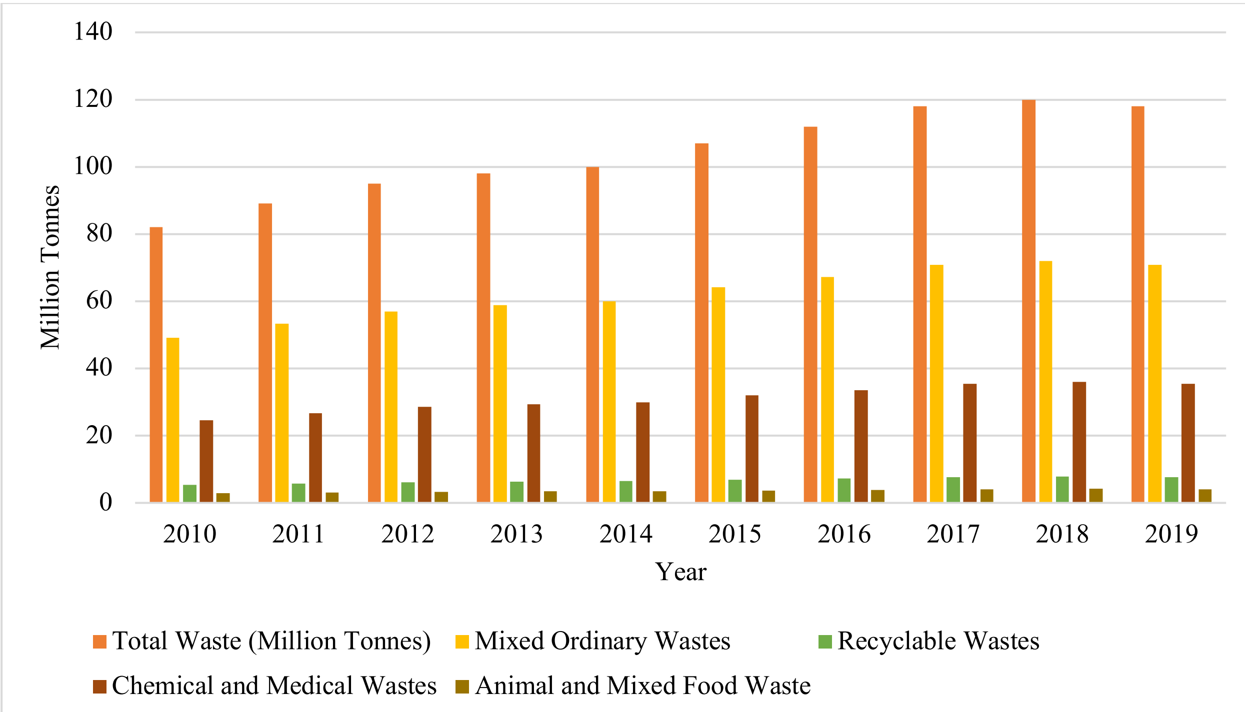
2.1.1. Composition

If we want to know the composition of municipal solid waste, we must understand the position of municipal solid waste in the environmental protection industry. As an important part of the circular economy, the urban domestic solid waste sorting and recycling industry has gradually attracted the attention of the state and the market in recent years.

Within the EU, two primary types of waste processing stand out: waste-to-energy conversion and recycling. The European Union disposes of about 200 million tonnes of waste per year for recycling, while the amount of waste-to-energy disposal has declined markedly because of the emphasis on the development of renewable energy sources and the improvement of the efficiency of energy consumption in the European Union.(Khadzhynova, 2023) The EU roughly divides waste into four categories: （Figure 1） 1. Recyclable waste. 2.Mixed ordinary wastes. 3.Animal and mixed food waste. 4.Chemical and medical wastes.

Figure 1: Main Types of Waste Processed in the EU

Source: own editing based on (Khadzhynova, 2023)

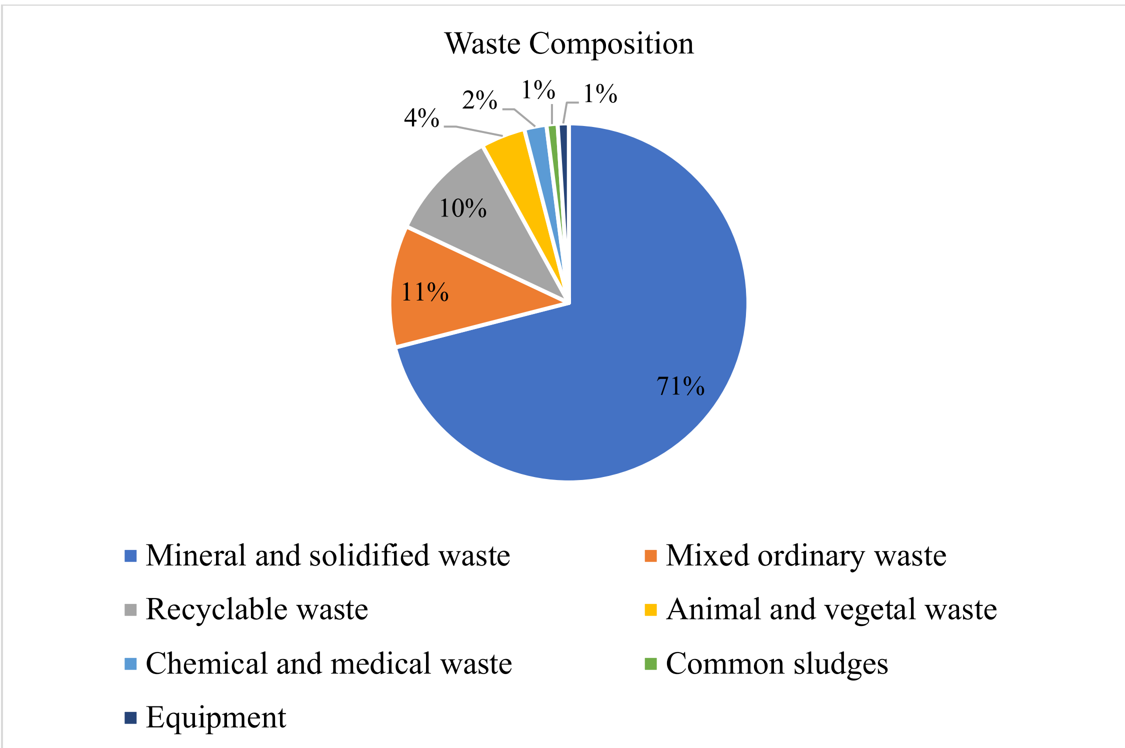


1）Recyclable waste

Recyclable waste is targeted for recovery, recycling, or reuse to minimize the environmental impact of waste disposal and conserve valuable resources. Recyclable waste, as shown in Figure 2, accounts for only 10% of EU waste, see Figure 2.(Bourguignon, 2015) According to the classification of Eurostat, it mainly includes five categories: waste electrical and electronic products, wastepaper, waste plastic, waste glass, and scrap metal (whether harmful or not). It is the main task of domestic waste classification at this stage and is also an important factor affecting waste reduction. But the recyclable waste here refers to if we want to incinerate recyclable waste as energy, that is, convert the waste into clean energy. Recyclable waste mainly includes residual municipal waste, commercial waste, industrial waste, and refuse-derived fuels. Waste-to-Energy (WtE) is the process of producing energy in the form of electricity and/or heat from the primary treatment of waste or processing waste into a fuel source. WtE is a form of energy recovery. Most WtE processes either produce electricity or heat directly through combustion or produce combustible fuel commodities such as methane, methanol, ethanol and synthetic fuels.

Figure 2: Waste Generation in EU-28 by Recyclable Waste

Source: own editing based on(Bourguignon, 2015)



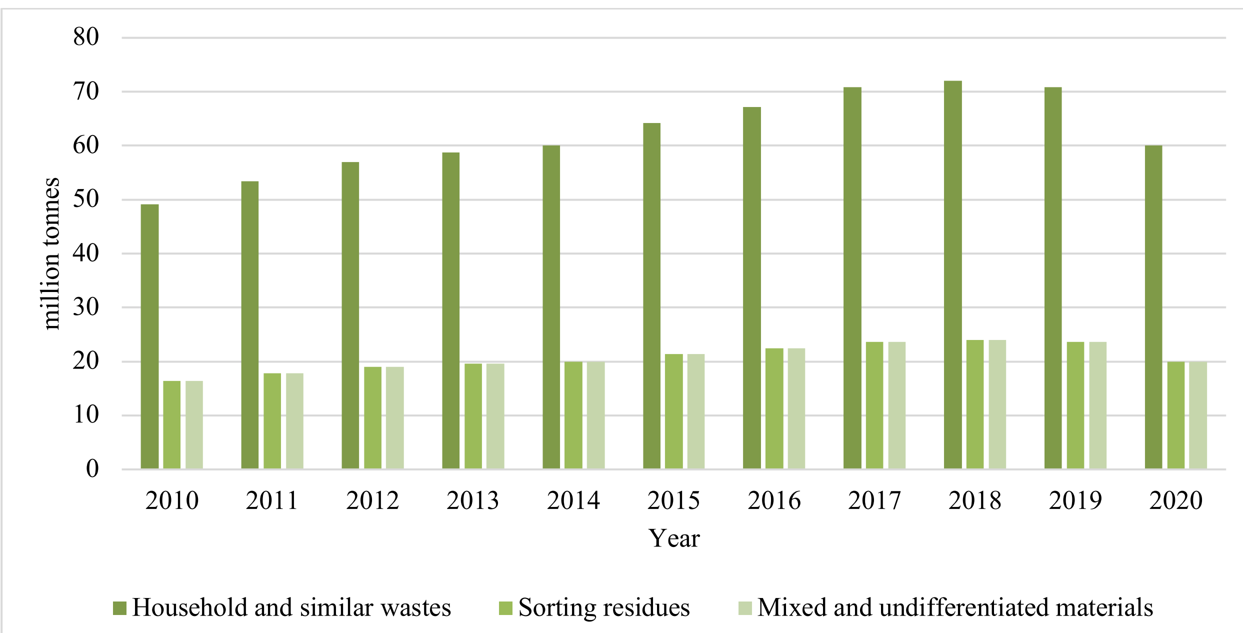
The RC (sensitivity coefficient) is intended for source separation of all wastes with recycling potential. There is a severe lack of data related to the SCW (small combustible waste) component in RC (sensitivity coefficient): UK's Government, Department for Environment, Food and Rural Affairs (2009) estimates that it, along with littering, is the most important data gap in waste composition analysis.(Faraca et al., 2019) Therefore, it is difficult to define the specific content of recyclable waste suitable for incineration and power generation. And it also varies according to the level of economic development of each country.

2）Mixed ordinary wastes

As shown in the figure, mixed general waste defined by the EU only accounts for about 11%. "Mixed ordinary wastes" typically refers to a combination of general household or municipal solid wastes that are collected without separation into specific categories. The bulk of mixed ordinary wastes consists of household wastes and sorting residues (Figure 3). In many waste management systems, households and businesses dispose of their waste in a mixed form, which includes a variety of materials. Mixed ordinary waste can be burned in incinerators, but the recovery rate is so low that it is not a mainstream recyclable waste. Because of its nature, 'mixed ordinary waste' has the lowest recycling rate of all categories (15%). (Bourguignon, 2015) It is worth noting that since 2010, the amount of household waste that undergoes processing has increased by 20 million tons, while the recycling of sorting residues has increased by more than 40 million tons.(Khadzhynova, 2023) Therefore, the best way to deal with mixed general waste in the EU is to have a proper recycling and sorting programme.

Figure 3: Mixed Ordinary Wastes in the EU

Source: own editing based on (Khadzhynova, 2023)



3）Animal and mixed food waste in the EU

Animal and mixed food waste are defined in two categories： see Table 1

Table 1： Animal and Mixed Food Waste Categories

Source: own editing based on (EUROSTAT, 2022)

Animal and mixed food waste	Vegetal Wastes
Animal-tissue waste	Wastes from forestry
Sludges from washing and cleaning	Biodegradable waste
Animal-tissue waste	Sludges from washing and cleaning
Materials unsuitable for consumption or processing	Plant-tissue waste
Materials unsuitable for consumption or processing	Sludges from washing, cleaning, peeling, centrifuging and separation
Wastes from preserving agents	Wastes from solvent extraction
Grease and oil mixture from oil/water separation containing only edible oil and fats	Materials unsuitable for consumption or processing
Biodegradable kitchen and canteen waste	
Edible oil and fat	

4）Chemical and medical wastes in the EU

The basis for recycling chemical and medical waste in the EU consists of industrial effluents, acids, alkalis, and used lubricants.(Khadzhynova, 2023) Both chemical and medical wastes are often considered controlled wastes due to their potential hazards. Special handling, transport, and disposal requirements apply to ensure safety and compliance with regulations.

Table 2： Percentage and Volume of Major Waste Types Generated in the EU and China （Unit： /year）

Source: own editing based on (China, 2020)

Region	EU	China
Recyclable waste	10%	
Mixed ordinary wastes	11%	
Animal and mixed food wastes	4%	
Chemical and medical wastes	2%	843,000 tons in 196 cities (2019)

General industrial solid wastes		1.38 billion tons in 196 cities (2019)
Industrial hazardous wastes		44.989 million tons in 196 cities（2019）
Urban domestic wastes		235.602 million tons in 196 cities（2019）

The Table 2 clearly shows the difference in waste classification between the EU and China. In Europe, in order to make the waste-to-energy process work, waste is also classified as recyclable and non-recyclable, and the amount of recyclable waste is counted and then the amount that can be converted into energy is calculated.

In China, however, due to its large size, only 196 cities participate in the China Solid Waste Pollution Prevention and Control Annual Report. Municipal solid waste is broadly divided into four categories: 1. general industrial solid waste, 2. industrial hazardous waste, 3. medical waste, and 4. municipal waste. Mainly because China's industrial waste rubbish accounted for the four categories of waste statistics dozens of times, so to better deal with industrial waste, China will be divided into two categories of industrial waste, to facilitate harmless treatment. In addition, China's municipal waste includes recyclables, bulky waste, compostable waste, combustible waste, hazardous waste, and other waste. So, China has not yet perfected the classification and treatment of recyclable waste.

In addition, the more similar waste classification in the two regions is the classification of medical and chemical waste.

2.1.2. Technologies of Municipal Solid Waste Treatment In EU

1）Recyclable Waste

Waste Electrical and Electronic Products

The treatment of WEEE requires a combination of technologies to recover valuable materials, minimize environmental impact, and ensure the safe disposal of hazardous components. Advances in recycling technologies and increased awareness of responsible e-waste management contribute to more sustainable practices in the treatment of electronic waste.

Waste Paper

Effective wastepaper treatment involves a combination of mechanical, chemical, and biological processes to transform discarded paper into high-quality recycled pulp and paper products. Advancements in technology and increased awareness of sustainable practices contribute to more efficient and environmentally friendly wastepaper treatment.

Waste Plastic

Waste plastics have a strong recycling capacity. Waste plastic treatment aim to manage plastic waste in an environmentally sustainable manner, focusing on recycling, reusing, and reducing the impact of plastics on the environment. The technology mainly consists of:1.Mechanical Recycling： Shredding , Sorting,Washing.2. Chemical Recycling 3.Biodegradation and Composting 4.Incineration.5.Landfilling.etc.

Waste Glass

It is worth noting that effective treatment of waste glass requires appropriate sorting, cleaning, and recycling infrastructure.

Scrap Metal

Scrap metal disposal technologies focus on managing and recycling metal waste to reduce environmental impact, conserve resources, and promote a circular economy.

2）Animal & Mixed Food Wastes

Reference(Garcia-Garcia et al., 2015) explains that in developing countries food waste is generated mainly in the beginning of the supply chain (caused by deficiencies in transportation and infrastructures and poor harvesting technologies) and in developed countries in the end of the supply chain, mostly at a consumer level (strongly influenced by new trends in consumerism and mass marketing). Chemical treatments for various applications can vary in suitability based on factors such as infrastructure, regulatory frameworks, and economic considerations. Therefore, composting, and integrated systems are well suited to developing countries. Some chemical treatments such as waste drying, anaerobic digestion, maturation, etc. are more suitable for developed countries.

3）Mixed Ordinary Wastes

The choice of mixed waste treatment technology depends on several factors, including waste composition, local regulations, environmental considerations, and available infrastructure. Separating mixed wastes is also a technical challenge. Recycling and recovery efforts aim to extract valuable materials from mixed waste streams, contributing to resource conservation and sustainability.

4）Chemical & Medical Wastes

Chemical and medical waste is a special type of waste with high requirements for storage, handling. There are several treatment methods for this type of waste, including the following four: 1. Pyrolytic incineration. 2. Chemical sterilization techniques. 3. Microwave sterilization. 4. Chemical disinfection techniques

Pyrolysis Incineration

At high temperatures, organic substances undergo pyrolytic reactions and decompose into gases, liquids, and solid products. Liquids and solids are easy to handle, but flue gas emissions are the most significant environmental risk when using pyrolytic incineration. For example, the production of toxic and hazardous substances such as dioxins.

Chemical Sterilization Techniques

High-temperature steam sterilization uses high-temperature saturated steam as the working medium, uses its strong penetrating power to penetrate deeply into the inner part of the sterilized articles and releases the latent heat contained in the steam, so that the sterilized articles are rapidly warmed up to the sterilization temperature and then maintained for a certain period of time, so as to make the proteins in the bacteria immobilize and denature, thus all the micro-organisms, including the bacterial buds, are all killed.

Although chemical sterilization technique has a lower environmental risk than pyrolysis incineration in the treatment of medical waste, it may still have some adverse effects. For example, thermal contamination， exhaust gases and wastewater.

Microwave Sterilization

Microwave disinfection is a treatment method that uses microwave or a combination of microwave and high-temperature steam to kill pathogenic microorganisms in medical waste to eliminate potential infection hazards. Microwave disinfection is a treatment method that uses microwaves or a combination of microwaves and high temperature steam to kill pathogenic microorganisms in medical waste and eliminate potential infectious hazards. Microwave radiation heats up the water molecules in the waste, causing damage to the cellular structure and thus killing pathogens such as bacteria and viruses. Microwave disinfection is suitable for small batches of clinical waste.

Microwave disinfection has a low environmental risk in the treatment of medical waste, but some adverse effects may still occur. In addition to the energy consumption and carbon emissions that may arise from the treatment of medical waste, electromagnetic radiation is generated during the microwave disinfection process.

Chemical Disinfection Techniques

Chemical disinfection is a treatment method that uses chemical disinfectants to kill pathogenic microorganisms in clinical waste and eliminate potential infectious hazards.

The use of chemical disinfection in the treatment of clinical waste carries a certain degree of risk inherent in the chemical disinfectant.

2.1.3. Management of Municipal Solid Waste Treatment In EU

1）Recyclable Waste

Understanding the characteristics of recyclable waste is essential to designing effective recycling systems, promoting sustainable practices, and maximizing the environmental and economic benefits of recycling. In addition, the development of regulations and environmental awareness are essential for the promotion of recyclable waste.

2）Animal & Mixed Food Wastes

Animal and mixed food waste treatment technologies are designed to manage organic waste generated from a variety of sources (e.g., households, food processing industries, and agricultural activities). The volume of animal and mixed food waste is increasing every year, but the recyclability rate is low. Therefore, to solve this problem completely, it is necessary to propose the potential of industrial utilization of animal and mixed food wastes.

To conclude therefore, the interconnection of biotechnological processes in the co-production of biofuels and bio-products represents a key strategy aimed at maximizing the utilization of food waste and raising the potential income of the entire bioprocess chain.(Girotto et al., 2015)

3）Mixed Ordinary Wastes

Efficient waste separation is a collective effort that involves individuals, communities, businesses, and local authorities. Sample analyses and surveys are therefore more appropriate as a way of studying and treating mixed general waste. Hazard identification, monitoring, and clarification of laws are all important.

4）Chemical & Medical Wastes

The management of chemical and medical waste is an important measure to safeguard public health and environmental protection.

Measure waste production: this step aims at gathering data on wastes compounding and identifying those wasteful practices and measures undertaken to handle these waste materials.

Minimization of Healthcare Waste： This goal can be achieved when purchasing stocks and supplies of low hazardous trace, eliminating mercury products, amalgam, batteries, and replace them with supplies without need of targeted disposal required.

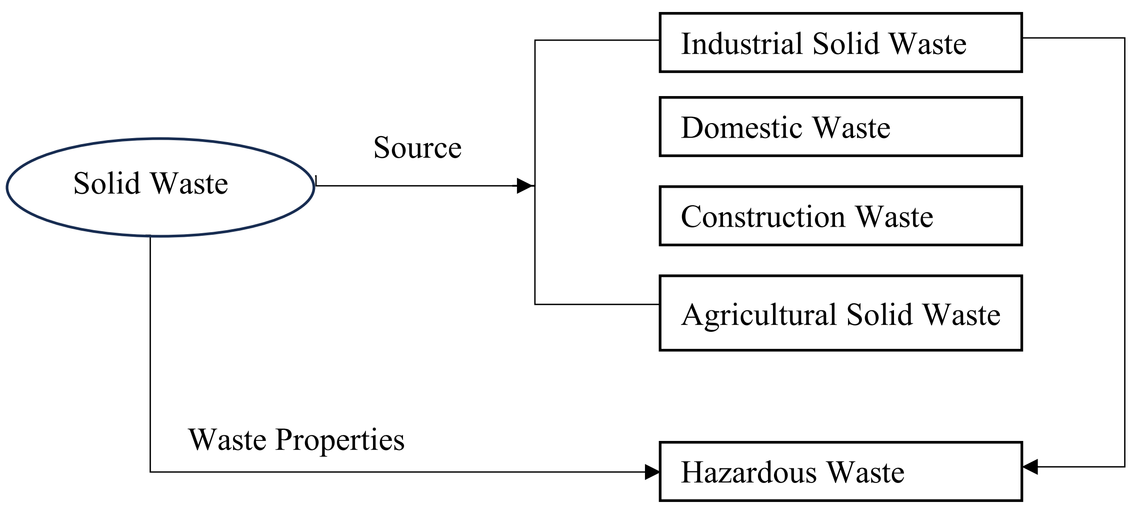
Safe reuse: The design of reusable custom packs can replace the disposable ones. Such an example is the sterilization and reuse of medical equipment to be used in a healthcare center.

Recycling: A portion of hazardous HCWs' is complex to be recycled due to special constraints and regulations of handling. However, other hospital material is conveniently and safely recyclable, offering environmental benefits and monetary savings. Such recyclable materials are glass, paper, polyethylene terephthalate (PETE) and high-density polyethylene (HDPE) plastic, as well as electrical appliances and electronic equipment.

Reprocessing: It is perceived as the potential to exploit health single- use medical devices (SUDs) after repair, cleaning, and sterilization upon already used ones. While there are also aroused moral issues (upon patients consent); legal issues (after accidental harm caused by reprocessed SUD); as well as safety risk issues to patient (mainly due to nursing malfunction, or infection caused by cross-patient implications).(Zamparas et al., 2019)

2.1.4. Comparison of Waste Treatment Systems in the EU and China

Figure 4： China Classification of Solid Waste
Source: own editing



China Solid Waste Classification System

1) Absence of high-level administration. In terms of administration and classification, it has not been feasible to combine all solid waste classifications into a single classification system because of the absence of a leading department. There is no single classification objective when it comes

to placement; instead, secondary classifications of construction and household trash are based on management demands, whereas secondary classifications of industrial solid waste are determined by statistical needs. There will inevitably be instances of crossover and omission in the secondary classification of construction trash, home garbage, and industrial solid waste that is currently in place. This is because there is a lack of systematic methodological direction.

2) The categorization scheme is flawed. Currently, China lacks a tertiary classification system and has a very shaky secondary categorization system for solid wastes other than hazardous wastes. Although they are first categorized at the secondary level, building waste, household trash, and industrial solid waste do not actually meet the requirements of solid waste management. It is challenging to meet the actual requirements of industrial solid waste discharge permits, management accounts, and other work if the classification is not refined. Some industrial wastes are generated in different industries and processes, and their main components and physical and chemical properties vary greatly.

3）Absence of matching codes. Environmental statistics currently designate a 2-digit code for industrial solid waste and an 8-digit identifier for hazardous waste in the National Hazardous Waste Inventory. Otherwise, home garbage, building waste, and agricultural solid waste are not covered by standardized code information. (Ministry of Ecology and Environment, 2021)

EU and China solid waste classification system

The EU Waste List is a three-tiered waste classification system created by the European Union (EU). Based on the combination of the trash's characteristics and its place of generation, the list divides solid waste into 20 types. Classifications 1–12 and 17–20 are based on where the garbage was generated; categories 13, 14, and 15 are based on the characteristics of the waste; and category 16 is made up of rubbish that is not included in any of the other 19 categories.(Commission Notice on Technical Guidance on the Classification of Waste, n.d.)

The amount of solid waste that can be used for different purposes varies between China and the EU, in addition to differences in solid waste classification. Two thirds of Europe's solid waste is recyclable, with building waste—that is, waste including metal—making up a sizable amount of the continent's solid waste. In contrast, China's solid waste is primarily household waste.

The four main issues with China's solid waste disposal strategy are as follows: First, a low recycling rate, hundred tons of solid waste are not recycled in China every year; Second, a high concentration of non-renewable resources in municipal garbage; Third, outdated recycling and reuse technologies combined with outdated treatment techniques. Fourth, the high expense of treating solid waste and its poor level of resource utilization. Because there are so many hygienic landfills and incinerator treatment techniques, most the waste's recyclable components are lost.

Main Ways of Waste Disposal in the EU

1.Incineration: Incineration is the most used method of converting solid waste into energy in the EU.

2. Gasification: Gasification is a technology that converts solid waste into syngas.

3. Pyrolysis: Pyrolysis is a technology that cracks solid waste into gas, liquid, and solid fuel under anoxic conditions.

4. Others: anaerobic digestion, biomass power generation, etc.

Main ways of waste disposal in China

1.Landfill: Landfill is currently the most important treatment method for municipal domestic waste（animal and food waste）, accounting for about 70 % of the total volume. Biogas utilization. The use of biochemical principles to achieve the decomposition of organic substances in waste and the discharge of leachate and biogas in compliance with standards. With the population growth, scarcity of land and technological progress, solid waste landfills have gradually withdrawn from the market.

2.Incineration：Incineration is a reasonable and superior technology, but there is much opposition to it, centered on the atmospheric pollution caused by waste incineration.

3.Comprehensive Treatment：The comprehensive utilization of solid waste is mainly focused on recyclable waste and food waste. China has built more than 200,000 treatment centers and has a strong treatment capacity.

4. Bio-composting: This process has a short fermentation cycle, is easy to mechanize, has a high degree of harmlessness, has similar investment costs to landfill and the finished product has agricultural fertilizer value. However, it has a poor hygienic environment at the work site, an average waste reduction rate and high operating costs.

5. Chemical / biochemical treatment: high temperature melting, metallurgical slag, chemical solid waste metal recycling, etc.

Table 3：Comparison of Waste Disposal Frequency in the EU and China

Source: own editing based on (Cai Feng & Xu Hai, 2022)

	Frequency %	
Region	EU	China
Incineration Without Energy Recovery	1.5%	Incineration 54.0% 2020
Waste-To-Energy Incineration Processes	6.5%	
Landfill Without Energy Recovery	19% 2020	Usage is gradually decreasing, no official data available
Waste-To-Energy Landfill		
Total waste recycling rate	58% 2022	59% 2023

As can be seen from the table, the EU is very concerned about the capacity of waste treatment and energy recovery and has specific data to show this. Only the energy recovery capacity of the landfill part of the waste is not counted. However, China's waste recovery capacity and methods are not very carefully divided, and statistics are not available. Of course, China is constantly transforming its industry to reduce landfills, but the sheer size of the country makes this statistic very difficult.

2.2. Technology For Sustainable Treatment of Municipal Solid Waste

2.2.1. The Process of Municipal Solid Waste Incineration

Municipal solid waste（MSW） treatment is the process of reducing the volume and accelerating the natural purification of solid waste by physical means (e.g., shredding, compression, drying, evaporation, incineration, etc.) or by biochemical actions (e.g., oxidation, digestion and decomposition, absorption, etc.) and chemical actions such as pyrolysis and gasification. There are five specific solid waste disposal methods: (1) Sanitary landfill. Using waste mines, ravines or digging deep trenches, the waste and soil are landfilled in layers, and the landfill can be used as parks and green areas. (2) High-temperature composting. The temperature of the rubbish rises through microbial fermentation, killing pathogenic bacteria, and the rubbish can be decomposed into high-quality fertilizer. (3) Incineration. Combustible rubbish is reduced in size and weight after incineration, and the heat energy can be recycled. (4) Safe landfill. Mainly landfill hazardous waste, higher than the sanitary landfill requirements. (5) Comprehensive utilization. Including metal back to the furnace, fiber paper, kitchen waste as feed and fertilizer.

Municipal solid waste incineration (MSWI) technology is predominantly used in European cities to burn waste to generate heat, which is used to generate electricity. Modern incineration plants are often equipped with efficient pollution control facilities to reduce the impact of air emissions. Although landfilling is a more traditional form of waste disposal, in Europe it is usually used as a complement to waste disposal systems rather than as a primary method.

Based on achieving self-sufficiency in the energy required for its own operation, this process provides various forms of energy such as electricity and heat to the outside world, and ensures low environmental pollution emission risks, making MSW an urban renewable energy cycle. An important link in the utilization process. Research shows that the mass reduction rate, volume reduction rate and energy recovery rate of MSWI can reach 70%, 90% and 19%.(Kumar & Samadder, 2017)Therefore, the MSWI process is an important factor in low-carbon, Areas such as environmental protection and sustainable energy all play a key role.

MSWI technology has the following processes：

1. Waste collection & transportation.
2. Waste sorting & shredding & drying.

3. Incineration：The two types of incineration，pyrolysis and gasification can be seen as key technologies for non-hazardous treatment and energy recovery. Pyrolysis is a process by which organic substances are heated to high temperatures in the absence of oxygen so that they decompose into gaseous, liquid, and solid products without complete combustion. The biochar produced by pyrolysis can be used for soil improvement, and the pyrolysis oil can be used as an energy source or a chemical feedstock. The biochar produced by pyrolysis can be used for soil improvement, and the pyrolysis oil can be used as an energy source or a chemical feedstock. Syngas from gasification can be used in fuel cells, power generation equipment and as an alternative energy source to conventional fuels.(Chopra et al., n.d.)
4. Energy Recovery：Boiler: The steam is used to drive a turbine connected to a generator, producing electricity.
5. Air Pollution Control
6. Ash Management
7. Emission Monitoring

In summary, the environmental friendliness of MSW incineration depends on how well it is managed and the extent to which it incorporates advanced technologies and pollution control measures. A comprehensive and balanced waste management approach that prioritizes waste hierarchy and minimizes environmental impacts is essential for sustainable waste management practices.

2.2.2. Utilization Rate of Municipal Solid Waste

The utilization rate is an important indicator of how efficiently a community, or a region manages its solid waste, emphasizing the reduction of waste sent to landfills and the promotion of sustainable waste management practices. Additionally, the utilization rate may be influenced by factors such as waste composition, available infrastructure, public awareness, and regulatory frameworks.

There are many factors that affect the combustion efficiency of complex waste components such as the activation energy of combustibles during thermal decomposition, the ambient temperature, the gas flow rate, etc. In general, the more complete the thermal decomposition, the more efficient the incineration process and the less secondary pollutants are produced.

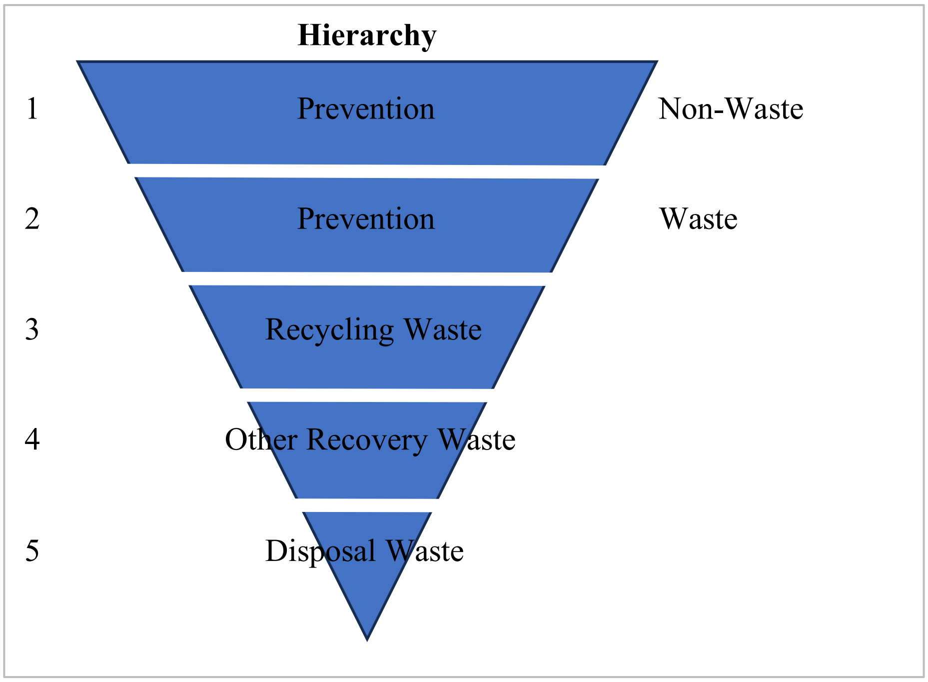
Another important reason for incomplete combustion is insufficient oxygen participation. Theoretically, combustible materials in solid waste can achieve complete combustion when they are sufficiently mixed with oxygen. In practice, however, for cost reasons, waste incineration plants do not connect directly to pure oxygen, but to air. The air contains non-combustible components such as carbon dioxide, which prevents complete combustion of the combustibles.(Hu Dechao, 2021)

2.3. Solid Waste Recovery

2.3.1. Waste Hierarchy

The European Commission introduced the Waste Framework Directive 2008/98/EC (WFD2008). The Directive not only makes recommendations for the treatment of end-of-life waste, but also for the treatment of discarded waste. It also recommends the adoption of a "waste hierarchy" applicable in the 28 EU Member States. The WFD2008 "Waste Hierarchy" creates a legal framework for dealing with waste in the EU has been established. The framework aims to protect the environment and human health by emphasizing the importance of appropriate waste management, recovery, and recycling techniques to reduce pressure on resources and improve their use. After that the European Union revised the directive in 2018 - (EU) 2018/851. make this directive more complete.

Figure 5: Waste Hierarchy
Source: own editing by (Gharfalkar et al., 2015)



Prevention，Reuse, Recycle, Recovery, Disposal：The EU's waste management policy is also based on:

1）Prevention: Using less material in design and manufacture. Keeping products for longer; re use. Using less hazardous materials.

2）Reuse: Checking, cleaning, repairing, refurbishing, whole items or spare parts.

3）Recycle: Turning waste into a new substance or product. Includes composting if it meets quality protocols.

4）Recovery: Includes anaerobic digestion, incineration with energy recovery, gasification and pyrolysis which produce energy (fuels, heat and power) and materials from waste; some backfilling.

5）Disposal: Landfill and incineration without energy recovery. (Guidance on Applying the Waste Hierarchy, 2011)

The EU no longer encourages waste-to-energy incineration to save resources and protect the environment, and clearly requires zero landfill of organic components in waste through separate recycling, waste incineration.

The waste hierarchy that has important implications for the circular economy include:

Effective use of resources:

The waste hierarchy emphasizes that resource reuse and recycling should be prioritized when dealing with waste to ensure efficient use of resources. This is in line with the core concept of circular economy, which is to convert waste into new resources and reduce dependence on primary resources.

Waste Reduction and Prevention:

By emphasizing waste reduction and prevention, the waste hierarchy prompts society to adopt more sustainable behaviors and reduce waste generation at both the production and consumption stages. This is consistent with the circular economy's goal of reducing linear economic models.

Economic and Environmental Benefits:

By prioritizing reuse and recycling, the waste hierarchy helps create jobs, increase resource efficiency, and reduce reliance on finite resources. This is in line with the goals of a circular economy, achieving sustainable development through economic and environmental benefits.

Social Participation and Awareness:

The promotion of the waste hierarchy can help improve society's awareness of waste management and encourage individuals and businesses to become more actively involved in waste reduction and circular economy practices. Social participation is an important component of the successful realization of a circular economy.

Regulations and Policy Guidance:

The waste hierarchy is often incorporated into regulations and policies by all levels of government and international organizations to guide and standardize waste management practices. This helps promote the implementation of circular economy at different levels.

Overall, the waste hierarchy promotes the transition of society to a circular economy model by promoting the best management of waste, achieving sustainable use of resources and reducing environmental pressure.

Technologies of Municipal Solid Waste Treatment

At the end of the 20th and beginning of the 21st century, modern waste management models in Europe were characterized by taking waste streams from the from the waste stream, selecting valuable materials and then sending the remainder to a newly built incineration plant. Only 30 years ago, the 25 per cent threshold for separate collection rates was considered unattainable anywhere on the continent. to be achieved anywhere on the European continent. As a result, huge incineration plants were built in Austria, France, Germany, the Netherlands, and Scandinavia.

The Spittelau Incinerator as a sample

In the Austrian capital of Vienna on the banks of the Danube River, located in the city center of the spittelau station exit, there is a very peculiar shape of the golden sphere-shaped building, both like a TV observation tower, but also like a revolving restaurant. In the sun's reflection, the ball looks particularly dazzling, in fact, it is a rubbish treatment plant, this no dust, no smell, no sewage rubbish treatment plant not only digested a large amount of waste/garbage/trash, but also the use of rubbish to provide steam, hot water, as well as a variety of useful curing material; at the same time it is a green rubbish disposal attracts tourists from all over the world, and has become one of the attractions of Vienna.

The entire landfill is worked and operated in 25 steps. From the first step of waste sorting, through a series of incineration, decarbonization and separation, with the clean water flowing into the Donau Canal, the solidified material in containers, and the steam being incorporated into the cogeneration plant.

Vienna has two such waste treatment plants. The city's 1.973.000 inhabitants and 5,300 industrial establishments are suppliers of raw materials to the dumps. The heat supply has crossed the Danube and covers 35 per cent of the city. Even the heating of the small UN City in NUcity (UN atomic energy structure) is heated by hot gas from here. The plant has safely exported 2,800 WM of heat energy to the region, and the total length of its pipelines has exceeded 1,000 kilometers, making it one of the longest pipelines in Europe.

While disposing of waste in a green way, the dump has become a proud tourist attraction in Vienna. The famous artist and social activist Friedensreich Hundertwasser transformed the dump into a work of art. From 1969, when the dump was built, to 1987, when it was remodeled, it had a very "traditional" appearance. It wasn't until 1991 that the dump took on an "artistic" look. The whole shape, material and decorative style changed radically.

The landfill is full of tiles, flamboyant colors, this is the style of Friedensreich Hundertwasser. He introduced colorful plants and fruits into the landfill with the purpose of asking people to abandon the thinking that rubbish must be "dirty and stinky", and that rubbish as a part of human life can be recycled in a green way, and at the same time warning people to be kind to the nature and protect the ecology.(Chaliki et al., 2016)

Figure 6: Spittelau's incineration plant in Vienna

Source: Google

Today, we know that waste prevention and new business models can reduce waste generation, and that separate waste collection rates can reach 90%. In other words, the shift from traditional waste management to resource management is a fundamental shift in the way materials and waste are handled. This is also a core principle of the circular economy, which aims to minimize waste, maximize resource efficiency, and promote sustainable practices throughout the product life cycle.

2.3.3. Assessing of Incineration

Generowicz (Generowicz et al., 2011) previously analysed three different incineration plants (Spittelau in Vienna, Warsaw and Tarnobrzeg) as well as alternative waste treatment versions and waste management infrastructures. The results show that waste incineration is more favorable than other disposal ways.

In all calculations, regardless of the priority or volume of criteria, incineration of waste was considered more beneficial than landfill, taking into account technical, economic and environmental criteria. The W5 option excelled in terms of environmental, technical and economic benefits, receiving a higher overall score than the other treatment technologies. The W5 technology reduces the overall harm to the environment and performs particularly well in terms of waste minimization and energy recovery. In addition, the Spittelau plant uses a highly efficient combustion gas cleaning system that significantly reduces environmental emissions. The Spittelau incineration plant is not only technologically mature but has also done a great deal to improve public relations and community acceptance. These factors combined to make W5 (Spittelau incineration plant) the optimal choice in a multi-criteria analysis, which combined environmental, economic, and social factors to demonstrate a comprehensive and sustainable waste management solution.

W5：example of the municipal waste incineration plant at Spittelau in Vienna

2.3.4. Reasons for the Success of Vienna's Circular Economy

Technical Reasons

The Spittelau incinerator was technically upgraded between 2011 and 2015 to minimize the environmental impact of the facility and answer ecological concerns, such as reducing the toxicity of combustion vapors (through denitrification processes) and increasing the efficiency of energy production. Constant upgrading of the facilities allows the Spittelau incinerator to always be able to respond to new problems in different times.

The Spittelau incinerator accepts municipal solid waste collected from households and businesses in Vienna. The Spittelau incinerator plays a key role in managing Vienna's waste, contributing to the city's efforts to minimize landfill, recover energy from waste and promote sustainable waste management practices.

Social Reasons

Art can become a way to introduce ecological concerns to citizens, in connection with waste management. The Spittelau incinerator successfully transformed the issue of waste into something positive, an object of active mobilization that people can relate to.(BEAUDOIN Marion et al., 2021)

Taking advantage of the high level of artistry and artistic atmosphere in the region, Vienna has promoted the Spittelau incinerator artistically, investing in public awareness campaigns and educational programmes to promote understanding and support for circular economy principles among citizens, businesses and other stakeholders. This engagement fosters a culture of sustainability and encourages participation in circular initiatives.

Political Reasons

Since Vienna is not only the capital but also constitutes one of the provinces, it has more legislative power than other cities.

Another key feature of the Austrian political system is the social partnership, a form of institutionalized dialogue on economic and socio-political issues, established after the Second World War, between the four social partners: on the one hand, the Chamber of Labor (Arbeiterkammer—AK) and the Austrian Trade Union Confederation (Österreichischer Gewerkschaftsbund—ÖGB) representing the interests of employees, and on the other, the Austrian Federal Economic Chamber (Wirtschaftskammer Österreich—WKO) and the Chamber of Agriculture (Landwirtschaftskammer Österreich—LKÖ) representing the interests of the employers.

Thirdly, the city has been governed by social-democratic mayors since the Second World War, since 2010 the social democrats are in a coalition government with the Green Party.(Brandl & Zielinska, 2020)

These have led to projects such as the Smart City Vienna Framework Strategy (SCWR)，"Biogas Wien". Vienna has established robust policies and regulations that support and incentivize the transition to a circular economy. This includes measures such as waste reduction targets, extended producer responsibility schemes, and procurement policies that favor environmentally friendly products and services.

2.4. Current Status and Challenges of Circular Economy Construction

2.4.1. The Problems Facing Europe Under the Energy Crisis

The Impact of the Energy Crisis in Europe on the Circular Economy

In the autumn and winter of 2022, the energy crisis in Europe caused by the outbreak of the Ukraine conflict was growing. Cuts in Russian gas supplies have created an immediate need for a transformation in the way energy is supplied to the European region. Europe may have to improve its energy efficiency and turn to green alternatives. Coupled with inflation and rising prices, protests and strikes are taking place in European countries. It is worth noting that this energy crisis may not only precipitate changes in the global energy map and national energy industries but may also have a spillover effect on climate action and a long-term impact on the world economy.

As a result of the crisis, many nations have had to reevaluate their needs for energy security. For example, Lützerath in Germany will restart coal lignite mining activities. German government allowed coal mining companies to extract lignite, considered to be the dirtiest form of coal, the images of environmentalists from all over Europe converging on the site and standing in front of huge bulldozers in protest went viral.

Germany has been undergoing an energy transition since 2011, with the goal of phasing out nuclear power plants by 2022, but this plan has been delayed until 2023 due to concerns about a possible energy crunch following Russian production cuts.

In addition, the governments around economist and climate minister Robert Habeck and North Rhine-Westphalia's Minister of Economy and Climate, Mona Neubauer, have proposed an agreement to phase out coal by 2030, instead of 2038 as previously announced. (Tatjana Winter, 2023)

All in all, there are signs that when economic and environmental interests come into conflict, governments are also forced to change their previous policies. The energy crisis has made the efforts of the world's environmentalists an elusive endeavor. It has also led to the outbreak of many environmental movements in Germany.

2.4.2. Environmental Management Systems Adopted by Countries at Different Levels of Development

"It is necessary to prioritize recycling, resource generation (such as decomposition, incineration, and anaerobic digestion), and waste reduction over landfilling to attain a high level of environmental friendliness. However, it is essential to observe that technologies necessitating large upfront investments and skilled labor are better suited for high-income countries. Conversely, low-income countries should prioritize waste reduction through recycling, waste depots, and methods that correlate with their existing capabilities to reduce the amount of waste sent to landfills."(Budihardjo et al., 2023) As this article suggests, high-income countries and low-income countries are suited to different approaches to reaching environmentally friendly levels.

The World Bank rates countries based on GDP growth (annual %), GNI per capita (PPP, current international US dollar), gross capital formation (% of GDP), inflation (GDP deflator, annual %), mobile cellular subscriptions (per 100 people), Multiple criteria, such as population growth (annual %), military expenditure (annual %), and fertility rate (total birth per woman), classify countries into five categories：High Income, Upper-middle Income, Lower-middle Income, Low Income, Not classified. However, there are still many factors that affect classification. This classification still needs to be improved. Here using the particularly distinct classifications of High Income and Low Income.(Nima MIRZAEI, 2011)

The Atlas method is a method used by the World Bank to calculate gross national income per capita (GNI per capita). The following are the standards.

Table 4: The World Bank Measures Countries' Scores in Terms of GNI Per Capita

Source: own editing based on(Nada Hamadeh et al., 2023)

Income Category	GNI per Capita ($)
Low Income	<= 1135
Lower-middle Income	1136 - 4465
Upper-middle Income	4466 - 13845
High Income	> 13845

High-Income Countries

Countries with high per capita income and GDP produce more plastic and paper than those with low per capita income and GDP. So, it's a side note that high-income countries are better suited to incineration to solve environmental problems. Such as Austria, Germany, etc. High-income countries are better placed to develop environmentally friendly measures that are heavily invested and technologically advanced.

Low-Income Countries

In contrast, the percentage of biodegradable garbage to total waste is higher in low-income countries. To minimize the quantity of garbage that ends up in landfills, these low-income nations should prioritize waste reduction through recycling, waste banking, and other techniques linked to current capacity. Additionally, it was suggested that low-income nations should speed up the creation of integrated municipal solid waste management systems, as this might have a major positive economic impact.

2.4.3. Plastic Waste Reduction on Energy Supply

Austria plays an active role on the international environmental stage, promoting global environmental protection and sustainable development by sharing its experience and technologies in plastic waste management and energy efficiency. In terms of plastics disposal, the Austrian Government has adopted strict environmental regulations and policies, such as limiting the use of single-use plastic products, promoting plastic recycling, and encouraging the use of environmentally friendly packaging materials. Austria has one of the most efficient waste management and recycling systems in the world. The country has clear guidelines and high standards of enforcement for plastics recycling, which ensures that a high percentage of plastic waste is recycled and reused rather than sent to landfills or incineration facilities, reducing energy consumption and environmental pollution. The Austrian technology for plastics disposal is therefore particularly suitable to be learnt from.

The most recyclable of municipal solid waste is plastics, and plastics management occupies a very important place in the Austrian circular economy. Plastics are involved in the operation of Austria's best-known incinerator - The Spittelau incinerator. Generally speaking, “States that display high incineration capacity at the national scale tend to have above average recycling and composting levels, but locally, cities and regions that host WtE facilities tend to have low recycling scores.”(Malinauskaite et al., 2017) However, Austria, with its great circular economy model and high recycling rate, faces a significant challenge. First off, Austria encourages citizens to separate and recycle recyclable garbage thanks to a comprehensive recycling and sorting system in place. This indicates that comparatively little garbage is burned in incinerators. Second, Austria is dedicated to advancing the circular economy, maximizing resource recycling and useful life. This includes encouraging resource conservation in both production and consumption, recovering and reusing resources, and designing products to generate less waste. But unfortunately, the conversion rate of Packaging and Packaging Waste is very low. After sorting, 26% ± 7% of the total waste plastic packaging stream is converted to secondary raw materials as regranulators, while the rest is processed in WtE plants (40% ± 3%) and in the cement industry (32% ± 6%).(Van Eygen et al., 2018)

Furthermore, the value of many mixed plastics cannot be seen. This paper(Picuno et al., 2021) tells us this. Austrian enterprises that recycle mixed plastics have a limited capacity, and the majority of them do not plan to expand because there is a restricted market for their products. Government initiatives to boost recycling rates have boosted the supply of sorted mixed plastics, but the demand for mixed recyclers has stayed essentially constant. In contrast, mixed plastics are primarily being used in the cement sector in Austria as an alternative fuel. Lastly, even though tougher sorting regulations can reduce the manufacturing of mixed plastics, it is still ineviA "mixed plastics sorting product" is the end result of any plastic waste sorting process. Therefore， it is impossible to categorize these mixed polymers as valued sorted items.

That's why Austria is currently facing the dilemma of having no waste to burn. This makes it impossible for Austria's perfect waste management system to work well and for residents to get enough heating, electricity from the incinerator, etc.

2.4.4. Solution

Waste Plastic Sorting and Processing

People don't take into account the plastics present in composites or other hybrid material compositions, such as hygiene products. (Schwarzböck et al., 2017) And it finds that even with thermal treatment technology in Austria, the plastic content of municipal solid waste is still low. Thinking about it the other way round, the number of plastics inside composites or other mixed materials cannot be underestimated, so in order to solve Austria's dilemma of having no waste to burn, isn't it possible to make use of these stuff materials. Before the waste is sent to landfill. What about the possibility of adding a process of uniform sorting?

The conversion of waste plastics into high-value materials is also a highly researched part of the process.(Gong et al., 2014) Waste plastics can be involved in the synthesis of carbon nanomaterials. In addition, waste plastic resources have been transformed into other carbon materials with exclusive functions. (Elessawy et al., 2020)

These research continue to promote the technical reliability, greenness and economic advantages of waste plastics resource utilization technology, so that the problems of waste plastics management and utilization plaguing the world can be fully solved, and ultimately support the energy and chemical industry to move towards green and circular development in the true sense.

Bio-based plastics could also be considered as new incineration materials. Bio-based plastics are a class of plastics produced from biological feedstocks (e.g., plants, microorganisms, agricultural by-products or renewable vegetable oils) rather than traditional fossil fuels. These biological feedstocks can be converted into monomers through a biochemical process and then polymerised into plastics. Bio-based plastics can be either biodegradable or non-biodegradable. When biobased plastics are biodegradable, the environmental impact is also relatively low compared to the risk of incineration. When bio-based plastics are not biodegradable and need to be incinerated, incineration as energy recovery has the potential to recover the energy contained in plastic waste, partially offsetting the use of fossil fuels and contributing to the reduction of greenhouse gas emissions. Specific cases of bio-based plastics, such as bio-based high-density polyethylene (HDPE), bio-based polyethylene terephthalate (PET), and bio-based expanded polystyrene (EPS), may result in negative emissions. (de Oliveira et al., 2021)Negative emission technologies are those that directly remove carbon dioxide from the atmosphere and are therefore also known as carbon removal technologies. Therefore, energy recovery incineration of biobased plastics is feasible.

2.5. Legal background

2.5.1. EU Circular Economy Development

The circular economy idea has long been important in the management of municipal solid waste. Reducing, reusing, and recycling resources is at the heart of the circular economy concept, and it aligns with the objective of treating municipal solid waste. The development of the circular economy has led to ongoing technological innovation in the handling of municipal solid waste. As a result, using the circular economy as a guide leads to sustainable development, which can result in the emergence of new markets, business models, and areas of economic expansion.

Development of the definition of circular economy. “The practical implication is that CE definitions currently popular in the academic community may be less applicable for practitioners than were definitions common five or more years ago.” (Kirchherr et al., 2023) The trends in the evolution of CE definitions over time. It is separated into the consensus and creation of new ideas.

It is generally agreed upon that the underlying ideas of CE have not changed much over time, with "reuse" and "recycling" being named as the two key tenets in 70–80% of the articles.

Value preservation and resource efficiency are mentioned as goals of CE in about 40% of definitions, which is a recent development. This focus is expected to become more significant in light of supply chain disruption, localization of production, and growing resource scarcity. Few authors concur that economic prosperity should be the primary objective of CE.

Second, the new data clearly demonstrates a broad spectrum of internal drivers. In addition to manufacturers and consumers, the envisaged CE alliance currently consists of academics and legislators. Furthermore, the importance of technological innovation and competencies is emphasized as the cornerstone for each member's participation in the alliance.

A hint of the shifts in policies supporting the circular economy's growth can be seen in the way the concept of the circular economy has evolved. It has yielded consensus worthy of application to development, but it has also been continuously adjusted to provide more suitable recommendations for the majority.

Table 5: Timeline of Circular Economy Action Plan

Source: own editing based on European Commission's database (Commission)

September-October 2023	Adoption of several initiatives on microplastics
May 2023	European Commission revises the circular economy monitoring framework
22 March 2023	European Commission adopted proposals on green claims and right to repair
30 November 2022	European Commission adopted measures proposed in the circular economy action plan
5 April 2022	European Commission adopted proposals for revised EU measures to address pollution from large industrial installations
30 March 2022	European Commission adopted package of measures proposed in the circular economy action plan
17 November 2021	European Commission adopted proposal for news rules on waste shipments
28 October 2021	European Commission adopted proposal to update rules on persistent organic pollutants in waste
22 February 2021	Global Alliance on Circular Economy and Resource Efficiency (GACERE) launched
10 December 2020	European Commission adopted a proposal for a new regulation on sustainable batteries
11 March 2020	European Commission adopted new circular economy action plan
11 December 2019	European Commission adopted European Green Deal

December 2015	European Commission adopted the first circular economy action plan

2.5.2. Hungarian's Attitude Towards Solid Waste Incineration

Hungary does not perform well enough in terms of waste management. Hungary's waste recycling rate in 2021 is only 34.9%, which is lower than the EU average of 49.6%. In 2021, 51% of Hungary's municipal waste will still end up in landfills, which is twice the EU average of 22.8%. Illegal waste dumping will also continue to be an issue, made worse by the low rate of composting and digesting (39 kg per person in 2021 compared to the EU average of 100 kg per person in 2021). At 39 kg per person, the rate of composting and digestion is likewise low when compared to the EU average of 100 kg in 2021.

Recycling of waste. Compared to the EU average, Hungary's industrial system recycles less. Hungary's standard purchasing power per kilogram in 2021 will be 1.6, while the EU's will be 2.3. (COMMISSION STAFF WORKING DOCUMENT 2023 Country Report-Hungary Accompanying the Document ,2023)

In conclusion, Hungary's waste treatment and management capacity falls short of EU criteria for a number of reasons, including recycling and reuse.

3. MATERIALS AND METHODS

3.1. Questionnaire Subjects

The data was collected using an online questionnaire in Hungary and Poland, which was filled out by a total of 178 participants. We used the resulting purchase pattern in our analyses. The empirical data collection was conducted between 1 March 2024 and 30 March 2024.

The questionnaire consisted of two major parts. The first part of the questionnaire was a basic collection of the participants' demographic variables (like age and gender).The second part was a series of seven questions employing the Likert-scale, where participants were asked to define how much they approve of the statements (1—Strongly disagree, 5—Strongly Agree) about perception of EU residents on the construction of waste incineration as a sustainable energy source towards natural cosmetics, and the statement given ("I like to try to use new way of waste incineration ."), furthermore, using Yes/No answers.

3.2. Methods

Interval technique: a quantitative approach

A Likert scale is a type of psychometric scale that is frequently used in questionnaire-based research. Although there are other kinds of rating scales, the word (or more precisely the Likert-type scale) is sometimes used interchangeably with rating scale because it is the most commonly used method for scaling responses in survey research.

Rensis Likert, a psychologist, is the inventor of the scale, hence its name. Likert made a distinction between the format in which replies are scored over a range and the scale proper, which is derived from collective responses to a series of items (often eight or more). In technical terms, a Likert scale solely pertains to the former. The contrast Likert established between the underlying phenomenon accounts for the difference between these two conceptions.

Respondents indicate how much they agree or disagree with a sequence of items on a symmetric agree-disagree scale while answering a Likert item. Consequently, the range expresses how strongly they feel about a certain thing. As a result, businesses, marketing, statistics, psychology, and the social sciences have all used Likert scales.

The Necessity of Questionnaires

This paper makes extensive use of the literature review to construct the results of the questionnaire within the wider context of existing research and theory. The acceptability of public perceptions of potential social barriers to the implementation of waste incineration projects is discussed.

Secondary source is important in providing a theoretical basis for research into sustainable approaches to municipal solid waste incineration, helping to explain the data collected through the questionnaire and the academic debate that took place. Secondary source and primary sources go hand in hand. Questions such as increased heating costs, public trust in environmental projects, capturing those aspects of waste incineration that the public does not trust, the price of building a green incineration plant, willingness to recommend an environmentally friendly and green incineration plant, and the cost of maintenance of a green incineration plant are used in the questionnaire to generate real-time insights into the public's perception of the implementation of a green waste incineration project, whereas the secondary data provides the context and validation framework to support the interpretation of these insights.

The Purpose of the Questionnaire Survey

This questionnaire aims to collect data on European citizens' perceptions of the construction and operation of green solid waste incineration plants as primary energy supply systems. Rationale: This is crucial as public acceptance is often a major barrier or facilitator to the implementation of new technologies and infrastructures, especially those related to waste management and energy production. Understanding public opinion can help policymakers and companies develop strategies that are more likely to gain public support and effectively address public concerns.

The Harvest of Questionnaire Survey

A questionnaire survey format can help by exploring the willingness of individuals to rely on such plants for their energy needs, and the survey can help measure the rate of adoption by potential users as well as the willingness to switch from traditional to new energy sources.

The questionnaire assesses the public perception of the pros and cons of waste-to-energy plants. This includes their views on environmental impacts, sustainability, and energy efficiency.

By correlating perceptions and intentions with demographic variables such as age, gender, income and educational background, the study can identify which demographic groups are more likely to be in favor of or against waste incineration plants.

Understanding the perceived risks associated with waste incineration plants from the public's perspective can help mitigate these concerns through better safety features, transparency, and community involvement.

In summary, the questionnaire is essential to comprehensively analyze the socio-economic and psychological conditions surrounding the acceptance of waste incineration as a sustainable energy solution. It helps to build a bridge between technology developers, policymakers and the public to ensure that future initiatives for sustainable energy production are welcomed and effectively integrated into society.

4. RESULTS

4.1. Reliability Test

Reliability analysis is a test of the stability, consistency, and reliability of the measurement results, in order to ensure the accuracy of the measurement results, the reliability analysis of the valid data in the questionnaire needs to be carried out before the analysis.

Generally speaking, if the reliability coefficient is above 0.9, it means that the reliability is very good, if it is between 0.8~0.9, it means that it is very good, if it is between 0.7~0.8, it means that it is good, if it is 0.6~0.7, it means that it is acceptable, and if it is below 0.6, it means that it needs to be revised.

As can be seen from the table, the reliability coefficient of the scale items is higher than 0.856, so it is considered that the survey data is more reliable.

Table 8：Reliability Statistics

Scale	**Cronbach's Alpha**
Total	0.856

4.2. Validity Test

Validity refers to the degree to which the psychological and behavioral characteristics of the required test can be accurately measured through a test or scale tool, that is, the accuracy and reliability of the test results.

In general, the smaller the significance level of Bartlett 's test (P<0.05), the more likely it is that there is a meaningful relationship between the original variables. The KMO value is used to compare the simple and partial correlation coefficients between items, and the value is between 0 and 1. The criteria for whether it is suitable for factor analysis are: greater than 0.9, very suitable, 0.7-0.9 suitable, 0.6-0.7 more suitable, between 0.6-0.5 not very suitable, and less than 0.5 to give up. The Bartlett spherical test value is used to test whether the correlation coefficient between items is significant, and if the significance is less than 0.05, it indicates that each item is suitable for factor analysis.

The validity test is used to verify whether the variables are independent of each other by the spherical test, in which the KMO value is 0.784, which is greater than 0.7, and the significance of the Bartley 's test statistical value is <0.001, which is considered to be good.

Table 9： KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.784
Bartlett's Test of Sphericity	**Approx. Chi-Square**	1768.804
	df	210
	Sig.	< 0.001

According to the extraction principle of the default eigenvalue greater than 1 of the principal component method in factor extraction, it can be seen in the table that the factor extraction of the data collected by the questionnaire is based on the default eigen root greater than 1, and a total of 7 common factors were extracted, and the cumulative variance contribution rate of 76.779% was greater than 60%, and the interpretation degree of the extraction was good, indicating that the extracted factor effect was better.

Table 10： Total Variance Explained

Component	**Initial Eigenvalues**			**Extraction Sums of Squared Loadings**		
	Total	**% of Variance**	**Cumulative**	**Total**	**% of Variance**	**Cumulative**
1	5.058	24.087	24.087	5.058	24.087	24.087
2	2.539	12.091	36.178	2.539	12.091	36.178

3	2.426	11.552	47.730	2.426	11.552	47.730
4	2.047	9.749	57.479	2.047	9.749	57.479
5	1.518	7.229	64.708	1.518	7.229	64.708
6	1.302	6.199	70.907	1.302	6.199	70.907
7	1.233	5.872	76.779	1.233	5.872	76.779
8	0.579	2.756	79.535			
9	0.503	2.394	81.929			
10	0.452	2.151	84.080			
11	0.428	2.039	86.119			
12	0.399	1.899	88.018			
13	0.361	1.717	89.735			
14	0.345	1.643	91.378			
15	0.336	1.602	92.980			
16	0.306	1.458	94.438			
17	0.282	1.345	95.783			
18	0.258	1.227	97.010			
19	0.249	1.187	98.197			
20	0.208	.992	99.189			
21	0.170	.811	100.000			

Extraction Method: Principal Component Analysis.

4.3. Frequency Analysis

The results of gender frequency analysis showed that: female frequency was 51, accounting for 28.7%; male frequency was 127, accounting for 71.3%. Male (71.3%) was the highest and female (28.7%) was the lowest.

The results of age frequency analysis showed that: 26-35 frequency was 121, accounting for 46.6%; 36-45 frequency was 83, accounting for 11.2%; 46-55 frequency was 24, accounting for 13.5%; <26 frequency was 42, accounting for 23.6%; >56 frequency was 9, accounting for 5.1%. Age between 26-35 (46.6%) is the highest and >55 (5.1%) is the lowest.

The results of the education frequency analysis showed that: the frequency of high school and below was 32, accounting for 18.0%; the frequency of bachelor's degree was 98, accounting for 55.1%; the frequency of master's degree was 38, accounting for 21.3%; the frequency of above master’s degree was 10, accounting for 5.6%.) was the lowest.

The results of income frequency analysis show that the frequency of < 150000Ft is 52, accounting for 29.2%; 150001-300000 Ft is 78, accounting for 43.8%; 300001-400000 Ft is 24, accounting for 13.5%; 400001-700000 Ft is 24, accounting for 13.5%. >700001 Ft is 0, accounting for 0%. Income between 150001-300000 Ft (43.8%) is the highest, >700001 Ft (0 %) is the lowest.

Table 11: Comparison of Gender，Age ，Education and Income

	variable	**Frequency**	**Percent**
Gender	female	51	28.7
	male	127	71.3
Age	< 26	42	23.6
	26-35	83	46.6
	36-45	20	11.2
	46-55	24	13.5
	>55	9	5.1
Education	High school and below	32	18.0
	Bachelor’s degree	98	55.1
	Master's degree	38	21.3
	Above master’s degree	10	5.6
Income	< 150000Ft	52	29.2
	150001-300000 Ft	78	43.8
	300001-400000 Ft	24	13.5
	400001-700000 Ft	24	13.5
	>700001 Ft	0	0
Total		178	100.0

4.2. Descriptive Analysis

Descriptive statistical analysis is generally performed to measure the level of each variable's indicator by means and standard deviations. The higher the mean indicates the higher the average level of the sample for this indicator, and the discrete trend is used to describe the dispersion of data in the data distribution, such as the standard deviation indicates the size of the difference between different samples on the same indicator. This questionnaire to the scale observation, mainly take the five-level Likert scale, the higher the score, the higher the degree of agreement, from the above table can be seen, the higher the score of each aspect, indicating that the subjects are more approved of this.

While the descriptive statistical analyses showed the smallest mean value for green trust, the sample standard deviation for green trust was relatively large. In general, green trust represents a moderating effect on the relationship between environmental concern and green product purchase intention. However, here the mean of green trust is the lowest while the sample standard deviation is large, and the standard deviation of green trust is closely related to the skewed distribution. Therefore, green trust has a negative effect on the willingness to build green waste incineration plants.

Whereas green value has the highest mean and the sample standard deviation is relatively small. Therefore, the effect of green value has a positive effect on the willingness to build green waste incineration plant. The influence of green value is a consideration factor for consumer consumption.

Also, the mean value of financial risk is high, and the sample standard deviation is relatively small. Therefore, the effect of fiscal risk has a positive effect on the willingness to build green waste incineration plant. The effect of financial risk also is a consideration for the use of green waste incineration plants by EU residents.

Table 12: Descriptive Statistics

	Mean	**Std. Deviation**	**N**
Consumer innovation	3.4757	1.23700	178
Green Trust	3.0637	1.27497	178
Green values	3.9363	0.95192	178
Energy Source	3.8521	0.98257	178
Plant Price	3.6948	1.01394	178
Plants Promotion	3.5281	1.05921	178
Financial Risk	3.8146	0.88792	178

4.3. Correlation Analysis

Correlation analysis is the process of describing and analyzing the nature of the interrelationship between two or more variables and the degree of their correlation. The correlation coefficient is marked with an * in the upper right-hand corner of the coefficient, which indicates that there is a relationship; conversely, there is no relationship. A correlation coefficient greater than 0 indicates a positive relationship between the two variables, while a coefficient less than 0 indicates a negative relationship between the two variables.

** stands for significant correlation at 0.01 level (two-tailed), so it can be seen from the above table that there is a significant correlation between Financial Risk and the variables, where the correlation coefficients of the variables are greater than 0, which indicates that there is a significant positive correlation.

Table 13: Correlations

	Consumer innovation	Green Trust	Green values	Energy Source	Plant Price	Plants Promotion	Financial Risk
Consumer Innovation	1	0.074	0.325**	0.386**	0.103	0.303**	0.380**
Green Trust	0.074	1	0.157*	0.071	0.123	0.020	0.162*
Green values	0.325**	0.157*	1	0.229**	-0.009	0.174*	0.241**
Energy Source	0.386**	0.071	0.229**	1	0.158*	0.088	0.320**
Plant Price	0.103	0.123	-0.009	0.158*	1	0.206**	0.249**
Plants Promotion	0.303**	0.020	0.174*	0.088	0.206*	1	0.312**
Financial Risk	0.380**	0.162*	0.241**	0.320**	0.249*	0.312**	1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

4.4. Regression Analysis

Regression analysis is a method of statistical analysis that further tests the degree of interdependence between variables. Multiple regression analysis refers to the establishment of a linear or non-linear mathematical model of quantitative relationships between multiple variables by treating one variable as the dependent variable in the correlation, and one or more other variables as the independent variables, and analyzing them using sample data.

Correlation analysis is the basis and prerequisite for multiple regression analysis, which is used to reflect the degree of correlation between the variables, and only if there is a strong correlation between the variables, there is a need for regression analysis. Regression analysis is the depth of correlation analysis, which can further reflect the quantitative relationship between the variables with strong correlation, reflecting the interaction between the variables.

From the above, it was confirmed that there was a significant correlation between the willingness to build green waste treatment plants and the influencing factor variables, so further regression analyses were conducted.

Table 14: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.516[a]	0.266	0.240	0.77387

a. Predictors: (Constant), Consumer innovation, Green Trust, Green values, Energy Source, Plant Price, Plants Promotion, Financial Risk.

Table 15: ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	**Regression**	37.141	6	6.190	10.363	<0.001[b]
	Residual	102.408	171	0.599		
	Total	139.549	177			

a. Dependent Variable: Financial Risk

b. Predictors: (Constant), Consumer innovation, Green Trust, Green values, Energy Source, Plant Price, Plants Promotion, Financial Risk.

Table 16: Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	**Std. Error**	**Beta**	**t**	**Sig.**
1	**(Constant)**	1.128	0.382		2.951	0.004
	Consumer Innovation	0.148	0.055	0.206	2.693	0.008
	Green Trust	0.069	0.047	0.099	1.478	0.141
	Green values	0.082	0.066	0.088	1.235	0.219
	Energy Source	0.156	0.065	0.173	2.389	0.018
	Plant Price	0.132	0.060	0.151	2.207	0.029
	Plants Promotion	0.156	0.059	0.186	2.638	0.009

a. Dependent Variable: Financial Risk

The goodness-of-fit test shows that the R-square is 0.266, indicating that the portion of the dependent variable that can be explained by the regression equation is 26.6%. The significance of the F-test is less than 0.05, which achieves the level of significance, indicating that the established regression model is valid.

The significance of Consumer Innovation, Green values, Energy Source, Plant Price, and Plants Promotion is less than 0.05, and the regression coefficient is greater than 0, which indicates that there is a significant positive effect on Financial Risk.

Except Green Trust and Green values. This means that the Green Trust and Green values do not provide enough evidence that the independent variables in the model have a significant impact on the dependent variable.

4.5. Results And Evaluation

Number of questionnaires

A total of 178 valid surveys were received.

Gender and age of respondents

Among the respondents, 127 (71.3%) were male and 51 (28.7%) were female, which is basically in line with the design ratio of the research. 83 (46.6%) of the respondents were aged between 26-35 years old, which is the highest, while 20 (11.2%) were aged between 36-45 years old, and 24 (13.5%) were aged between 46-55 years old. People younger than 26 years old totalled 42 people, accounting for 23.6%. The lowest number of respondents was older than 56 years of age, 9 persons or 5.1%.

Educational level of respondents

Among the respondents, 32 (18.0 % had a high school education or below. Bachelor's degree is the highest with 98 respondents, accounting for 55.1%. There were 38 respondents with master's degree, accounting for 21.3%. The least number of respondents was 10 (5.6 %) with a master's degree or higher.

Average monthly income of the respondents (hereinafter referred to as monthly income)

The average monthly income of the respondents is highest in HUF 150001-300000, totaling 78 people (43.8%), up to HUF 150,000, 52 people (29.2%), between HUF 300001- 400000 and between HUF 400001-600000, both 24 people (13.5%), and above HUF 700001, the lowest number is 0 people.

The result of the survey shows that the Consumer Innovations have significant correlation between Financial Risk, Energy Source, Green values in the correlation analysis. Plant Price has no correlation with green values.

The result of the survey shows that the Green Trust have slightly significant correlation between green values and Financial Risk in the correlation analysis.

The results of the survey show that green values have strong significant correlation between Consumer Innovation, Energy Source, and Financial Risk in the correlation analysis of the respondents. Green values had a slightly stronger significant correlation with Green Trust and Plants Promotion.

The results of the survey show that the Energy Source have strong significant correlation with the factors Consumer Innovation, Green values, and Financial Risk in the correlation analysis. Energy Source has a slightly stronger significant correlation with Plant Price.

The results of the survey show that the Plant Price have slightly significant correlation between Energy Source, Plants Promotion and Financial Risk in the correlation analysis.

The results of the survey show that the Plants Promotion have a slightly significant correlation between Energy Source, Plants Promotion, and Financial Risk in the correlation analysis.

The findings show that Financial Risk has strong significant correlations with almost all factors in the correlation analysis. Only Financial Risk has slightly significant correlation with Green Trust.

5. CONCLUSION

So, from the questionnaire it is clear that Financial Risk is the most concerned factor in the survey. The respondents are still worried that Eco-energy plants will not solve the country's energy shortage problem and will cost the government a lot of money in terms of expenses and maintenance costs.

Regression analyses reflect the interaction of variables and Financial Risk. The numerical relationships of Consumer Innovation, Energy Source, Plant Price, and Plants Promotion are not very different from each other, but the significance is greater than 0.05. These four independent variables have a significant effect on the dependent variable Financial Risk.

Suggest Improvements Based on Displayed Results

1. Improving environmental standards and technologies

Adoption of advanced incineration technologies. Convert the heat energy generated in the incineration process into electricity or heating energy to improve the efficiency of resource utilization.

2. Enhance transparency and public participation

Regularly publish detailed information on incineration plant operations, emission data and environmental impact assessments to enhance transparency.

3. Enhanced Environmental Regulation

Strict environmental standards: Regular environmental monitoring to ensure that the incineration plant meets or exceeds EU environmental protection standards.

4. Highlight case studies and environmental accomplishments

Present successful case studies of incinerator plants in the EU and around the globe, with a focus on those that have excelled in energy recovery, environmental preservation, and community involvement.

5. Financial information disclosure and transparency

To improve project openness, make the costs of building, running, and maintaining trash incinerator plants clear and transparent, along with the anticipated financial gains. Provide evidence of the long-term financial advantages of investing in trash incinerator plants, such as energy recovery, better environmental outcomes, and possible job creation.

6. Financial support and incentives

In order to partially offset operational expenses, highlight the financial gains that garbage incinerator plants can make through energy recovery (such as the production of heat and electricity). Provide evidence of the financial advantages of waste incineration over more conventional waste disposal techniques, such as landfilling, in terms of lowering long-term environmental remediation and landfill expenses.

6. SUMMARY

This thesis investigated municipal solid waste (MSW) incineration within the context of sustainable energy production, focusing on the EU's waste management practices and drawing comparisons with China's approach. The research revealed critical insights into waste classification systems, technological innovations in waste incineration, and public attitudes towards waste-to-energy facilities.

A literature review provided the foundation for understanding the EU's and China's waste treatment infrastructures and policies, highlighting the advancements in sustainable MSW treatment technologies and the role of incineration in the circular economy. This thesis shows the potential of municipal solid waste (MSW) incineration as a sustainable energy source, with a focus on Austria's practices and its role in addressing the current European energy crisis. The study investigates the technological innovations in MSW incineration processes and explores the success of Vienna's circular economy through its waste management systems, particularly the renowned Spittelau incinerator. The research identifies the factors impacting public perception and acceptance of waste-to-energy (WtE) facilities within the European Union.

A comprehensive literature review provides the backbone for this thesis, examining EU waste classification, treatment technologies, and the integration of solid waste recovery into the circular economy.

Key findings include a recognition of the EU's stringent waste management practices and its focus on circular economy principles, as well as the challenges faced under the current energy crisis.

The thesis utilized a comprehensive quantitative and qualitative methodology, resulting in a robust analysis of the data. Correlations between public perception and the adoption of MSW incineration for energy recovery were explored, with results emphasizing the importance of enhancing public understanding and trust in sustainable waste management.An extensive questionnaire survey gauges European attitudes towards MSW incineration and circular economy concepts, contributing to the analysis of current challenges and potential solutions for optimizing energy supply amidst stringent environmental policies. The findings suggest that Austria's proactive stance on environmental policy and its innovative waste management techniques play a critical role in its energy landscape. This study contributes to the broader discourse on sustainable urban construction, energy crisis response, and the pivotal role of MSW incineration in future energy strategies.

The research contributes to the body of knowledge on waste-to-energy processes and offers practical recommendations for policymakers and stakeholders to foster sustainable urban construction and waste management practices.

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8. LIST OF TABLES AND FIGURES

FIGURE

Figure 1: Main Types of Waste Processed in the EU

Source: own editing based on (Khadzhynova, 2023)

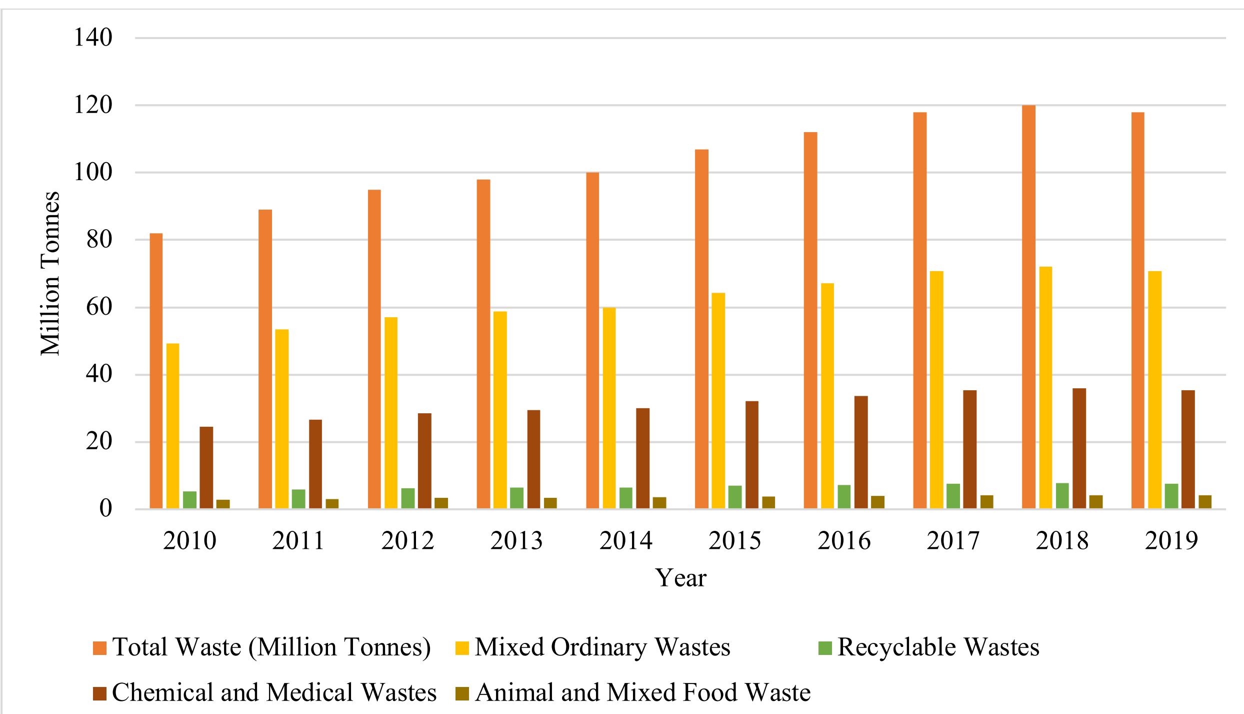

Figure 2: Waste Generation in EU-28 by Recyclable Waste

Source: own editing based on(Bourguignon, 2015)

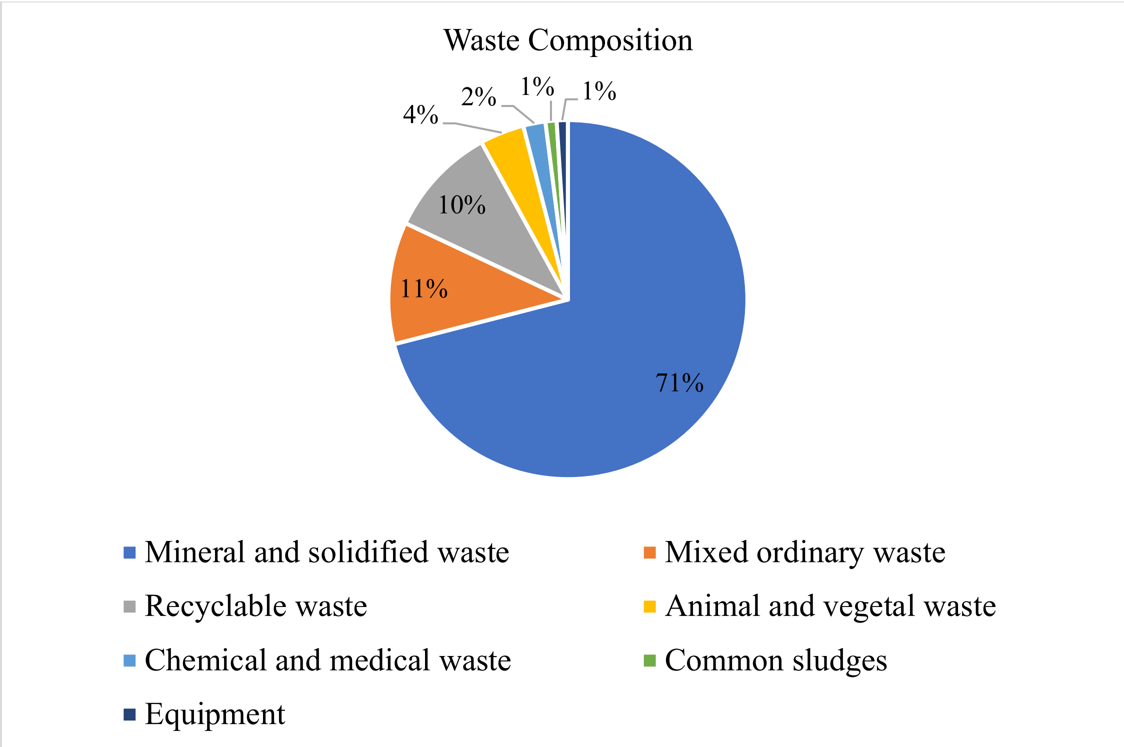

Figure 3: Mixed Ordinary Wastes in the EU

Source: own editing based on (Khadzhynova, 2023)

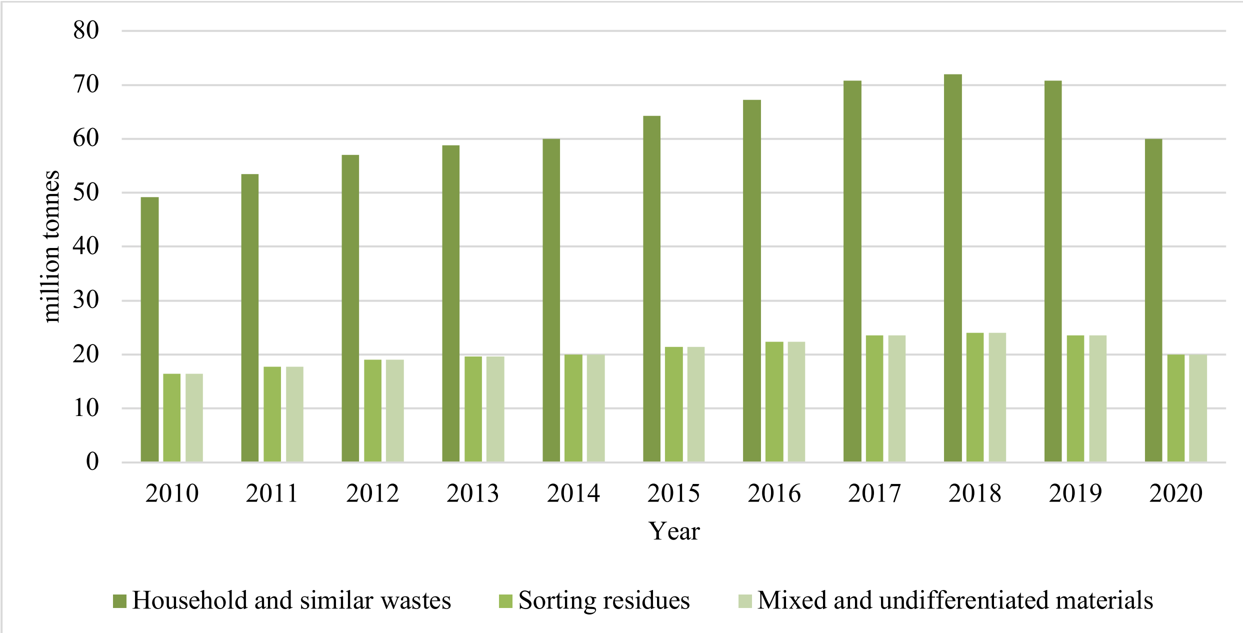

Figure 4: China Classification of Solid Waste
Source: own editing

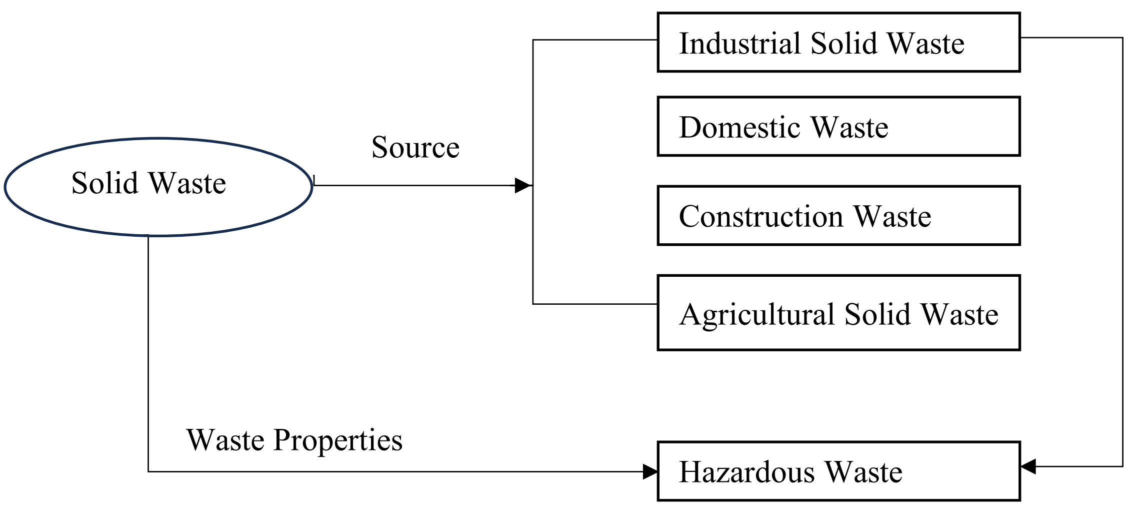

Figure 5: Waste Hierarchy

Source: own editing based on (Gharfalkar et al., 2015)

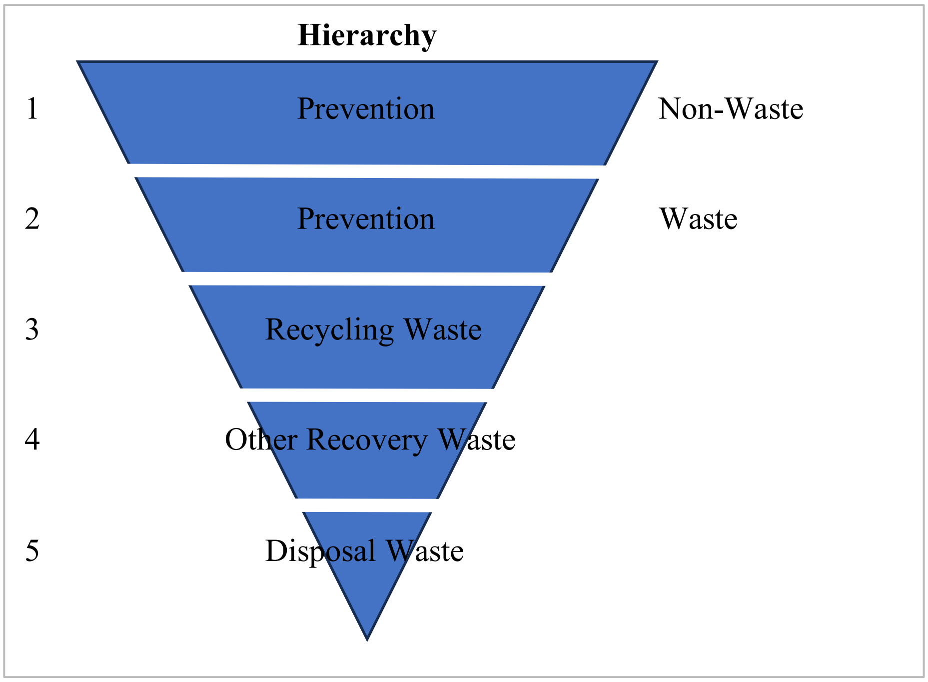

Figure 6: Spittelau's Incineration Plant in Vienna

Source: Google

TABLE

Table 1：Animal and Mixed Food Waste Categories

Source: own editing based on (EUROSTAT, 2022)

Animal and mixed food waste	**Vegetal Wastes**
Animal-tissue waste	Wastes from forestry
Sludges from washing and cleaning	Biodegradable waste
Animal-tissue waste	Sludges from washing and cleaning
Materials unsuitable for consumption or processing	Plant-tissue waste
Materials unsuitable for consumption or processing	Sludges from washing, cleaning, peeling, centrifuging and separation
Wastes from preserving agents	Wastes from solvent extraction
Grease and oil mixture from oil/water separation containing only edible oil and fats	Materials unsuitable for consumption or processing
Biodegradable kitchen and canteen waste	
Edible oil and fat	

Table 2：Percentage and Volume of Major Waste Types Generated in the EU and China （Unit：/year）

Source: own editing based on (China, 2020)

Region	**EU**	**China**
Recyclable waste	10%	
Mixed ordinary wastes	11%	
Animal and mixed food wastes	4%	
Chemical and medical wastes	2%	843,000 tons in 196 cities (2019)
General industrial solid wastes		1.38 billion tons in 196 cities (2019)
Industrial hazardous wastes		44.989 million tons in 196 cities（2019）
Urban domestic wastes		235.602 million tons in 196 cities（2019）

Table 3: Comparison of Waste Disposal Frequency in the EU and China

Source: own editing based on (Cai Feng & Xu Hai, 2022)

	Frequency %	
Region	EU	China
Incineration Without Energy Recovery	1.5%	Incineration 54.0% 2020
Waste-To-Energy Incineration Processes	6.5%	
Landfill Without Energy Recovery	19% 2020	Usage is gradually decreasing, no official data available
Waste-To-Energy Landfill		
Total waste recycling rate	58% 2022	59% 2023

Table 4: The World Bank Measures Countries' Scores in Terms of GNI Per Capita

Source: own editing based on (Nada Hamadeh et al., 2023)

Income Category	GNI per Capita ($)
Low Income	<= 1135
Lower-middle Income	1136 - 4465
Upper-middle Income	4466 - 13845
High Income	> 13845

Table 5: Timeline of Circular Economy Action Plan

Source: own editing based on European Commission's database (Commission)

September-October 2023	**Adoption of several initiatives on microplastics**
May 2023	European Commission revises the circular economy monitoring framework
22 March 2023	European Commission adopted proposals on green claims and right to repair
30 November 2022	European Commission adopted measures proposed in the circular economy action plan

5 April 2022	European Commission adopted proposals for revised EU measures to address pollution from large industrial installations
30 March 2022	European Commission adopted package of measures proposed in the circular economy action plan
17 November 2021	European Commission adopted proposal for news rules on waste shipments
28 October 2021	European Commission adopted proposal to update rules on persistent organic pollutants in waste
22 February 2021	Global Alliance on Circular Economy and Resource Efficiency (GACERE) launched
10 December 2020	European Commission adopted a proposal for a new regulation on sustainable batteries
11 March 2020	European Commission adopted new circular economy action plan
11 December 2019	European Commission adopted European Green Deal
December 2015	European Commission adopted the first circular economy action plan

9. ANNEXES

QUESTIONNAIRE

Table 6: Questionnaire on the perception of EU residents on the construction of waste incineration as a sustainable energy source

1. Have you ever used waste incineration as an energy system（(e.g. sustainable heating systems)?） for sustainable energy?
A. Yes B. No
2. Your gender.
A. Female B. Male
3. Your age.
3. Your age: A. 25 years old and below B. 26-35 years old C. 36-45 years old D. 46-55 years old E. 56 years of age or older
4. Your academic qualifications:
A. High school and below B. Bachelor's degree C. Master's degree D. Above Master's degree
5.Your monthly income.
A. Less than 150000Ft B.150001-300000 Ft C.300001- 400000 Ft D.400001-700000 Ft E.700001 Ft or more
6. Your occupation is:
A. Staff of government agencies or public institutions B. Employees of the enterprise C. Self-employed D. Students E. Miscellaneous
7. Your monthly heating expenses are:
A. Under 25 euros B. 25-60 euros C. 60-100 euros D. 100 euros and above

8. If there is a green waste incinerator (e.g. The Spittelau incinerator, Vienna) as a solution to the heating shortage, would you be willing to make it the main source of energy in the country?
A. Willing (Jump Scale Questions) B. Unwillingness (Skip to Question 9)

9. How much more are you willing to spend on the total price increase of home heating under the energy crisis?
A. Under 10 euros B. 10-20 euros C. 20-40 euros D. 40 euros and above

Table 7-1: Personal factors - Consumer innovation

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
1. I like to experiment with energy systems that use advanced sustainable energy sources (specifically: waste incineration as a sustainable energy source).	1	2	3	4	5
2. I like to read all kinds of information and news about sustainable energy	1	2	3	4	5
3. I like to learn and master the development and characteristics of sustainable energy	1	2	3	4	5

Table 7-2: Green trust

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
4. I believe that environmentally friendly energy procurement methods can be trusted to have the function of protecting the environment	1	2	3	4	5
5. I believe that environmental claims on environmentally friendly energy sources are credible	1	2	3	4	5
6. I believe that environmentally friendly energy procurement can fulfill our commitment to environmental conservation	1	2	3	4	5

Table 7-3: Green values

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree

7. In my life, I am concerned about the impact that waste incineration plants may have on the environment	1	2	3	4	5
8. In my daily life, I am concerned about whether I can use less energy from waste incineration plants that have a negative impact on the environment before using the energy of the waste incineration plants	1	2	3	4	5
9. In my life, I am thinking about the environment, and I will struggle with whether to use the energy of some waste incineration plants that have a negative impact on the environment	1	2	3	4	5

Table 7-4: Environmentally friendly energy plants factor - Energy Source (Waste)

	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
10. I will be concerned about whether the source of energy (waste) of the eco-friendly waste incineration plant is environmentally friendly	1	2	3	4	5
11. I will pay attention to whether the source of energy (waste) of the environmentally friendly waste incineration plant is consistent with the green positioning advertised by the waste incineration plant	1	2	3	4	5
12. I will pay attention to whether the source of energy (waste) of the environmentally friendly waste incineration plant has a compliant collection and treatment system	1	2	3	4	5

Table 7-5: Plants Price

	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
13. I am more concerned about the construction price of environmentally friendly energy plants	1	2	3	4	5
14. The price of building eco-friendly energy plants is not a deterrent factor for me to recommend	1	2	3	4	5
15. Even if the price of building an eco-friendly energy plant is higher than that of conventional energy plant, I would still recommend an eco-friendly energy plant for the sake of environmental protection	1	2	3	4	5

Table 7-6: Plants Promotion

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
16. I believe that there is a need to promote environmentally friendly energy plants	1	2	3	4	5
17. I think that the promotion method on social media platforms is suitable for the promotion of environmentally friendly energy plants	1	2	3	4	5
18. I believe that the promotion of environmentally friendly energy plants should be greater than other environmental protection measures	1	2	3	4	5

Table 7-7: Perceived risk - Financial Risk

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
19. I am concerned that the environmentally friendly energy plants supported will not solve the problem of energy shortages in the country	1	2	3	4	5
20. I am concerned that the lack of technology to support environmentally friendly energy plants will lead to high government expenditures	1	2	3	4	5
21. I am concerned that there is a possibility that the maintenance cost of environmentally friendly energy plants will be too high in the future	1	2	3	4	5

Abstract

Municipal Solid Waste Incineration (MSWI) offers a dual solution of waste reduction and sustainable energy production, critical in the face of escalating urban waste challenges and energy crises. This thesis examines the viability and efficiency of MSWI within Austria, drawing significant comparisons with China, to highlight diverse global approaches. Through a comprehensive literature review and a multifaceted survey analysis, the study explores European and Chinese waste classification systems, technological advancements in waste management, and public perception regarding waste-to-energy (WTE) processes.

Key findings indicate a strong preference for MSWI over landfilling in Europe due to its lower environmental impact and higher energy recovery rates. Technological enhancements and stringent EU regulations support the environmental sustainability of MSWI, aligning with circular economy principles. However, public skepticism, driven by environmental concerns, persists as a major barrier to broader acceptance.

The thesis advocates for integrated waste management strategies that balance technological innovation with robust regulatory frameworks and active public engagement. Recommendations focus on enhancing public awareness and trust through transparent communication and educational initiatives, which are essential for the social acceptance of MSWI facilities.

This research contributes to the ongoing discourse on sustainable urban development, suggesting that MSWI, when executed with consideration for technological, environmental, and social dynamics, can significantly contribute to energy landscapes and waste management solutions in urban settings.

DECLARATION

on authenticity and public assess of master's thesis

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Student's Neptun ID: E92K3D

Title of the document: Municipal Solid Waste Incineration as a Sustainable Way of Energy Production

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Department: Department of International Regulation and Business Law

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