Brainstorm Brigade team, led by Eren Tahiroğlu, consisting of Aysın Aybüke Şimşek, Kemal Uğurlu, and Furkan Delice, all students at Abdullah Gül University, has developed an idea in the field of biology. We aim to minimize the harmful effects of our carbon footprint on our lives. (You can find our resumes attached.)

Our design can be summarized as follows: the separation, recycling, incineration, and reincorporation of solid waste. Our team focuses on the issues of waste occupying excessive space, storage conditions for waste, and carbon footprint. In addressing the potential challenges in our design, we need to consider synchronization loss within the production, consumption, and disposal cycle, which can present significant problems. For instance, if our waste incineration facility falls behind the consumption rate, it may lead to unwanted consequences such as waste accumulation and the formation of massive garbage heaps.

Processing separation is a method that is carried out considering the characteristics of waste, its natural processing properties, and the quality of the products that will be obtained through processing. Solid waste separation methods ensure the proper management of waste components for recycling, reuse, composting, or disposal [1]. The primary methods used are as follows:

1) Source Separation: It involves the separation of waste at homes, workplaces, and public areas. Recyclable materials such as plastic, glass, metal, and paper are placed in separate containers. This way, a portion of household waste becomes suitable for recycling, reducing the overall waste volume and facilitating the recycling process.

2) Mechanical Separation: It refers to the physical separation of solid waste based on its properties. This method includes the following elements:

a) Automated Sorting: Waste is subjected to air or mechanical forces while being transported on conveyor belts to facilitate the separation of specific materials. For example, lightweight materials like paper are carried away by air currents, while heavier materials like glass and metal remain on the conveyor belt and are sorted.

b) Screening: Screens with different-sized openings are used to separate waste based on their size. Waste passing through screens with different hole sizes is sorted according to its suitability for recycling.

c) Magnetic Separation: It allows for the separation of materials in waste that possess ferromagnetic properties. By using a magnetic drum or magnetic belt, metal parts or particles are detected and separated, facilitating the recycling of metals containing iron, nickel, or cobalt.

d) Density Differentiation: It enables the separation of waste with different densities. Special density separators are used to separate materials with different densities by employing water or airflow.

3) Biological Separation: It involves the decomposition of waste using microorganisms or enzymes. Organic waste naturally decomposes into compost through the interaction of air, moisture, and microorganisms. The obtained compost can be used for agricultural purposes, contributing to soil fertility.

4) Chemical Separation: It is a method based on chemical reactions for waste separation. Depending on the composition and properties, various processes are applied:

a) Neutralization: It is used to neutralize the pH levels of hazardous or acidic waste. Basic substances like Ca(OH)2 (slaked lime) or NaOH (sodium hydroxide) are added to acidic waste. This reaction reduces the harmful effects of the waste.

b) Chemical Oxidation: It involves the decomposition of organic waste using oxygen or oxidizing chemicals. Chemical oxidation is used for the disposal of hazardous waste or waste that is difficult to biologically degrade.

c) Coagulation-Flocculation: It is employed in the separation of liquid waste. Coagulation causes particles in the solution to come together by adding metal salts like iron or aluminium. Flocculation aids in the aggregation of large particles, facilitating their precipitation. This process separates solid matter from liquid waste, resulting in cleaner water.

5) Thermal Treatment: It is a method where solid waste is subjected to high temperatures to undergo physical and chemical changes. It consists of two stages:

a) Incineration: It involves subjecting waste to high temperatures for oxidation. The heat generated during incineration can be used for energy production. Additionally, suitable filtration systems are used to control environmental emissions. Incineration helps reduce organic matter, hazardous waste, and certain types of waste.

b) Pyrolysis is the thermal decomposition of organic waste in an oxygen-free environment at high temperatures. Pyrolysis transforms waste into gas, liquid, and solid products. These products can be utilized for energy generation or chemical production. Biocharcoal, gas, and liquid fuels are among the products of pyrolysis.

Singapur and Istanbul both have various advantages in waste management.

In Singapur, waste is stored in specially created offshore areas, with a daily delivery of 2,100 tons of waste. A significant portion of this waste is incinerated, and the ash from the incineration process is stored. Singapur aims to achieve a 70% recycling rate by 2030. Incineration reduces the waste volume by 90% and allows for more efficient waste storage. Singapur also embraces a circular economy approach, aiming to keep resources in use for as long as possible and promoting sustainable production and consumption. With a daily generation of 8,559 tons of solid waste, there is potential for reducing waste, especially from households. Key waste streams in Singapur include dry waste (packaging waste) and wet waste (kitchen waste) [2].

In Istanbul, there are several advantages to waste management. Istanbul has Turkey's first and Europe's largest waste-to-energy plant. This facility saves 8 million kilometres of transportation for the annual transport of 1,000,000 tons of waste. Additionally, it supports domestic production and contributes to addressing Turkey's energy deficit. By reducing the amount of waste going to landfill sites, the lifespan of these areas is extended. The plant maintains emission levels below EU limits. Furthermore, the facility prevents the release of 1.38 million tons of greenhouse gases annually, reducing carbon emissions. The electricity generated, around 85 MWh, meets the electricity needs of approximately 1.4 million Istanbul households. Istanbul also obtains 1.5 million tons of carbon credits annually, totalling 3 million tons of carbon credits [3].

COMMON FEATURES
1) Waste incineration projects ensure the recovery and evaluation of waste.
2) Sustainable production and resource management creates new jobs and demand for skills
3)Contributes to industry transformation and workforce skills enhancement
4)Helps reduce greenhouse gas emissions and conserve natural resources
5)Strives to secure food, water and supplies
6) It works to reduce climate change and protect its location from its effects.
7)difficulties may exist such as high cost, waste diversity, odour, environmental problems

Figure 1-2 Thermal Waste Incineration Plants [3]

Singapur and Istanbul demonstrate efforts to manage waste effectively and promote sustainability through incineration, recycling, and energy generation. These approaches contribute to reducing waste volumes, minimizing environmental impacts, and utilizing waste as a resource.

The idea of waste incineration has been developed to reduce the volume of waste by burning it and to store the resulting ash in a smaller area or use it for different purposes. This concept has been implemented in certain facilities, such as waste-to-energy plants managed by the Istanbul Metropolitan Municipality (IBB) in Turkey and similar waste incineration facilities in Singapore, which we have selected as references for our project.

The issue of land scarcity lies beneath the principle of waste incineration. By employing these processes, we can reduce the volume of waste by up to 90%. The remaining 10% of ash can be utilized in various ways, which will be discussed further in the project [4].

Thermal waste treatment involves the controlled combustion or decomposition of waste at high temperatures. This process is carried out with the aim of either utilizing the energy generated from the waste or disposing of the waste. Below, you can find the contributions and examples of thermal waste treatment in the field of waste management, considering that previously segregated waste undergoes this process:

The application of thermal treatment or incineration to waste for energy production is referred to as thermal waste treatment. In this process, waste is burned at high temperatures, and the heat generated from this combustion can be utilized for energy production. This energy can be used for electricity generation or heating purposes. For example, biomass waste can be thermally reacted to produce biomass energy. In this way, the thermal treatment of waste contributes to energy production and can be utilized as a sustainable energy source.

Thermal waste treatment is an effective method for waste reduction. In this process, waste is burned or decomposed at high temperatures, resulting in the formation of ash. As mentioned earlier, these ashes significantly reduce the original volume of the waste. For example, the ashes generated from the thermal reactivation of municipal waste can constitute approximately 10% of the original waste volume. Thus, thermal waste treatment facilitates waste reduction and minimizes environmental impact.

The thermal waste treatment method contributes to the destruction of hazardous substances. High temperatures can break down or render hazardous chemical compounds inert, ensuring the safe disposal of hazardous waste. Thermal waste treatment reduces environmental and human health risks by eliminating the effects of hazardous substances contained in the waste. This approach represents a significant step in waste management, offering an effective solution to prevent hazardous waste from harming the environment.

The thermal waste treatment process enables the recovery of materials with recycling potential. During this process, metallic materials can melt and be found within the ashes. These metals can be recovered and reused through thermal reactivation. Thermal reactivation is a method used for energy recovery or the destruction of pollutants. It involves using heat to recover or restart chemical reactions or processes. Thermal reactivation plays a crucial role in waste management by evaluating waste and ensuring its sustainable disposal. Its benefits include energy production, waste reduction, destruction of hazardous substances, recovery, and energy efficiency. This method provides environmentally and economically sustainable waste management.

One method for transforming waste ashes into reusable products is through a process of thermal treatment. This process involves heating the waste ashes at high temperatures and subjecting them to chemical changes. It is designed to enhance the potential value of waste ashes and minimize their environmental impact.

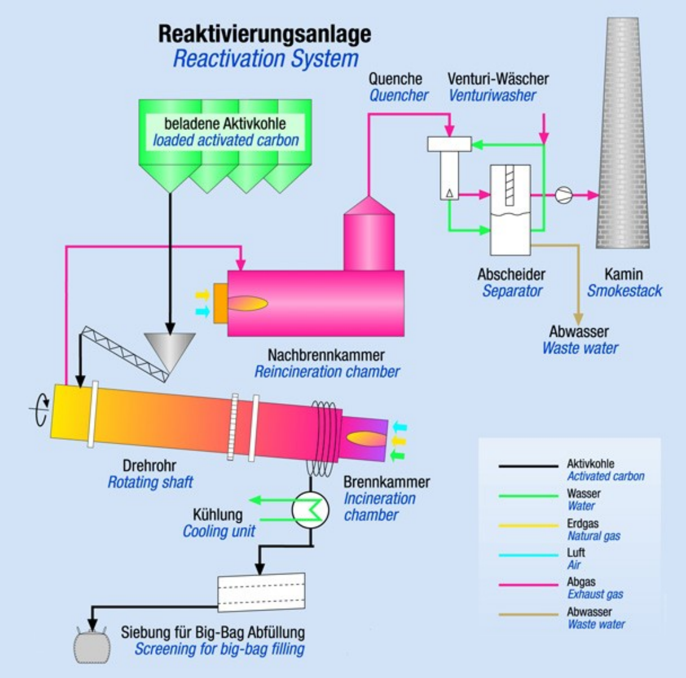

Figure 3: Reactivation System [5]

The thermal reactivation process is carried out by following specific steps. Firstly, the waste ashes undergo preprocessing steps. These steps involve processes such as screening and magnetic separation to separate larger particles. Then, the waste ashes are fractionated into their components. Metal pieces, glass, plastic, and other materials with recycling potential are separated from the waste ashes. This stage enables the recovery of materials with recycling potential.

Next, the waste ashes are exposed to high temperatures in a controlled environment. Typically, temperatures ranging from 800 to 1200 degrees Celsius are used. The heating process triggers chemical reactions and leads to changes in the composition of the waste ashes.

At high temperatures, the minerals and other compounds within the waste ashes undergo various chemical reactions. As a result of these reactions, silicates, aluminium oxides, and other valuable substances in the waste ashes are reorganized to form different compounds.

After the completion of the waste incineration process, the reaction products are cooled, facilitating the formation of desired products and the solidification of the reorganized compounds. This cooling process optimizes the disposal of waste ashes through a process called thermal reactivation and also contributes to the recovery of valuable materials. Thermal reactivation enhances the recycling potential of waste ashes and enables the production of various products. Products such as construction materials, cement, bricks, fillers, and materials used in road construction can be obtained as a result of the thermal reactivation process. Additionally, the thermal energy generated during thermal reactivation can be recovered and used for electricity generation or heating purposes.

Thermal reactivation is commonly used for the type of solid waste known as bottom ash, which is generated in waste incineration plants. Bottom ash is a mixture of solid ash and burned waste materials that accumulate in the lower part of the combustion chamber of the incineration plant and are collected in ash hoppers. This type of ash can be processed through thermal reactivation to be valorized and reused in various applications.

The ashes resulting from thermal waste treatment undergo recovery or disposal processes. The management of these ashes should be carried out in accordance with local regulations and environmental standards. Ashes generated in waste incineration plants are generally classified into two main categories: fly ash and bottom ash. This classification is determined based on the characteristics and formation locations of different types of ashes produced during the waste incineration process.

Suitable methods are employed for the recovery of ashes to recycle materials containing metals and minerals. This aims to promote resource reuse and reduce waste generation. However, hazardous or non-inert waste ashes should be managed through appropriate disposal methods. Throughout this process, the protection of the environment and human health should be prioritized. Therefore, the proper recovery or disposal of ashes generated in waste incineration plants is of great importance.

The ashes resulting from the incineration of waste can vary in type. These include fly ash and bottom ash. Fly ash is a waste form that is formed through the cooling and filtration of gases emitted from the chimneys of waste incineration plants. On the other hand, bottom ash is a mixture of solid ash and burned waste materials that accumulate in the lower part of the combustion chamber of the incineration plant and are collected in ash hoppers. Bottom ash, which is formed as a result of complete combustion, is denser and heavier. Bottom ash generated in waste incineration plants is collected, stored, and appropriately disposed of. A portion of the ashes resulting from thermal waste treatment should be processed through suitable storage or disposal methods.

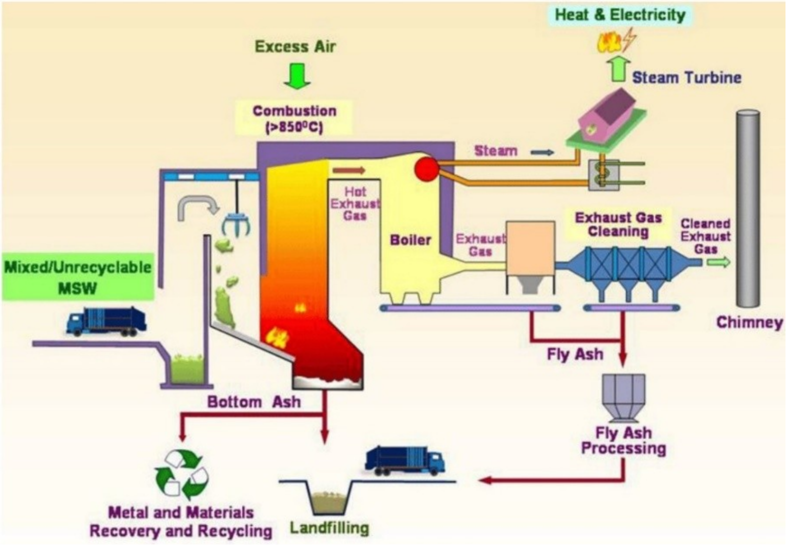

Figure 4: Ash Transformation in Waste Incineration Plant [6]

The methods used for ash storage can vary and are typically determined by the type, quantity, quality, and environmental factors of the ash being generated. Here are some commonly used ash storage methods:

Ash Storage Ponds: Large quantities of ash can be temporarily stored in ash storage ponds constructed in open areas or suitable locations. These ponds are typically lined with impermeable ground coverings and carefully designed to prevent environmental pollution. Ash storage ponds are widely used in thermal power plants and industrial facilities.

Figure 5: Ash Storage Pond [7]

Ash Storage Areas: In some cases, ash can be directly stored in flat, open areas that are covered. This method is typically preferred for smaller quantities of ash, and a portion of a frequently used area can be designated as an ash storage area. A layer is created, using soil or synthetic materials, to prevent the ash from spreading into the environment.

Figure 6: Ash Storage Area [8]

Ash Solidification: In some cases, ash can be solidified and stabilized as a preferred method. In this process, the ash is mixed with special binders and additives to transform it into a structural material.

Solidified ash can be stored in smaller volumes and, in some cases, can be reused as a construction material.

Figure 7: Ash Incorporation [9]

Closed Containers: Ash can be stored in closed and leak-proof containers. These containers are designed to prevent the spread and mixing of potentially harmful substances present in the ash with the environment. Containers are typically made of durable materials such as metal or concrete and are properly sealed to prevent any leakage.

Figure 8: Ash Container [10]

Integrated Waste Management Facilities: Ash can be stored in integrated waste management facilities. These facilities perform multiple processes to separate, treat, and manage waste based on its different components and characteristics. Integrated management facilities have the necessary equipment, technology, and expertise for the proper storage and disposal of ash.

Figure 9: Integrated Ash Management Facility [11]

Ash storage methods continuously evolve due to environmental factors, regulations, and technological advancements. Additionally, ash storage methods can vary depending on the characteristics, composition, and potential utilization of the ash. Therefore, ash storage processes should be planned and implemented in accordance with local and national regulations.

There are certain details to consider in ash storage processes. Ash analysis is important for determining the composition of the ash, the presence of toxic substances, and identifying recoverable components. These analyses provide fundamental data for the proper management and storage of ash.

Storage capacity plays a significant role in determining the quantity and continuity of ash storage. These factors influence the size, volume, and transport capacity of storage areas, assisting in the identification of suitable storage methods.

Compliance with regulations and standards is also crucial in ash storage processes. Compliance with local, national, and international regulations encompasses meeting environmental requirements, fulfilling requirements related to ash processing and transportation, and adhering to safety protocols [12].

Ash storage areas should be regularly monitored and maintained. Monitoring processes ensure early detection of leaks and the implementation of necessary precautions. Maintenance operations are performed regularly to ensure the safety of storage areas and to preserve the impermeability of floor coverings against leaks.

Impermeability involves rendering the floors of ash storage areas impermeable. This is aimed at preventing the infiltration of ashes into groundwater sources or mixing with the soil. Impermeability can be achieved through the use of a layer of clay, a clay-bentonite mixture, or synthetic membranes.

Sealing and drainage systems are essential elements that need to be incorporated into ash storage areas to prevent leaks. These systems include special membranes, soil sealing materials, and drainage systems located at the base and sides of the storage area. This way, any potential liquid leaks are collected and managed.

In some cases, ash stabilization may be necessary. Stabilization aims to reduce and control the effects of toxic or environmentally harmful compounds present in the ash. Stabilization processes, which can involve chemical treatments or additives, allow for the safer storage of ash.

Storage areas should be protected with coverings to prevent the dispersion of ash into the environment. These coverings are typically provided using soil, bentonite layers, or synthetic coverings.

Ash storage areas should be equipped with appropriate signage. These signs are important to maintain the organization of the storage area, protect individuals, and provide accurate information. Additionally, they are necessary for compliance with local regulations and safety standards.

Ash obtained from waste incineration facilities may contain recyclable materials such as metal pieces, glass, bricks, and ceramic fragments. These materials are separated for recovery. In accordance with waste management guidelines, a portion of the ashes obtained at waste incineration facilities can be disposed of or utilized.

Ash generated from thermal waste treatment processes can be evaluated in different ways in storage or reuse areas. Fly ash, in particular, can be used in various sectors and has potential applications in the following areas:

1. Construction Materials Production: The use of fly ash in the production of cement is quite common. Fly ash can improve cement quality and contribute to resource conservation.

2. Road Construction: Fly ash can be used as a filling material in road construction. Its stabilizing properties help reinforce the roadbed.

3. Brick and Ceramic Production: Fly ash can be used as a raw material in the production of bricks and ceramics. Its ability to enhance material properties can contribute to the production of more durable products.

4. Fill Material: Fly ash can also be used as a filling material. It provides practical solutions for filling empty spaces and land reclamation.

By utilizing fly ash resulting from thermal waste treatment in various industries and applications, resources can be used more efficiently, representing an important step towards sustainability.

Figure 10: Ash Recycling [13]

Fly ash, as the molten material cools down and transforms into spherical ash particles, either partially or completely, through gas flow. These ash particles are very fine and are referred to as fly ash due to their entrainment with flue gases. The main components found in fly ash are SiO_2, Al_2O_3, Fe_2O_3, and CaO, with their quantities varying depending on the type of fly ash. Additionally, minor components such as MgO and SO_3 are also present as alkali oxides. The major oxides in fly ash are typically found in the following proportions: SiO_2 (25-60%), Al_2O_3 (10-30%), Fe_2O_3 (1-15%), and CaO (1-40%). These varying ranges of values characterize the type of fly ash. The chemical composition of fly ash exhibits variations due to the different sources of coal. Nevertheless, the primary compounds in fly ash are silica and alumina [28-29].

The morphology and structure of fly ash are variable and complex, while the particle shape is spherical due to surface tension. The particle structure and size are influenced by the cooling rate. The common types of fly ash generally consist of crystalline compounds such as quartz, mullite, and hematite, as well as glassy compounds like silica glass and other oxides [28].

Low-lime fly ashes predominantly consist of an amorphous or glassy phase composed of silica and alumina. These types of fly ashes exhibit pozzolanic properties as they react with hydrated lime ($Ca(OH)_2$) in a moist environment. High-lime fly ashes can exhibit both pozzolanic properties and possess a certain degree of binding ability due to the presence of free lime, tricalcium aluminate, amorphous silica, and alumina. The amount of the glassy phase in low-lime fly ashes is higher compared to high-lime fly ashes. In low-lime fly ashes, the mineral phases include the glassy phase, mullite ($Al_6Si_2O_{13}$), hematite (Fe_2O_3), magnetite (Fe_2O_4), quartz (SiO_2), and others. In addition to the aforementioned minerals, high-lime fly ashes contain calcium silicates such as free lime (CaO), anhydrite ($CaSO_4$), tricalcium aluminate ($Ca_3Al_2O_6$), plagioclase, gehlenite, feldspar, and other calcium silicates.

The classification of fly ashes is based on the percentages of chemical constituents according to ASTM C 618 and TS EN 197-1 standards. Fly ashes are classified as Class F and Class C. According to ASTM C 618, Class F fly ashes, also known as low-lime fly ashes, are derived from bituminous coal. The combined percentages of SiO_2+Al_2O_3+Fe_2O_3 in these fly ashes should be greater than 70%, while the CaO percentage should be less than 10%. They exhibit pozzolanic properties. Class C fly ashes are derived from lignite or sub-bituminous coal and have a total percentage of SiO_2+Al_2O_3+Fe_2O_3 greater than 50%. The CaO percentage is above 10%, thus they are referred to as high-lime fly ashes. Class C fly ashes possess both pozzolanic and binding properties [30].

In the classification according to TS EN 197-1, fly ashes are divided into two groups: siliceous (V) and calcareous (W). Siliceous (V) fly ashes generally consist of spherical particles with pozzolanic properties and primarily contain reactive SiO_2 and Al_2O_3. They also contain iron oxide and other substances. The reactive CaO content in these fly ashes should be less than 10%, while the reactive silica content should exceed 25%. Calcareous (W) fly ashes have hydraulic and/or pozzolanic properties and mainly contain reactive CaO, reactive SiO_2, and Al_2O_3. Other components include Fe_2O_3 and other substances. The reactive CaO content in these fly ashes should exceed 10%, while the reactive silica content should exceed 25% [31].

To enhance concrete properties and save cement, alternative materials are added to the cement. These materials are classified into three groups: natural, artificial, and thermally processed materials, based on their mineral sources [17]. Fly ash is known as one of the artificial pozzolans used among these materials.

The pozzolanic activity of pozzolanic materials, such as fly ash, used as mineral additives in cement and concrete production, is dependent on the amount of reactive silica they contain. Therefore, the type and quantity of silica-rich and alumina-rich minerals in pozzolans play a crucial role in their pozzolanic activity [32]. Pozzolanic activity is defined as the rate and capacity of reaction between calcium hydroxide and aluminosilicates in cement-based materials. The activity of pozzolans is influenced by both short-term surface area and long-term chemical and mineralogical compositions [33]. Furthermore, pozzolanic activity is not solely related to chemical composition, as minerals with the same composition can exhibit different activities [34].

For pozzolanic materials like fly ash to possess sufficient pozzolanic activity, they need to have a fine particle size and an amorphous structure and contain the "silica+aluminum+iron oxide" content [17].

Low-lime fly ash is commonly used in concretes. The utilization of high-lime fly ash in concrete can have a negative impact on its durability and stability due to its high CaO content [35]. When fly ash reacts with the cement, the carbon and sulfur they contain increase the alkali content in the concrete, thereby accelerating corrosion. Additionally, as the carbon content in fly ash increases, the electrical conductivity of concrete also increases, resulting in a dark colour. The increased carbon content in fly ash also raises the water requirement of concrete [36]. Nevertheless, studies have shown that the use of fly ash at levels of 20-30% yields positive results in terms of corrosion resistance and concrete strength [37].

The use of finely ground fly ash as a cement replacement in concrete enhances impermeability and significantly reduces chloride permeability [38]. Short-term strengths of fly ash concrete may be affected negatively, but long-term strengths and resistance to capillary water permeability increase when fly ash is used in low proportions [39].

The grinding time for pozzolanic cements with fly ash is generally shorter than that for regular cements, and their 28-day strength values are higher than those of fly ash replacement cement mortars [40].

The hydration of cement is delayed when fly ash is substituted for Portland cement, leading to a reduction in early strength. Chemical activators such as Na2SO4 and CaCl2 can be used to prevent this adverse effect by accelerating the pozzolanic reaction and modifying the reaction between fly ash and free lime [41-43]. The addition of 3% Na_2SO_4 to cement containing 40-60% fly ash can expedite hydration [44].

Self-compacting concrete with 30-40% Class F fly ash content can exhibit improved strength properties [45]. Economical and environmentally friendly self-compacting concrete with strengths exceeding 35 MPa can be produced using 50% fly ash [46].

The use of fly ash allows for the production of lightweight aggregates, promoting cost-effective and eco-friendly concrete production [47]. Lightweight fly ash aggregates can exhibit different behaviours due to variations in fly ash compositions [48].

In concrete production, Class F fly ash can be used as a substitute for fine aggregates. Fly ash concrete demonstrates favourable workability, compressive strength, elastic modulus, and shrinkage values compared to control concrete [49-50]. The abrasion resistance of concrete increases when fly ash is used at up to 40% replacement of fine aggregates [51].

Fly ash has found usage not only in concrete and cement but also in the brick industry, although research in this area is limited. Brick samples produced with fly ash have exhibited similar textures to reference bricks. The durability of fly ash-containing samples has significantly improved, resulting in a reduced number of micro-pores and decreased deterioration caused by salt crystallization [22].

In bricks produced with the fly ash from the Seyitömer thermal power plant, the addition of fly ash slightly increased the unit weight but did not significantly affect drying, firing, and total shrinkage. The water absorption of bricks produced with fly ash has decreased, although the achieved strength values did not reach those of reference bricks [18]. The optimal composition for bricks produced with Seyitömer fly ash was found to be 65% fly ash, 20% sand, and 12% hydrated lime. Bricks produced with fly ash exhibited lower unit weight and thermal conductivity compared to clay bricks. Furthermore, the thermal conductivity values of the experimental samples were found to be similar to those of aerated concrete grades [52].

In the production of autoclaved aerated concrete, fly ash is used as a material to replace fine sand rather than cement. The American Concrete Institute recommends using fly ash in autoclaved aerated concrete up to 75% [54]. Since fly ash possesses adequate fineness, it does not require additional grinding. It is argued that aerated concrete produced with fly ash exhibits superior thermal insulation and strength properties compared to those produced with quartz sand [55]. This is likely due to the pozzolanic nature of fly ash, which interacts with lime to form new bonds that strengthen the microstructure. Additionally, the incorporation of dark grey or near-black fly ash waste in aerated concrete production can darken or shift the final product's colour towards grey [56].

In aerated concrete, the substitution of sand with fly ash (fly ash replacement) for a specific density enhances the compressive strength. Generally, the water absorption rate of cement-fly ash mixtures is higher than that of cement-sand mixtures [57].

There is a study that replaces cement with up to 75% fly ash in foam concrete mixtures. Porosity generally varies with dry density rather than the type or amount of fly ash used. Water absorption value can show significant differences depending on the unit weight of foam concrete [59-60]. Due to the finer particle size of fly ash, the addition of fillers to foam concrete results in a more homogeneous pore distribution. As the pore size in the pore distribution decreases, the strength of foam concrete increases [61-64].

Research has shown that substituting up to 60% of cement with fly ash improves the properties of cement paste. When higher proportions of fly ash (up to 75%) are used as a replacement for cement, a significant increase in the compressive strength of foam concrete can be achieved [65].

Fly ash can be used in soil applications depending on the characteristics of the natural soil and the fly ash itself to improve soil problems and increase productivity. Fly ash tends to collect elements such as Boron (B), Molybdenum (Mo), Selenium (Se), and Aluminum (Al), particularly in soils that are not in contact with air. The collection of these elements contributes significantly to reducing toxicity levels in agricultural fields, benefiting human and animal health [68].

The addition of fly ash in different proportions (0%, 3%, 5%, and 10%) to clayey soil has been observed to not affect the plasticity of the soil but increase the optimum water content and unconfined compressive strength with increasing fly ash content [19].

In a study on the road applications of fly ash, different chemical additives were used, and it was determined that a 1.5-2.5% addition of fly ash-lime mixture had positive effects and significantly increased early-age strengths [67].

Thus, it can be concluded that the use of fly ash improves soil properties, contributes to element accumulation in agricultural areas, does not affect plasticity in stabilized clayey soils but increases strength, and enhances the strength in road applications.

The various areas of application for fly ash include concrete and asphalt pavements, filler material in road sub-base layers (with a particle size below 0.25mm), soil stabilization, production of lime-sand blocks, manufacturing of industrial ceramics and refractories, paint production, stabilization of solid waste, and use in agricultural fields [27].

In one study, chloroprene rubber and fly ash were used to test the effect of binder behaviour on the mechanical properties of composite materials, and a composite material using 1% fly ash as a binder was successfully produced [68].

In another composite material production, epoxy resin composites containing varying weight percentages of fly ash were prepared under centrifugal force to study density, hardness, and electrical properties. As the weight percentage of fly ash increased, the alternative conductivity and insulator stability of the material was enhanced [69].

Latex mortars show a decrease in compressive strength as the fly ash content increases [70]. Composite materials were produced using F and C-class fly ash in combination with cement, and the findings showed that composites using C-class fly ash exhibited lower elastic modulus values compared to F-class composites [41]. Additionally, it was noted that the flowability of F-type fly ash and cement composites is closely related to the particle distribution of fly ash [71].

Thus, it can be concluded that fly ash is used in various applications such as concrete and asphalt pavements, soil stabilization, composite material production, and other industrial applications, and it affects the properties of different materials.

This ash consists of a mixture of powder particles and unburned organic matter. Fly ash, composed of finer particles, is captured using gas purification systems. Gases generated during the thermal waste treatment process are cleaned using gas purification systems. This step aims to reduce harmful gas emissions to the environment and preserve air quality. Gas purification systems can include different technologies such as particle filters, electrostatic filters, absorption, or adsorption methods.

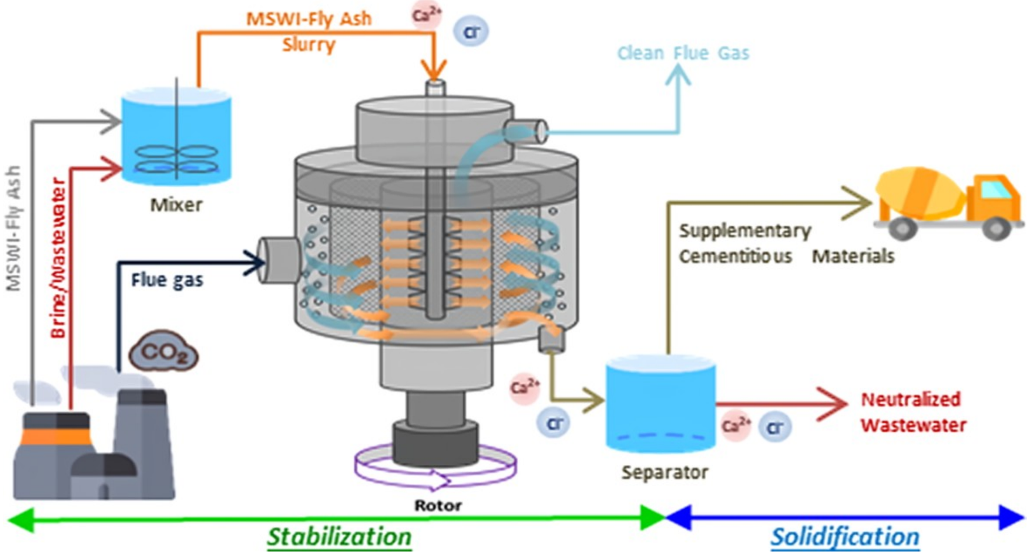

Figure 11: Gas Purification [72]

The thermal reactivation method is commonly used in the processing of the following types of bulk ashes. Firstly, the burnt coal ash generated in thermal power plants or industrial coal combustion processes can be processed through thermal reactivation. This ash typically contains a high amount of calcium and is suitable for the production of calcium hydroxide. The obtained calcium hydroxide can be used in the production of construction materials. Secondly, the burnt wood ash resulting from wood-burning processes can also be processed through the thermal reactivation method. Wood ash also generally contains calcium and is suitable for the production of calcium hydroxide. The obtained calcium hydroxide can be used in the production of construction materials and soil amendments. Lastly, waste ash generated during brick and ceramic production can also be processed through thermal reactivation. This type of ash typically contains calcium and is suitable for the production of calcium hydroxide. The obtained calcium hydroxide can be used in the production of new bricks and ceramics.

Each type of ash may be suitable for the production of calcium hydroxide through thermal reactivation, but recycling or disposal methods may vary depending on the composition of the ash, its source, and other factors. Waste incineration plants require certain components for the thermal reactivation of bulk ash. These components include calcium oxide (CaO), metal oxides, silica (SiO_2), aluminium oxide (Al_2O_3), potassium oxide (K_2O), sodium oxide (Na_2O), sulfur oxides, and carbonates. Calcium oxide can originate from the combustion of inorganic materials during waste incineration and can be converted to calcium hydroxide through the thermal reactivation process. Metal oxides are formed from the combustion of metal objects in waste incineration plants or the oxidation of metals present in the waste. The thermal reactivation of these metal oxides can aid in the transformation or recovery of metal compounds. Silica present in bulk ash can be transformed into different forms through the thermal reactivation process, making it usable. Aluminium oxide is formed through the combustion of various metal objects or the oxidation of aluminium-containing waste and can be recovered or made suitable for other uses through thermal reactivation. Oxides of alkali metals such as potassium oxide and sodium oxide can be generated by the incineration of certain wastes in waste incineration plants and can be transformed into different forms and compounds or recovered through thermal reactivation. Sulfur oxides can be formed through the combustion of certain wastes during the waste incineration process, and the thermal reactivation process may involve processes to control the emissions of these oxides. Additionally, some carbonates present in bulk ash can be recovered or made usable by transforming them into different forms through thermal reactivation.

The presence of these components can vary depending on the composition of the bulk ash, the processing methods of the waste incineration plant, and the waste stream. The thermal reactivation process is a method used to enhance the stabilization and recyclability of specific components in bulk ash.

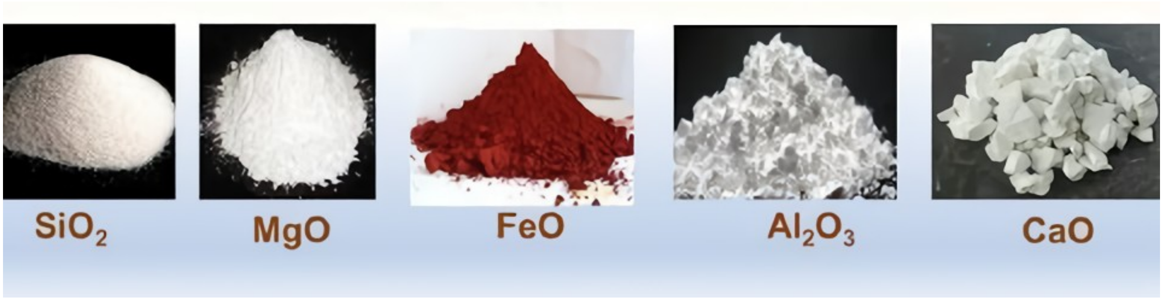

Figure 12: Oxide Samples [73]

The ashes generated from waste incineration can be used in various areas as substitutes for the materials used. For example, these ashes can be utilized in road construction, concrete production, as fertilizer to improve soil fertility, ceramic and brick production, and as filling material in underground mining. This way, the ashes arising from the waste incineration process can be recycled, leading to a more sustainable utilization. These methods enable the reuse of ashes resulting from the waste incineration process, aiming to achieve more efficient resource utilization. This contributes to reducing environmental impacts and establishing a sustainable cycle.

Aggregates play an important role in the materials used in road construction. Aggregates are used in the production of granular materials such as asphalt, concrete, or road fill. When the ashes obtained from waste incineration are mixed with such materials, it can enhance the strength of the material and enable sustainable road construction. Therefore, using bulk ash in road construction can contribute to waste recycling, reduce environmental impacts, and efficiently utilize resources. In this way, the ashes generated from waste incineration plants offer an environmentally sustainable solution by being reused in road construction.

Figure 13: Utilization of Ash in Road Construction [74]

Bulk ash can be used as a supplementary cementitious material in concrete production. This application has the potential to reduce cement consumption and enhance the strength and durability of concrete. By incorporating fly ash, ashes can be regarded as a material that reduces environmental impacts in concrete production. This way, the sustainable utilization of ashes obtained from waste incineration plants can be achieved in the concrete industry.

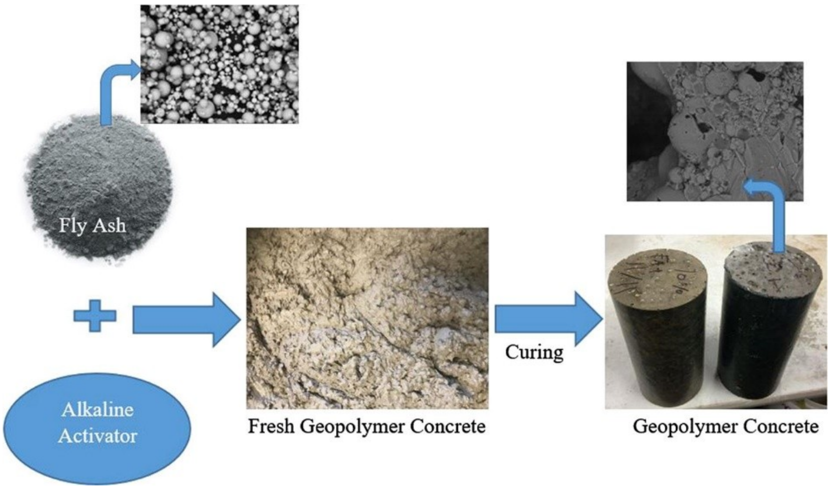

Figure 14: Utilization of Ash in Concrete Production [75]

Ashes can be reutilized in various fields. When used for soil improvement, ashes can regulate the pH balance, increase mineral content, and enhance soil structure. In this way, when used in agriculture, gardening, or landscaping, ashes can improve soil fertility. Additionally, ashes used in ceramic and brick production can contribute to the conservation of natural resources and the sustainability of the production process by being utilized as raw materials. Thus, the recycling and reuse of ashes are significant steps from an environmental perspective.

Figure 15: Utilization of Ash in Improving Soil Quality [76]

Ashes, generated from waste incineration plants, can be utilized in various ways through the thermal reactivation process. As one option, ashes can be used as filling material in underground mining. This use can help reduce the negative impacts of mining activities and enhance environmental sustainability. The use of ashes as filling material in disposal sites used in underground mining contributes to more effective waste management and minimizes negative environmental impacts. This method presents an example of waste reuse and valorization.

When conducting market research for our waste incineration idea, we found that besides hazardous and medical waste, all types of waste and garbage can be utilized. The ashes resulting from our inputs can find a place in various markets. A prime example is their use in asphalt production, where they can enhance strength while reducing costs. Similar examples can be seen in concrete production and different industrial applications, where they have a cost-reducing effect. Major market areas can be identified as asphalt, concrete plants, and government bodies.

We can consider standard recycling facilities as direct competitors. Indirect competitors will be diverse. For instance, when considering the reuse of our waste ashes in areas previously relying solely on raw materials, we will compete with raw material suppliers. Furthermore, based on our research, we have realized that incorporating our ashes in certain proportions in concrete production, asphalt construction, and various structures can reduce the demand for raw materials. Our industry holds significant importance for the future of our planet. While some countries consider launching their waste into space, we find such a solution intriguing and support it as a more sustainable approach for the health of our solar system.

The objectives of our thermal waste treatment project encompassed within the ESG (Environmental, Social, Governance) framework are as follows:

Goal 9: Aim to support sustainable development through innovation and infrastructure investments. Our objective of reducing waste and redirecting it to different areas aligns with this goal.

Goal 9.4: Plan to implement adequate filtration in our waste incineration system to address global carbon dioxide (CO_2) emissions resulting from energy combustion and industrial processes.

Goal 12: Pertains to achieving sustainability in production and consumption. It emphasizes the regulation of natural resource utilization and the establishment

of effective waste management. Managing the environmental impact by reducing waste generation falls within the scope of this goal.

We aim to process and reuse the waste in an organized manner while considering the potential reformation of waste materials.

Goal 12.2: In 2019, the total material footprint reached 95.9 billion tons, closely approaching the world's local material consumption of 95.1 billion tons. While North America and Europe have a material footprint approximately 14% higher than local material consumption, Latin America, the Caribbean, and Sub-Saharan Africa have material footprints 17% and 32% lower, respectively. Therefore, our goal is to produce raw materials and auxiliary products from waste, thereby reducing the reliance on new materials.

Goal 13: The objective of climate action emphasizes the urgent need for global action to combat climate change, a global crisis. With the increasing prevalence of thermal power plants and industrialization, filtration has gained tremendous importance. We prioritize filtration to achieve a lower CO_2 footprint and contribute to a world with reduced emissions. The high oxygen density in the filtered gas further contributes to addressing climate change.

Thermal reactivation processes focus on reducing environmental issues and playing a significant role in combating climate change by reducing waste, improving energy efficiency, and utilizing renewable energy sources for a sustainable future.

Goal 14: The conservation of oceans, seas, and marine resources underscores the importance of ecosystems and biodiversity. This goal centres around the preservation of natural resources through a holistic approach to sustainable development. It is closely related to reducing marine pollution.

Goal 14.3: Ocean acidification is increasing, and unless CO_2 emissions threatening marine ecosystems and the services they provide are curtailed, this trend will persist.

Existing waste incineration facilities currently dispose of a significant portion of their ash residues in seas and lakes, with some exceptions. However, we strive to expand the recycling ecosystem by delivering all ash residues to recyclable areas, thus increasing the recycling of ash waste.

Goal 15: Pertaining to terrestrial life, this goal encompasses vital areas such as forests and biodiversity. Halting deforestation, and combating drought and desertification, underscores the necessity of preserving natural habitats. Preserving terrestrial ecosystems with a sustainable approach also contributes to preventing the decline of biological diversity. To prevent the need for new facilities, improper storage or direct disposal of ash waste into the environment must be addressed as the volume of waste increases.

Goal 17: This goal serves as a complement to all other goals, focusing on revitalizing global partnerships for sustainable development. It aims to enhance international cooperation in areas such as finance, technology, and trade. We propose suggestions for companies that continuously utilize raw materials to proportionately incorporate readily reusable ash into their formulas. By transforming non-functional ash waste into useful materials, we strive towards a common objective, which holds significant importance for the sustainability of our world.

According to the calculations based on the Net Present Value (NPV), taking into account the net income and expenses of each year, the project is projected to be profitable in some years and incur losses in others. For example, a net income of 44,314,815 Euros is forecasted in the year 2030, while a loss of -3,371,163 Euros is projected in the year 2046. Therefore, the project can have varying levels of profit and loss between the projected years. By considering the cash flows and costs of the investment project, there is a forecasted need for cash outflows or inflows in certain years. For instance, a cash outflow of 28,909,185 Euros in 2030 and 22,585,612 Euros in 2046 is projected. This indicates a potential financing requirement for the project in those years. Project managers and financial experts need to analyze the financing needs in detail and determine appropriate sources of financing [80]. In this project, we are working on a design that involves waste sorting, recycling, and incineration processes. However, as we only possess theoretical knowledge, we require support and consultancy in terms of implementation and technical aspects. We need to collaborate with an application or software company to develop an application or system to bring our project to life. Additionally, obtaining assistance from an engineering and technology expert to optimize our processes and achieve the best results is crucial. We are also seeking support in business planning, strategy development, and accessing financial resources. We will explore options such as engaging with investors, applying for grant programs, and establishing partnerships with environmental organizations. Furthermore, we aim to connect with environmental non-governmental organizations to build networks with experienced individuals in the industry, establish collaborations, and stay informed about industry developments.

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