ABSTRACT

Title of Thesis: STOP WASTING CAIRO: REDUCE AND RE-USE TO PRODUCE SUSTAINABLE ENERGY SOLUTIONS

Samanty R. Habib, Master of Architecture, 2023

Thesis Directed By: Professor, Juan Burke, School of Architecture, Planning & Preservation

Cairo is known for its history and beauty, although there is not a proper disposal system for the citizens to keep the streets clean. Parts of Cairo include garbage on the streets, inside buildings, and in neighborhoods. Using waste to produce energy could bring many benefits to the town of Cairo. The citizens of Cairo do not have proper infrastructure, there are no waste bins on the street or an efficient waste collecting service which forces them to toss it on the streets. Cairo is very hectic and crowded, and it will only get busier. Cleaning up the roads in Cairo is necessary for the urban image, enjoyment of the built environment, and good hygiene.

Many citizens in Cairo do not have the funds to turn on the AC or run a dryer. With Cairo's weather conditions, temperatures can get as high as 120 degrees. This thesis will reuse the waste that is produced by citizens to give back to the community

through a waste-to-energy facility. There are tons of waste being produced daily, this waste includes organic waste that will be used to design a community garden outside the facility. Reusing the waste in Cairo will reduce landfill waste and create significant power. The citizens have developed a mindset of tossing waste onto the streets, the facility will also include education to educate the citizens of Cairo on reusing, reducing, and reusing.

STOP WASTING CAIRO:
REDUCE AND RE-USE TO PRODUCE SUSTAINABLE ENERGY SOLUTIONS

By:

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Thesis submitted to the Faculty of the Graduate School of
the University of Maryland, College Park, in partial fulfillment
of the requirements for the degree of
Master of Architecture
2023

Advisory Committee:

Professor Juan Burke, Chair
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Dedication

I would like to dedicate this thesis to my hometown, Cairo.

Acknowledgements

I would like to acknowledge my family, friends, and professors for all their support on this thesis. Especially my chair, Professor Juan Burke, for being there and helping me overcome such a challenging project.

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Chapter 1: Background

City Introduction

This thesis will analyze the amount of waste produced in Cairo and provide a waste-to-energy facility to give back to the community through energy and education. Cairo is the capital of Egypt, known as one of the largest cities in Africa and the Middle East.[1] Located on the right bank of the Nile River in the northeast of the country. Cairo is a very hectic and crowded city with a dry climate and little or no rain. The population in Egypt is increasing. Currently, there are about 67 million inhabitants while Greater Cairo makes up about a quarter of it with 14-15 million inhabitants.[2] Greater Cairo is organized into three governorates and those governorates contain districts within them. The first is Cairo, which is classified as an urban governorate with 26 districts. Giza is classified as a rural governorate with five districts plus some village administrative units. Lastly, Qaliubia is classified as a rural governorate with two districts of Shubra plus some village administrative units.[3] In Egypt, governorates are described as, "executive bodies, with all important officials appointed by the central government."[4]

[1] David Sims, Marion Sejoume, and Monika El Shorbagi *Cairo, Egypt Understanding Urban Slums* (Cairo, 2003), 1.
[2] Sims, *Cairo, Egypt*, 3.
[3] Sims, *Cairo, Egypt*, 4.
[4] Sims, *Cairo, Egypt*, 4.

Defining the Problem

Most people think of Cairo's rich history and beauty, but no one imagines the city being filled with waste along the streets. Many parts of Cairo are considered poor and unhealthy, while, contrastingly, other areas of the city are adequately maintained and with functional waste infrastructure. Cairo does not have a proper disposal system, so the citizens are forced to toss their trash on the streets. As mentioned, earlier, whether it is vehicle traffic or foot traffic, Cairo is very hectic and crowded. Almost all their streets/sidewalks are packed with people selling and buying goods. Although there is a lot of vehicle traffic, there is also a lot of pedestrian traffic because all the necessary shops and stores are within walking distance. Vehicles and pedestrians are the main cause of traffic in Cairo; there are not many bicyclists but a few motorcyclists.

Figure 1: A view of a typical street in Cairo

In some of the most economically challenged areas, you may find more foot traffic than car traffic due to the lack of citizens owning vehicles. Cairo also has no traffic pattern, meaning there are few traffic lights and intersections, no stop signs, no crosswalks for pedestrians, and barely any street signs.

There are few buses. The main transportation services are taxis and minibuses referred to as Tok Tok's. This results in the streets being extremely crowded and noisy. That said, the issue of the lack of proper treatment of waste exacerbates the already dire and pressing environmental degradation of the city and its environs.

There is a large percentage of people living in poverty are mixed into areas that are considered lower- and middle-class neighborhoods. A portion of Cairo has been redeveloped by the government and is now labeled as New Cairo. It consists of some of the wealthiest people and a lot of the nicer developed housing complexes and commercial spaces. "New Cairo is a new settlement created, in the nineties, to the east of Cairo by the Egyptian government in the hope of finding solutions for the old city's problems."[5] Other parts of Cairo are considered less wealthy, and this is where most lower and middle-class citizens live.

[5] Mahmoud, Randa *New Cairo's Urban Dynamics: Redefining Gentrification as a Main Actor of Social Resilience*. (Procedia Environmental Sciences, 2017) 430.

Figure 2: Urban Evolution of New Cairo's Master Plans between 1993 and Present

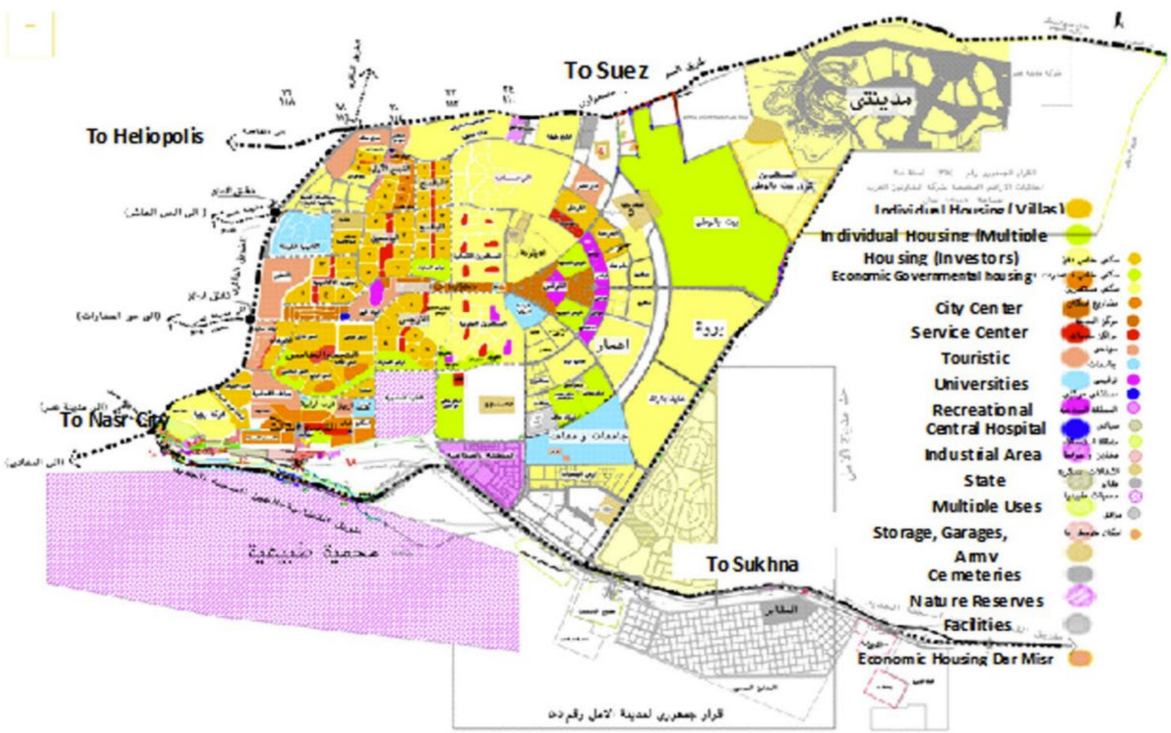

Figure 3: Most Recent Master Plan with Extensions

Within Cairo, the citizens have a habit of tossing their waste in the streets because they were used to the door-to-door service. This next section of the chapter will discuss how the Zabaleen system worked in some areas of Cairo and also mention the different types of waste and how they are being collected along with the type of energy that can be produced from it. Today, the Zabaleen system has slowly faded away due to economic disagreements between the residents and the government.[6] This put a tremendous strain on the city's infrastructure and has caused many public health problems in Cairo and adjoining areas. Lastly, disposing of solid waste in water bodies has led to contamination of water supplies in serval parts of the city.[7] Overall, this thesis will show the lack of architecture in waste management and help design a solution that reuses the waste produced into energy to help change the perception of sanitation in the city of Cairo.

Previous Solutions

Although Cairo's trash system seems bad now, there have been previous solutions that worked at the time. One was the Zabaleen Garbage Recyclers, and as mentioned before, Zabaleen translates as "trash people." In the past, there have been other solutions as well. An article written by Wael Salah Fahmi and Keith Sutton discusses the different waste collection systems that were incorporated in the city of Cairo. One was about 100 years ago when a group of migrants from the Dakhla oasis came to

[6] Dana Hooshmand, *The Zabbaleen: The Unique Story of the "Garbage People" of Cairo* (Discover Discomfort, 2022).
[7] *Drowning in Waste-Case Cairo, Egypt* (Woima).

Cairo. They were known as the “wahiya”, meaning “people of the oasis.” This group was responsible for collecting and disposing of the trash from Cairo’s household waste. They were working under contracts with the owners of the buildings where they would collect a monthly fee from the tenants and an initial sum was given to the owners of the buildings.[8] Later came the Zabaleen collectors but as the article states, “there is a distinction between the wahiya and the garbage collectors.”[9] The Zabaleen group would take the waste and have their family members sort it into “16 different types of trash, including making use of the organic waste for feeding pigs.”[10] They would then sell those pigs to tourist hotels. They also sold “secondary materials such as paper, tin, rags, glass, plastic, and materials to middlemen.”[11] At this point, the wahiya group was much higher than the Zabaleen group and they did not get any shares from the monthly fees. Not getting paid was frustrating to the Zabaleen group because they collected a lot of the trash, but they had to pay the wahiya to gain access to the waste garbage so they can make a living from the waste.

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[8] Fahmi, Wael Salah, and Keith Sutton. *Cairo's Zabaleen garbage recyclers: Multi-nationals’ takeover and state relocation plans*. (Habitat International, 2006) 811.
[9] Fahmi, Wael Salah, and Keith Sutton. *Cairo's Zabaleen garbage recyclers: Multi-nationals’ takeover and state relocation plans*. (Habitat International, 2006) 811.
[10] Fahmi, Wael Salah, and Keith Sutton. *Cairo's Zabaleen garbage recyclers: Multi-nationals’ takeover and state relocation plans*. (Habitat International, 2006) 811.
[11] Fahmi, Wael Salah, and Keith Sutton. *Cairo's Zabaleen garbage recyclers: Multi-nationals’ takeover and state relocation plans*. (Habitat International, 2006) 811.

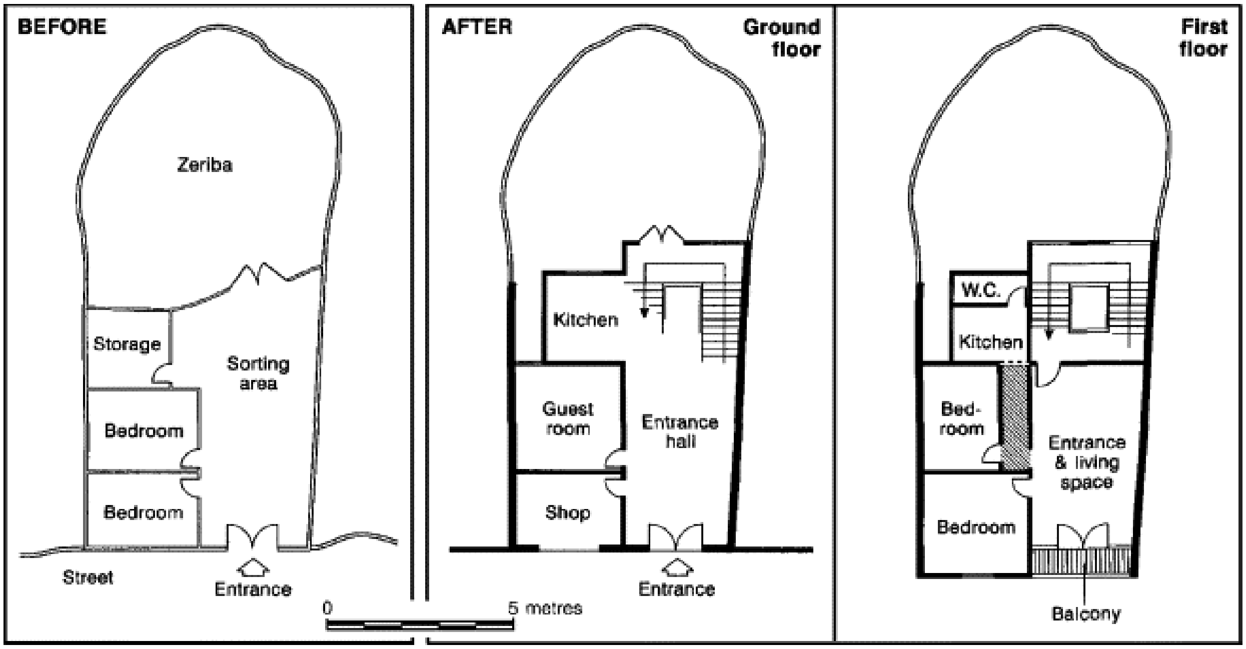

Figure 4: A Before and After representation of an Upgraded Zabaleen House

Transportation and traffic have always been an issue in Cairo, where there is no traffic pattern and many cars on the road. In 1989, there was an “agreement between wahiya and the Zabaleen to establish new mechanized companies for waste collection.”[12] At first, they were collecting trash with donkey carts, but they wanted to upgrade to motorized trucks, although they had no assistance in converting to a new mechanized system. The article states that the agreement implied “that the informal-sector groups of garbage collectors (Zabaleen) are contracted to collect and dispose of solid wastes, by local contractors, known as wahiya, with such cooperation transformed into the private Environmental Protection Company (EPC).”[13] The government wanted to upgrade the

[12] Fahmi, Wael Salah, and Keith Sutton. *Cairo's Zabaleen garbage recyclers: Multi-nationals' takeover and state relocation plans*. (Habitat International, 2006) 812.
[13] Fahmi, Wael Salah, and Keith Sutton. *Cairo's Zabaleen garbage recyclers: Multi-nationals' takeover and state relocation plans*. (Habitat International, 2006) 812.

solid-waste management in Cairo and divided to have the two services work together. Still, the Zabaleen were just now starting to receive a minimal fee for their hard work. Once the pandemic occurred, no one wanted to work anymore, and many of the workers under the Zabaleen became homeless due to the increasing prices and because they were never getting paid enough from the start. So once the pandemic hit, they stopped the services, and since then, no one has returned to it. Some parts of Cairo are worse than others, but citizens toss trash onto the streets, in neighborhoods, and inside buildings. Although the Zabaleen were around, they did a lot of fantastic work for the city to ensure it was maintained clean. The next part of the chapter will cover the areas of Cairo where the Zabaleen workers were present.

Zabaleen Cities:

Before the pandemic, the Zabaleens were scattered around Greater Cairo's urban regions to collect trash. Those areas were "Ein El Ssira, Moatamadia, El Baragil, Tora, Ezbet El Nakhl, Helwan, and Muqattam."[14] The largest Zabaleen community was situated in Muqattam, which is east of Cairo. Muqattam suffered many environmental issues and low income back in the 1970s. Although they suffered many problems, the population in Muqattam continued to grow, and it went from 8,000 people to about 20,000 people. Those 20,000 people lived in the "Garbage City" of Muqattam, and the article states that "almost all of them live off, or are involved in, garage activities."[15]

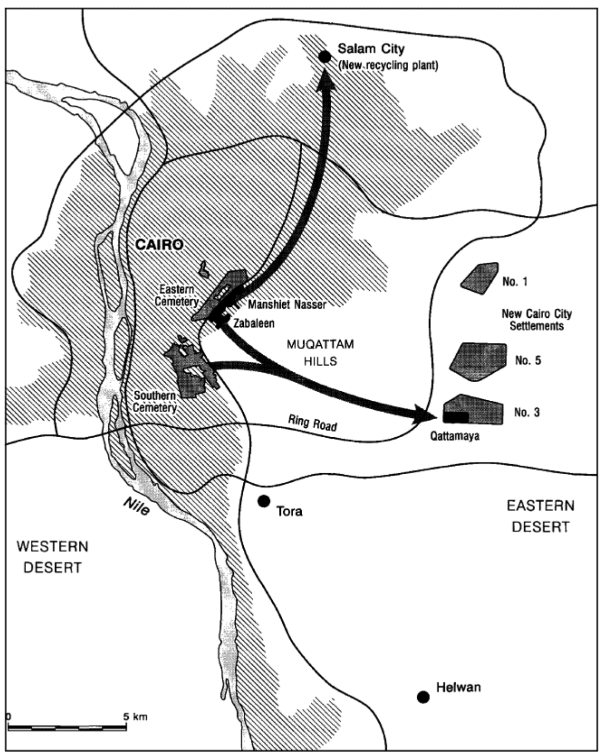

Figure 5: Relocation and Resettlement Scenarios

[14] Fahmi, Wael Salah, and Keith Sutton. *Cairo's Zabaleen garbage recyclers: Multi-nationals' takeover and state relocation plans*. (Habitat International, 2006) 812.
[15] Fahmi, Wael Salah, and Keith Sutton. *Cairo's Zabaleen garbage recyclers: Multi-nationals' takeover and state relocation plans*. (Habitat International, 2006) 812.

Those involved in the garage were mainly women and girls who worked 10-12 hours a day sorting through garbage to make a living. It was "estimated that the Zabaleen informally handled one-third of Cairo's garbage from 14 million people."[16] This means that the Zabaleens collected about 3,000 tons of garbage every day. Cairo is known to produce about 15,000 tons of trash per day, and 3,000 of it comes from Muqattam. Figure one represents the location of the Muqattam Zabaleen settlements and cemeteries in Cairo and its relation to the Nile River. The next chapter will discuss the lack of architecture in waste management, the types of waste, and the different treatments to produce less waste.

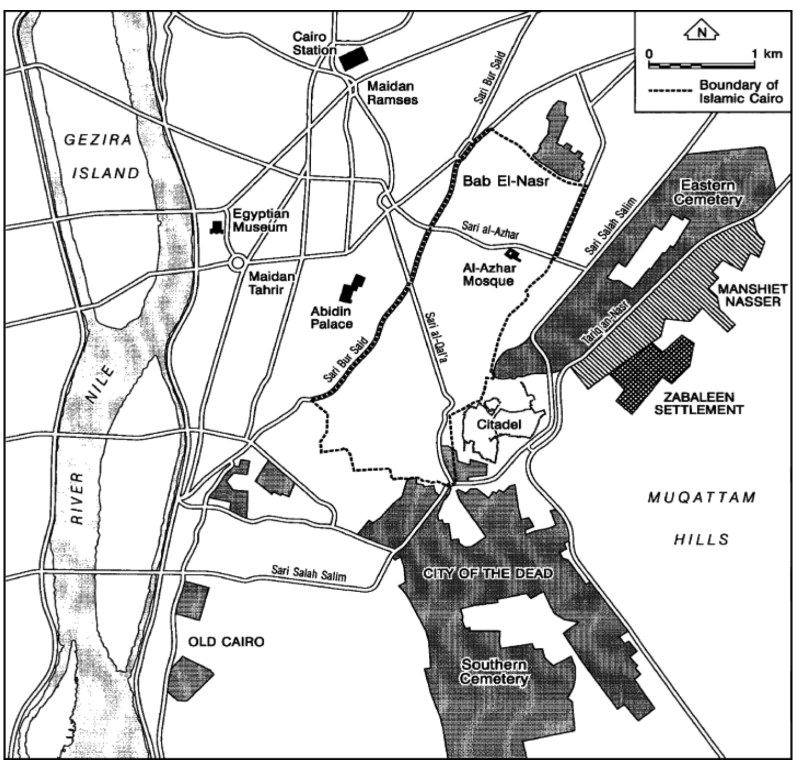

Figure 6: Location of the Muqattam Zabaleen Settlement and Cemeteries in Cairo

[16] Fahmi, Wael Salah, and Keith Sutton. *Cairo's Zabaleen garbage recyclers: Multi-nationals' takeover and state relocation plans*. (Habitat International, 2006) 812.

Chapter 2: Waste

Lack of Architecture in Waste Management

This thesis focuses on the architecture of waste and its socio-cultural context. As a typology, the architecture of waste is an underexplored topic and architectural typology. Garbage continues to be an out-of-sight, out-of-mind topic, however, architecture can change the way people view all kinds of waste and their relationship to it. Harvard's Graduate School of Design founded a Waste-to-Energy Design Lab back in 2014 to have people rethink architecture and waste.[17] Their mission is to "rethink the relationship between architecture and waste through research and design." [18] Waste-to-Energy facilities, given their industrial aesthetics, do not feature prominently in the design and architectural discussions. One example is the Waste-to-Energy facility designed by BIG architects located in Copenhagen, Denmark. This Waste-to-Energy project features prominently by including tourist attractions that bring visitors to the area to learn about waste while also still producing all the necessary functions. If we change how people view Waste-to-Energy facilities by using architecture, it could benefit the community and educate them on waste and its relationship to architecture. Harvard's Graduate School of Design's goal is "to develop hybrid WTE building typologies which not only re-connect and communicate to the public but also weave new public or institutional programs with energy production in a mutually beneficial

[17] *About,* Harvard Graduate School of Design Waste to Energy. 1.
[18] *About*, Harvard Graduate School of Design Waste to Energy. 1.

way."[19] Most do not think of architecture when you say the term "waste" the goal here is to change that.

There are many power plants and waste-to-energy facilities worldwide, but they are not appealing to the viewer's eye. Some examples are, Lausward Combined Cycle Power Plant located in Dusseldorf, Germany, completed in 2018 by Kadawittfeldarchitektur, Recycling Plant located in Madrid, Spain, completed in 1999 by Abalos and Herreros, Waste Disposal Facility located in the Netherlands, completed in 2000 by UN Studios, Amager Bakke Waste-to-Energy Plant located in Copenhagen Denmark, completed in 2016 by BIG Architects, and Waste Treatment Facility located in Vacarisses, Spain, completed in 2010 by Batlle and Roig. Combining architectural features and waste could benefit the environment, create healthier neighborhoods, and educate citizens on waste management by including a facility nearby. Harvard Design Magazine states, "Within this space of opportunity, new design concepts can offer hybrid solutions to generate clean energy, contribute to cities' social and cultural activities, and protect wider urban atmospheres and microclimates."[20] Cairo is one example of a city that is constantly growing and developing over time. Their population continues to grow, and more buildings continue to rise. Changing the citizen's perspectives on sanitation will allow for a cleaner city and a chance to give back to those in need. A waste-to-energy facility could include many features to benefit the community. There needs to be more

[19] *About*, Harvard Graduate School of Design Waste to Energy. 1.
[20] Andreas Georgoulias, Hanif Kara, and Leire Asensio Villoria, *The Missing Link: Architecture and Waste Management*, (Harvard Design Magazine, 2015).

sustainable infrastructures rising in Middle Eastern countries to contain the waste that is produced daily by the citizens.

Types of Waste and Their Definitions

Solid waste could be considered a number of things and can differ when looking from country to country. Solid waste or Municipal Solid Waste (MSW) can be defined as: "…all wastes generated, collected, transported, and disposed of within the jurisdiction of a municipal authority. In most cases, it comprises mainly food waste, and rubbish from residential areas, street sweepings, commercial and institutional nonhazardous wastes as well as (in some countries) construction and demolition waste."[21] Some examples of where solid waste can come from include, "office trash, un-reusable packaging, lunchroom wastes, and manufacturing or processing wastes that are not overwise classified as "hazardous.""[22] A lot of this trash is usually placed in dumpsters or recycling bins and are then picked up by a local trash hauler's to eventually dispose of the trash in a municipal landfill or take it to a treatment center.[23] Each country is different from one other when it comes to the amount of waste produced or even the type of waste produced. Whether it comes more from the residents or from commercial buildings or even a mixture of both. But taking all this waste and reusing it could be so beneficial to many parts of the world.

[21] Periathamby, Agamuthu. *Municipal Waste Management Waste*, (2011): 109-125.
[22] Woodard, Curran, *Industrial Waste Treatment Handbook*, (Amsterdam: Butterworth-Heinemann, 2006).
[23] Woodard, Curran, *Industrial Waste Treatment Handbook*, (Amsterdam: Butterworth-Heinemann, 2006).

Waste Treatment and Management

There are three categories of waste that are discussed in a book called “Industrial Waste Treatment”, those three categories are, “normal solid waste (trash), industrial or “special” waste, or federally regulated hazardous waste.”[24] Understanding these three categories could impact the design chosen for a waste treatment system because one would have to categorize the waste in order to see what type of energy could be produced from this waste. There is nonhazardous waste which is defined as, “industrial or “special” waste or solid waste.”[25] There is also hazardous waste which is defined as, “the most toxic, expensive, and regulated type of industrial waste.”[26]

“The first and most important order of business in a solid waste management program is to identify any and all opportunities for reducing the volume, strength, and hazardous nature of wastes, always with the goal of elimination.”[27] This is something to keep in mind because trying to reduce the amount of waste that is being produced daily by citizens is necessary to help keep the city cleaner while also coming up with a plan on how to collect all the trash. Educating them on how much waste they produce daily could keep a lot of waste off the streets and it would be easier to collect a smaller amount.

[24]Woodard, Curran, *Industrial Waste Treatment Handbook*, (Amsterdam: Butterworth-Heinemann, 2006).
[25] Woodard, Curran, *Industrial Waste Treatment Handbook*, (Amsterdam: Butterworth-Heinemann, 2006).
[26] Woodard, Curran, *Industrial Waste Treatment Handbook*, (Amsterdam: Butterworth-Heinemann, 2006).
[27] Woodard, Curran, *Industrial Waste Treatment Handbook*, (Amsterdam: Butterworth-Heinemann, 2006).

Chapter 3: Waste to Energy

Waste to Energy Process Introduction

There is an industrial process by which to transform waste into energy. This chapter will describe the energy to waste process and describe the types of energy that can be produced. The incineration process has been around since the beginning of the 20th century. This process “transforms environmentally hazardous components of waste, such as aromatic hydrocarbons and organic solvents, into harmless compounds. Additionally, incineration plants convert the released combustion heat into steam and electricity.”[28] The next portion of this chapter will discuss the process of how to produce energy from waste. These processes include drying, pyrolysis, gasification, char combustion, and ash sintering. The waste combustion phase, which includes drying, pyrolysis, and char combustion, all take place on a moving grate bed.[29] An overall waste incineration plant can be divided into four sections, the discharge area, the feeding system, the boiler, and the flue gas cleaning one.[30]

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[28] S. Bardi and A. Astolfi*, Modeling and Control of a Waste-to-Energy Plant* (IEEE Control Systems Magazine, 2010) 27-37

[29] S. Bardi and A. Astolfi*, Modeling and Control of a Waste-to-Energy Plant* (IEEE Control Systems Magazine, 2010) 27-37

[30] S. Bardi and A. Astolfi*, Modeling and Control of a Waste-to-Energy Plant* (IEEE Control Systems Magazine, 2010) 27-37

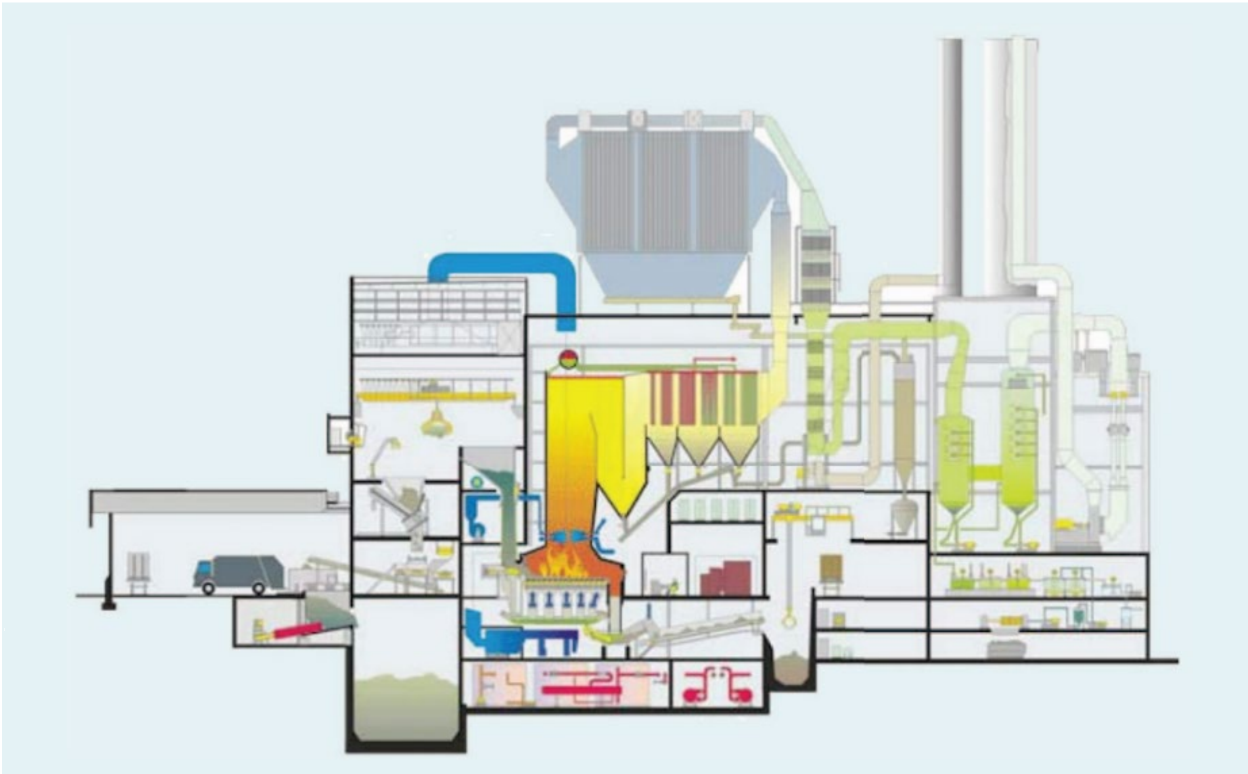

Figure 7: Schematic representation of a municipal waste incineration plant

Step One: Drying

Each part of the process is in a different area of the facility/plant. The drying part is one of the most important components because "it influences the location of the combustion area on the grate".[31] The drying component is dependent on the timing of the combustion and temperatures. Parts that depend on the onset timing of the combustion include, "… temperature distribution in the furnace, the residence time of the flue gases,

[31] S. Bardi and A. Astolfi, *Modeling and Control of a Waste-to-Energy Plant* (IEEE Control Systems Magazine, 2010) 27-37

and level of the material stress of the combustion bed grate."[32] This component is very dependent on time because if the onset timing is off by even a little but then the temperature distribution may not be the same which will then affect the whole drying process. This is also connected to the heat transfer in the waste bed.[33] When the timing starts, everything must follow immediately afterward, so nothing is off.

Step Two: Pyrolysis and Gasification

The next steps are pyrolysis and gasification. Pyrolysis is the "decomposition brought about by high temperatures."[34] Gasification is "to convert into or become a gas."[35] Waste has water in it, so when the water in the waste has dried up the temperature of the waste increases. To start pyrolysis the waste is first heated up to a temperature where the oxygen will react with some of the hydrocarbons and solid components. Pyrolysis will then occur when the oxygen is missing and when the "higher hydrocarbons are cracked into smaller gaseous species."[36]

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[32] S. Bardi and A. Astolfi, *Modeling and Control of a Waste-to-Energy Plant* (IEEE Control Systems Magazine, 2010) 27-37
[33] S. Bardi and A. Astolfi, *Modeling and Control of a Waste-to-Energy Plant* (IEEE Control Systems Magazine, 2010) 27-37
[34] "Pyrolysis Definition and Meaning" *Dictionary.com*. (Dictionary.com, 2022).
[35] "Pyrolysis Definition and Meaning" *Dictionary.com*. (Dictionary.com, 2022).
[36] S. Bardi and A. Astolfi, *Modeling and Control of a Waste-to-Energy Plant* (IEEE Control Systems Magazine, 2010) 27-37

Step Three: Char Combustion

After pyrolysis is complete the remaining residual carbon char will then start to combust. “Char combustion is described relative to the combustion of a carbon sphere since all pyrolyzing solids, once completely charred are attacked by oxygen in much the same manner as carbon. The burning rate of simple solids depends on the rate at which the oxygen diffuses to the fuel surface.”[37] There are reactions that occur throughout this component and those reactions have the same five sequential steps. Those five sequential steps are, “oxygen diffuses to the fuel surface, diffused oxygen is absorbed by the surface, absorbed oxygen reacts with the solid to form absorbed products, absorbed products are desorbed from the surface, and desorbed products diffuse away from the surface.”[38] Each one of these steps will occur in series and the slowest step will determine the rate at which the waste burns.

Step Four: Ash Sintering/Burnout

There are some materials/wastes that cannot be part of the process or cannot be destroyed/burned. The waste could go through the whole process of drying, heating, and carbonizing but cannot achieve the last step, which is burnout.[39] The waste that cannot be burned falls in between the grates and is considered either bottom ash or fly ash. Bottom ash “is the ash that falls from the end of the grates combined with the

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[37] S. Bardi and A. Astolfi*, Modeling and Control of a Waste-to-Energy Plant* (IEEE Control Systems Magazine, 2010) 27-37
[38] S. Bardi and A. Astolfi*, Modeling and Control of a Waste-to-Energy Plant* (IEEE Control Systems Magazine, 2010) 27-37
[39] S. Bardi and A. Astolfi*, Modeling and Control of a Waste-to-Energy Plant* (IEEE Control Systems Magazine, 2010) 27-37

siftings that fall through the grates."[40] Fly ash "either settles in the ducts and devices of the incinerator or continues to the air-pollution control system."[41] The last portion of the process consists of the ash being logged, and it is then later "quenched and cooled with water before it is transported to the sag bunker by means of a conveyor belt."[42] Throughout this process, some of the heat is lost and needs to be considered in the overall heat balance.

Generating Electricity

There are different types of energy that can be produced from a waste-to-energy facility/plant. When it comes to releasing steam from the plant, this can be used for "industrial processes or district heating, and the electricity is usually fed into the national grid."[43] Waste-to-energy plants burn garbage or waste to produce steam in a boiler that is used to generate electricity. There are seven stages to generating electricity. The first stage is taking the waste from the garbage trucks and dumping it into a large pit. Then a giant claw on a crane will grab the waste and dump it in a combustion chamber. The waste will then be burned which will release heat and the heat turns the water into steam in a boiler. The high-pressure steam will turn the blades of the turbine generator to produce the electricity. An air pollution control system will remove all pollutants from

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[40] S. Bardi and A. Astolfi, *Modeling and Control of a Waste-to-Energy Plant* (IEEE Control Systems Magazine, 2010) 27-37

[41] S. Bardi and A. Astolfi, *Modeling and Control of a Waste-to-Energy Plant* (IEEE Control Systems Magazine, 2010) 27-37

[42] S. Bardi and A. Astolfi, *Modeling and Control of a Waste-to-Energy Plant* (IEEE Control Systems Magazine, 2010) 27-37

[43] S. Bardi and A. Astolfi, *Modeling and Control of a Waste-to-Energy Plant* (IEEE Control Systems Magazine, 2010) 27-37

the combustion gas before it gets released into a smokestack and the ash will be collected from the boiler and the air pollution control system.[44]

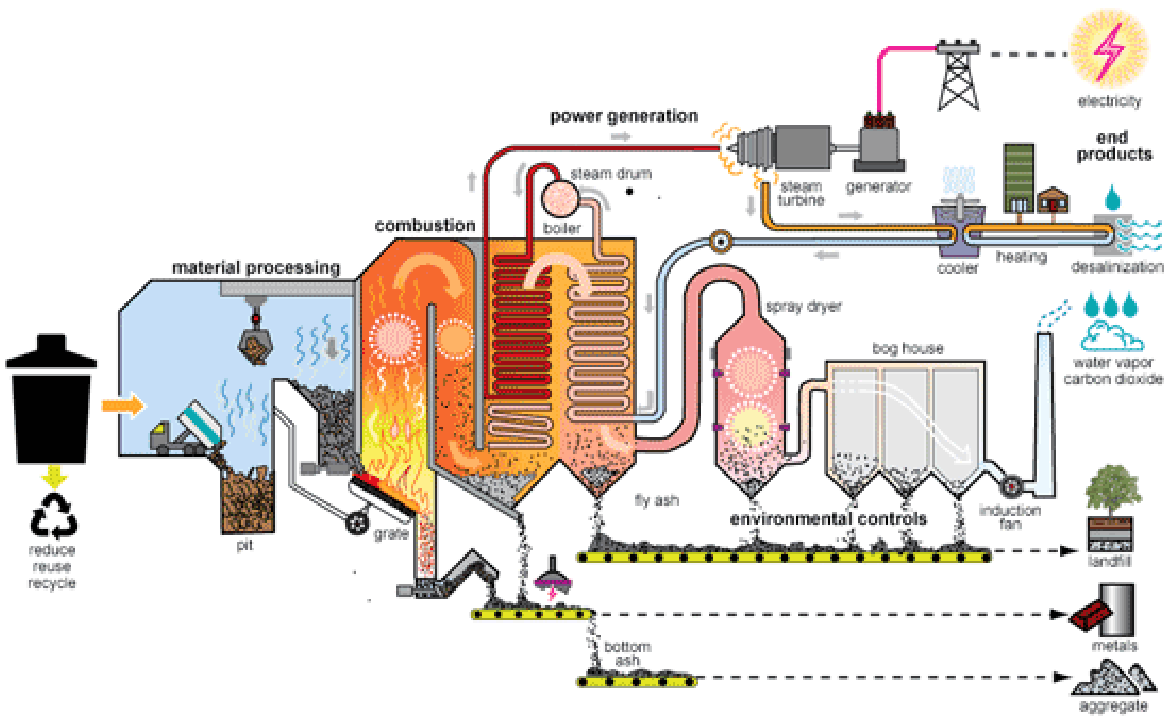

Figure 8: Process of Waste to Energy plant

[44] *Waste-to-Energy* (Covanta).

Chapter 4: Precedent Study

Introduction of Precedents

To understand the functions of a waste-to-energy facility in relation to its urban context, this precedent analysis studies waste-to-energy facilities and plants. Some precedents include multi-functional recreational spaces within the waste-to-energy facility/plant, which is necessary to study for this thesis based on the intended program use. This precedent analysis will lay out the foundations of each project, including location, architects, additional program use, exterior features, and intended visitors. This thesis will have the necessary program use to have a functional waste-to-energy building along with additional features, which include education and an organic community garden. Providing education will teach visitors about how much waste to produce and how they could start to reduce, reuse, and recycle it. A community garden will reuse the organic waste that is being produced and give back to the community.

Precedent Analysis

A Refuse Treatment Center located in Madrid, Spain was designed by Abalos and Herreros and was completed in 2000. The building has a sloped garden roof and a centralized courtyard space. For the garden roof, they reuse the compost to fertilize the garden-roof. The programmatic requirements for this project consisted of a "weight stations for trucks, recycling plant, compost shed, and rejected residues are sent to the dump."[45] This treatment center is not only focused on the garbage and its disposal but

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[45] Angel Jaramillo, *Refuse Treatment Center, Madrid*, (Arquitectura Viva, 2021).

there are other features included within the building. The treatment center emphasizes its central space with an educational mission that is comprised of a museum that is designed “to raise awareness of environmental issues.”[46]

Figure 9: Refuse Treatment Center

The Waste Treatment Facility (CTRV in Spanish) located in Vacarisses, Spain was designed by Batlle and Roig Architects and completed in 2010. The location of this project played a huge role when deciding on a proper site. When choosing a site, the architects looked for “different criteria of logistical and economic suitability as well as the

[46] Angel Jaramillo, *Refuse Treatment Center, Madrid*, (Arquitectura Viva, 2021).

minimization of the environmental impact resulting from the installation and operation of waste management-related activities." [47] The overall scope of the project consisted of two large treatment centers under a sloped roof, these centers were divided by a driveway. The roof's geometry differed in location according to the programs and dimensions of each boundary.[48] The programmatic requirements of this design include a pretreatment center, truck access, pit, biofilters, waste reception, office building, parking and storage, stabilization ship, rejection stabilization ship, and ship of refining. A unique feature of this facility is the roof, there are circular geometries that contain earth, gravel, and native groundcovers and shrubs.[49]

Figure 10: Waste Treatment Facility

[47] Victoria King, *Waste Treatment Facility / Batlle and Roig Architects* (ArchDaily, 2011).

[48] *Centre De Tractament De Residus Del Valles Occidental a Vacarisses* (Batlleiroig, 2022).

[49] Victoria King, *Waste Treatment Facility / Batlle and Roig Architects* (ArchDaily, 2011).

Amager Bakke is a waste-to-energy plant located in Copenhagen, Denmark. It was designed by Bjarke Ingels Group (BIG) and completed in 2017. It is known as one of the largest waste-to-energy plants in northern Europe.[50] This complex is not only an energy plant but also serves as a recreational and environmental education center. Amager Bakke is an example of a waste-to-energy plant that combines landscape and public activity. Those recreational programs consist of an "artificial skiing slope, a running path, an 80-meter-high artificial climbing wall, a café, and a grove of trees."[51] Amager Bakke is not only economically viable, but it also attracts tourists because of its unique features. Along with its unique features, the plant also "burns waste collected from 500,000 – 700,000 inhabitants and 46,000 companies in and around Copenhagen."[52] There was a waste-to-energy plant that was replaced with Amager Bakke so it could output more energy. This waste-to-energy plant was used a lot by visitors during the coronavirus pandemic since a lot of activities shifted outdoors during this time.[53] Many events and festivals are also held at this plant which includes "an open-mic comedy night, a gin-tasting event, a freestyle ski competition, and planned J-Day festivals."[54]

The interior of the plant includes the necessary functions to fully generate electricity for homes and companies in the Danish capital. As mentioned earlier, the plant receives combustible waste from about 400,000 – 700,000 citizens and approximately 46,000

[50] *Amager Bakke Waste-to-Energy Plant* (Power Technology, 2019).
[51] *Amager Bakke Waste-to-Energy Plant* (Power Technology, 2019).
[52] *Amager Bakke Waste-to-Energy Plant* (Power Technology, 2019).
[53] https://www.archpaper.com/2020/11/copenhill-bigs-skiable-waste-to-energy-power-plant-gets-sweeping-new-photos-from-hufton-crow/
[54] https://www.archpaper.com/2020/11/copenhill-bigs-skiable-waste-to-energy-power-plant-gets-sweeping-new-photos-from-hufton-crow/

companies.[55] There are nine steps to take to generate electricity, they are, bringing the waste to the plant, unloading the waste in the silo, feeding the incinerators which burns the waste, the slag and fly ash is then collected, each incinerator has a boiler that is integrated so it then goes through the boiling process, then it goes through the turbines and heat exchangers, flue gas purification, water treatment, and lastly. Monitoring. Amager Bakke will only accept waste that cannot be recycled and about 50% of the combustible waste that it receives is from private homes and the rest is from companies.[56] The process starts with about 250-300 trucks carrying the waste and bringing it every day to be weighed and inspected. It is then unloaded and the "residual waste is tipped directly into a 30 x 50 meters silo, 36 meters high."[57] This silo is very large and can hold approximately 22,000 tons of waste which is equal to about three weeks of waste from Amager Bakke's owner municipalities.[58] The waste will then get mixed and lifted into the incinerator feeding hoppers. Each one can grab up to 15 tons of waste. Once the waste is fed into the feed hoppers, it falls down a shaft, and once it hits the bottom, it hits a grate mat, and the waste moves forwards, it starts to ignite and takes about 1.5-2 hours to burn the waste in the incinerator which is set at a temperature of 950-1,100 degree Celsius.[59] "When the waste reaches the end of the grate, virtually all of the energy has been released as heated smoke."[60] There are parts of the waste that cannot be used which is usually about 17-20% which is considered

[55]"From Waste to Energy," *ARC*, last modified October 27, 2022, accessed November 29, 2022, https://a-r-c.dk/english/from-waste-to-energy/.)
[56] *From Waste to Energy,* (ARC, 2022)
[57] *From Waste to Energy,* (ARC, 2022)
[58] *From Waste to Energy,* (ARC, 2022)
[59] *From Waste to Energy,* (ARC, 2022)
[60] *From Waste to Energy,* (ARC, 2022)

slag. The slag consists of “ash from the waste, gravel, sand, metals, and other non-combustible materials.”[61] The slag is then collected and transported to go through a process called maturation which means the slag is watered and turned for 3-4 months. The boilers are the next portion in the process, Amager Bakke has two boilers and each one of them has “a box with a large number of close-fitting pipes carrying water under high pressure.”[62] The boilers are integrated with the incinerators, and they can produce up to 137 tons of steam per hour. About, “90% of the energy from waste is converted to high-pressure steam.”[63] The next step is the turbines and the heat exchangers, the turbines have a series of impeller blades mounted on a shaft, and that “shaft is connected to a generator, which converts the energy into electricity.”[64] The purification process is next which happens once all the smoke has passed through the boilers and has released its heat. Water will be collected from the purification process because it is generated from it. The last step is monitoring, an energy plant is running seven days a week, 24 hours a day, for 365 days. Within the control room, the employers are monitoring the plant and the entire process.[65] Overall, the plant has a very complex procedure that ends up providing energy for many residents and companies in the area.

[61] *From Waste to Energy,* (ARC, 2022)
[62] *From Waste to Energy,* (ARC, 2022)
[63] *From Waste to Energy,* (ARC, 2022)
[64] *From Waste to Energy,* (ARC, 2022)
[65] *From Waste to Energy,* (ARC, 2022)

Figure 11: Amager Bakke Waste-to-Energy Plant

Chapter 5: Zabaleen's of Cairo

History/Background

The main question starts with is Cairo currently drowning in waste? The answer is no! On the outside skirts of Cairo lies a district named Mansheya Nasir that is now being referred to as the garbage city. The Zabaleen (garbage people) all currently live within this district. They have created a waste management process and it is the only waste management process in all of Cairo. They will take their trucks and roam the streets of Cairo collecting all the waste, they make 56 cents per day from each apartment complex, this is in U.S. currency so 56 cents in Egyptian Pounds is 14 Egyptian Pounds.

How did the Zabaleen come to Cairo? In 1900 a group called the Wahiya group migrated from the Dakhla Oasis in Egypt's western desert region and settled in downtown Cairo. Thirty years later, the Zabaleen came to Cairo from Assiut in Southern Egypt. Both groups started working together to collect all the waste and bring it back to the district, although the Zabaleen started to make an income from the waste by feeding their pigs all the organic waste. 55% of Cairo's waste is organic and Zabaleen use it to feed their pigs and then sell their pigs to large tourists. The Zabaleen make about $80-$100 per pig sold and in Egyptian Pounds this is actually 2,500 Egyptian Pounds. To the Zabaleen this is a very large amount of money although it might not seem like it to us. In 1990, an agreement between the two groups resulted in purchasing new trash trucks, they did this without any governmental assistance. In 2000, the Zabaleen have now created what is arguably one of the world's most efficient resource recovery and recycling system. Nine years later when the Swine Flu Pandemic hit the government went around and started killing all the pigs but then later realized that they were not the cause of deaths, but they were really killing them because it represented a religious bias against the Muslim majority. 90% of Egypt's population practice the Muslim religion and they do not eat pork.

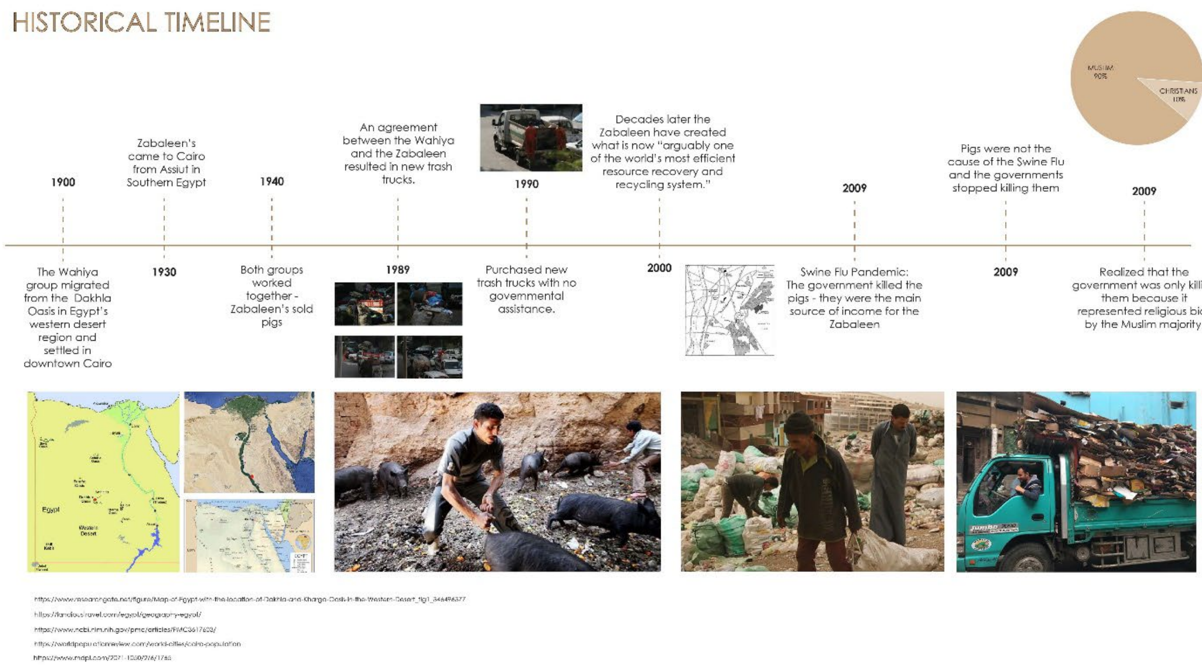


Figure 12: Historical timeline of how the Zabaleen (trash people) came to Cairo from 1900-2009.

Current Solutions

The Zabaleen are Cairo's only waste management process in Cairo today. They collect, transport, and sort all the waste by hand. This results in many diseases and sicknesses because the families who sort through the waste do not wear gloves, masks, or any protection. Women, men, and children are the ones sorting through the waste again with no protection at all. The entire district, Mansheya Nasir, is filled with piles and piles of garbage and currently all these families are really living within all the waste.

Figure 13: An image from a youtube video of how the women and girls in Manhseya Nasir are currently sorting throughout the waste with their bare hands.


Figure 14: A representation of the children also sorting through the waste with their bare hands.

Proposal Solution

The Zabaleen have really identified a niche in Cairo's infrastructure to capitalize on. As a family effort they all collect, transport, sort, and dispose of waste inefficiently by hand. Family members are exposed to harmful waste, bacteria, and possible injury in order to make a living. The new facility takes danger out of the equation. Members would continue collecting and transporting waste, but now they will transport it to their new facility where waste can be sorted and disposed of efficiently and safely while still retaining profit.

Chapter 6: Site Selection

Site Criteria

When choosing a proper site for the waste to energy facility and its outdoor components the size, waste amount, environment, context, weather, education rate, average income, population, living conditions, and services were all characteristics when thinking of a proper site. Debating on which criteria meets expectations significantly and which one does not meet expectations. Each site is unique and differs from one another drastically, one of the main characteristics that is the same throughout all three sites is the weather conditions. The weather is similar throughout with it being a high of 58 degrees in January and it can get as high as 100 degrees in August. (SOURCE) The next portion of the chapter will discuss the characteristics of each site. The first site is located in Mokattam, the second is Rod Al Farag, and the third is Al Marg.

Site 1: Mokattam

Mokattam is located south from Cairo, Egypt, with a population of about 20,000-30,000 people. The chosen area is about 6,330 square feet and the citizens here produce about 3,000 tons of waste. The citizens in the area make a very low income of about $11.50 per month during the year 2005. When this translates to Egyptian Pounds it is about 276 Egyptian Pounds per month. There are some environmental issues around the area because there is low health and high rates of disease due to the lack of services. There are no pharmacies, health centers, or schools where this site is located.

This site is surrounded by apartments and condos, not as many commercial buildings.

Most of the living conditions are considered poor in this area as well.

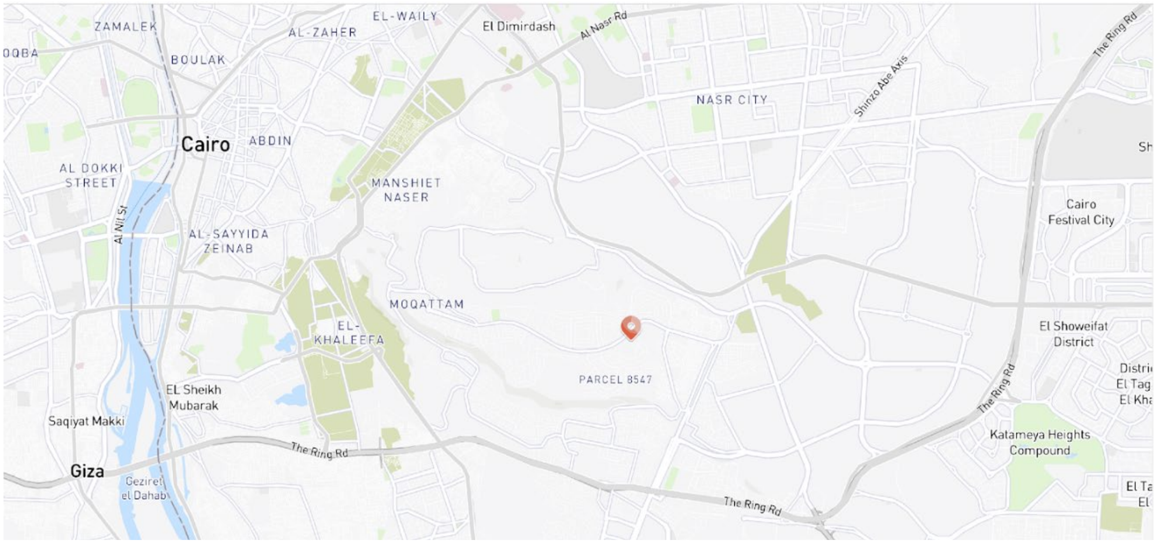


Figure 15: Location of the Mokattam site in relation to Cairo, Giza, and the Nile River.

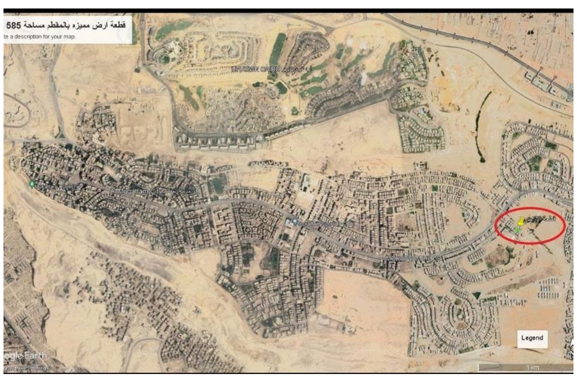


Figure 16 (left) and 17 (right): The image on the left is representing a zoomed in aerial view of the site and the image of the right is showing a closer aerial view of the site and its surrounding context along with the relationship it has to exisiting buildings.

Figure 18: A street view of the Mokattam site in relation to the surrounding context.

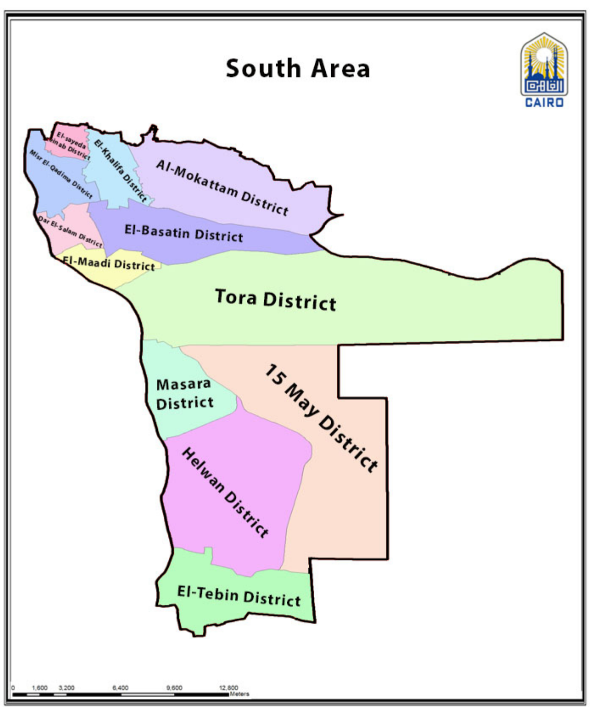


Figure 19: South Area of Cairo representing the location of Mokattam.

Site 2: Rod Al Farag

Rod Al Farag is located (NESW) of Cairo, Egypt (GET EXACT LOCATION), it is 138,600 square feet with a population of 153,000 people. There is about 5,000 tons of trash being produced by the citizens daily. This site is located near the Nile River and has a good amount of greenery surrounding the site. There is good education in the area that include a wide variety of programs. Some of the surrounding context includes more commercial than residential, there are some of the best shopping malls in the area but a shortage of living space. This concludes that the area is very crowded and dense and has a lot of people. Although compared to the other site the people here make about 44.2 thousand pounds per year which means they make, give or take, $1,840 American dollars per year. This may seem like it is not much but goods in Cairo are much cheaper.

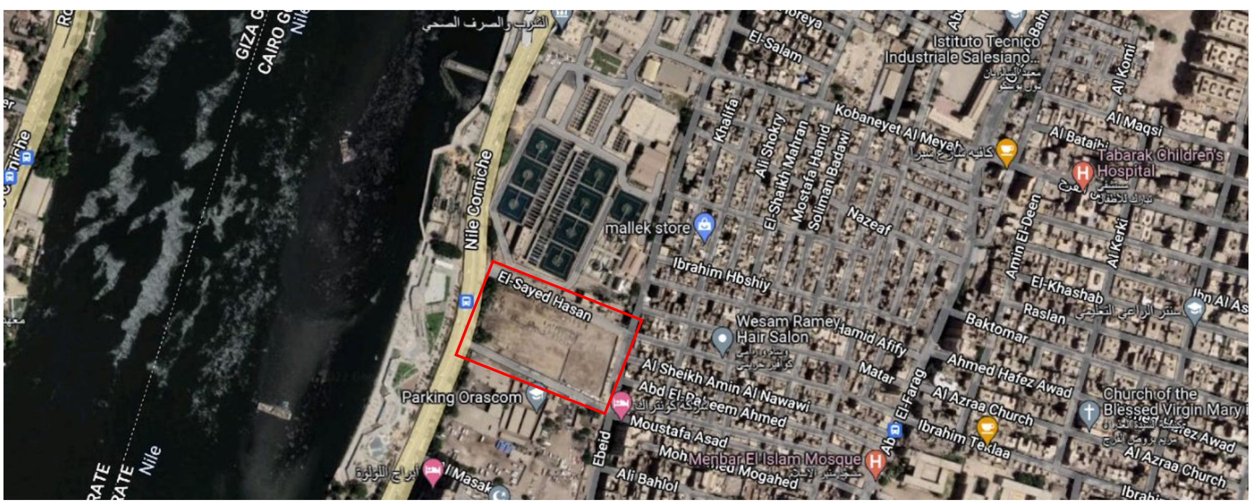


Figure 20: Aerial view of Rod Al Farag in relationship to the Nile River


Figure 21: View from the overlooking the street traffic, surrounding greenery, and the view of the Nile River.

Site 3: Al Marg

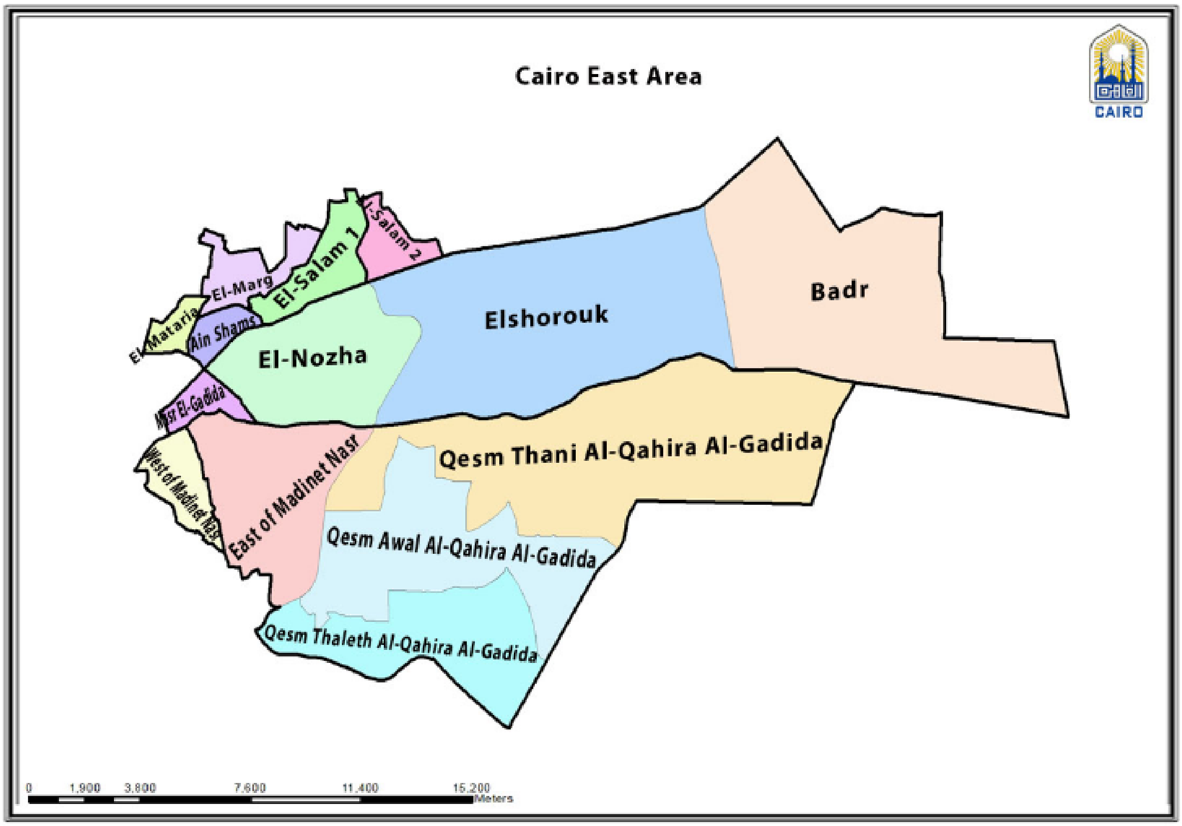


Figure 22: East area of Cairo showing the location of Al Marg.

Al Marg is located east of Cairo, is it 611,000 square feet with a population of over 800,000 people that produce over 15,000 tons of waste per day. This area around the winter time is considered nice weather but for the citizens it is too cold for them but it can also get very warm at some points during the season. The surrounding context is a lot of green space but mainly residential buildings. There are schools in the area that have good education with a wide variety of programs. One can also find many shops in the area and other small business. Although this area is considered crowded and there is not much living space. The citizens here make about $138 per year during the year 2021. In Egyptian Pounds this translates to about 3,312 Egyptian Pounds per year.

Figure 23: Aerial view of the overall site located in Al Marg.


Figure 24: View of the site and the surrounding residential buildings in the background.

Site 4: Al Marg - Nile Location

This site is similar to site number three, but it is closer to the Nile River. It is still considered east of Cairo. The size is amount 1,170,000 square feet. This site is surrounded by commercial buildings which include clothing stores, gas stations, cafes, and restaurants. Other buildings like mosques and schools are also in the area. This site is different from the previous one because it has a view of the Nile River. The citizens in the area still make about the same amount of money per year and the area is still very crowded but it has less residential spaces here and more commercial.

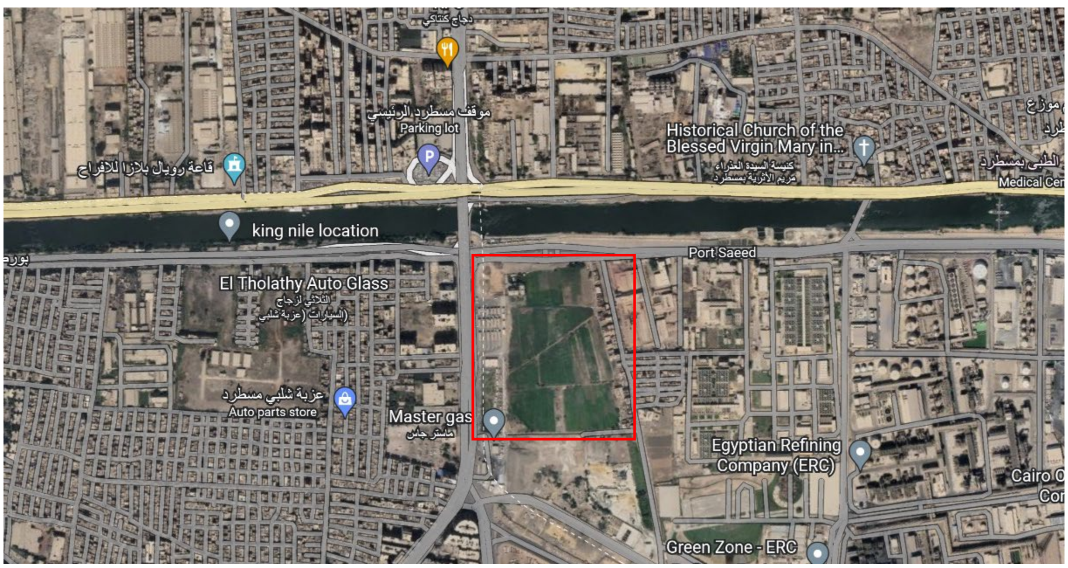


Figure 25: Aerial view of the overall site showing its relation to the Nile River and its surrounding commercial context.

Site 5: Mansheya Nasir "Garbage City"

Mansheya Nasir is now known as the Garbage City, it is located on the outside skirts of Cairo, specifically east of Cairo. It is about 15 miles from the center of Cairo and the Nile River. The site is about 13.8 acres large. The site is surrounded by commercial stores, fast food shops, a large underground cave church, mosques, and small green spaces. There are no residential buildings around the site which is needed because of the smells and sounds coming from the facility. The Zabaleen (garbage people) all live in Mansheya Nasir, and they have easy access to this site.

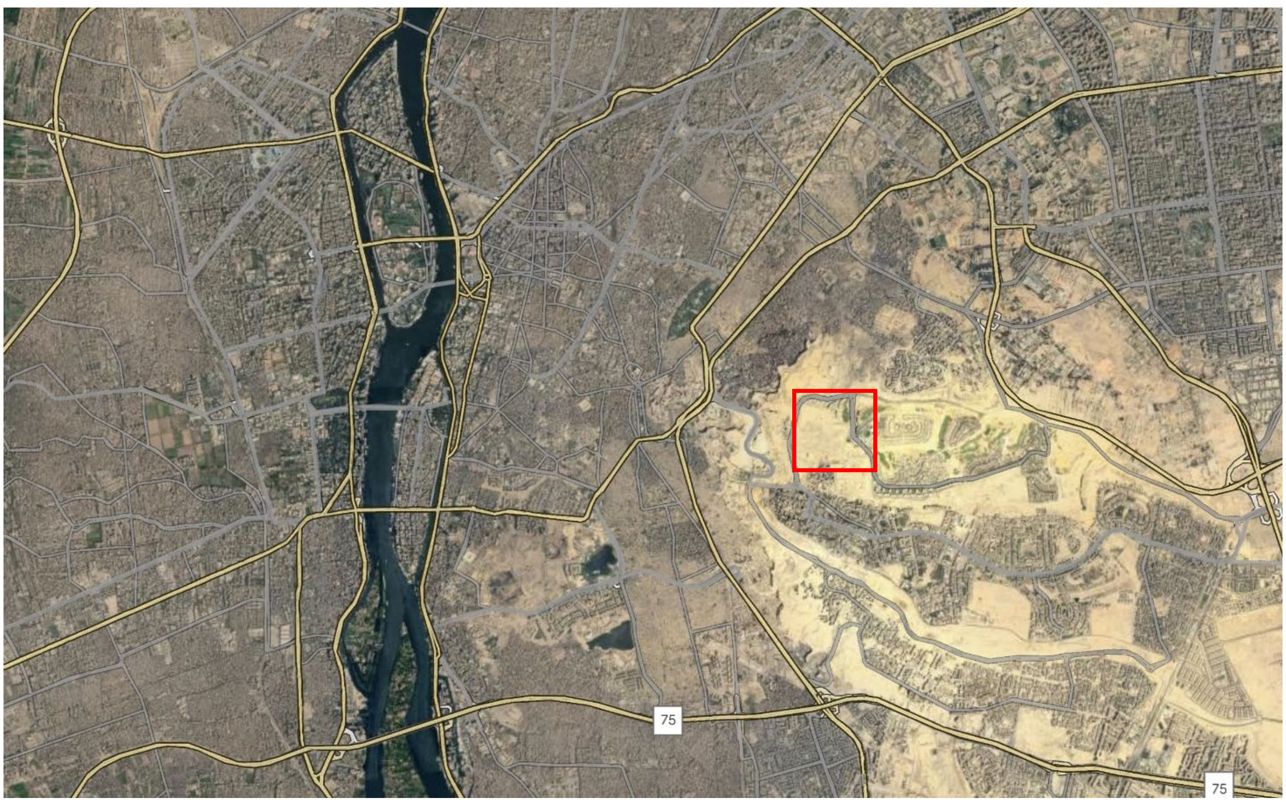


Figure 26: Aerial view of the overall site in relation to the Nile River and Cairo.

Selecting Site 5 Mansheya Nasir (Garbage City)

When choosing the right site for a waste to energy facility, size makes a difference because the average waste to energy facility is about 400,000-500,000 square feet. After examining the five potential sites, site five is over 500,000 square feet which is necessary due to the exterior components of this design. Some exterior components include xeriscaping or an outdoor park. This site is also very easily accessible by the Zabaleen (garbage people) so instead of the Zabaleen bringing the garbage to their district they can now bring it to the newly selected site.

SELECTED SITE

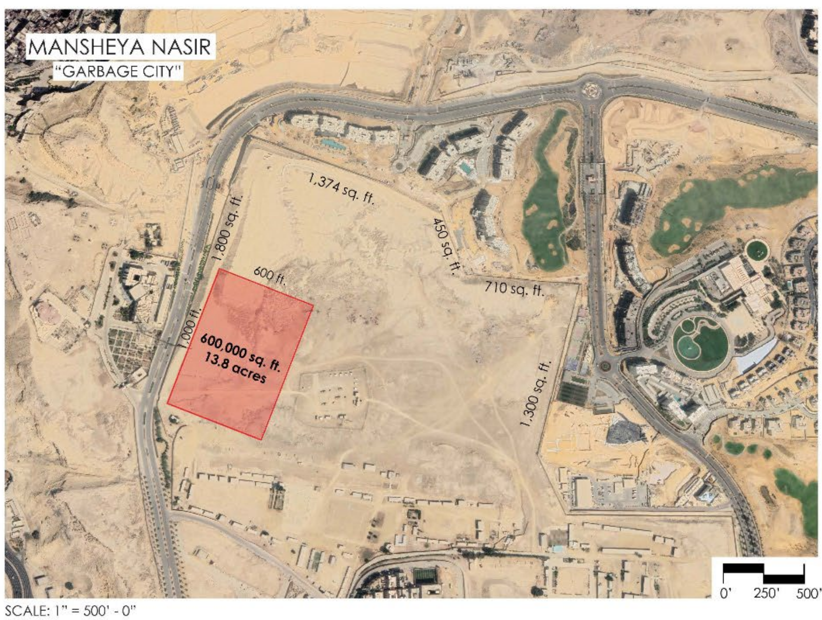


Figure 27: An aerial view representing Mansheya Nasir in relation to the selected site. Also, the size of the overall site.

Chapter 7: Mansheya Nasir (Garbage City)

Location/Size

Mansheya Nasir is located East of Cairo, just on the outside skirts of Cairo. The overall site, as mentioned earlier, is 13.8 acres. A large site is necessary for this thesis due to the size of a waste to energy facility. A waste to energy facility can vary from sizes but based off the precedent analysis they can range from 400,000-500,000 square feet. An educational component will be added as well to this facility which means it will be larger than the average size. Also, a new sorting facility will be added to the site as well for the Zabaleen (garbage people) to do all their sorting in a cleaner and safer environment. Lastly, having a large site is necessary because of the exterior landscaping components that will be included within this thesis, like xeriscaping. The overall location of the site is surrounded by commercial buildings, this is important because of the fumes that come from waste to energy facility. It is better for it to be isolated away from residential buildings. In this case the energy that is being generated will be used to give back to the surrounding community as well.

SERIES OF MAPS

Figure 28: A series of maps showing where Mansheya Nasir and the selected site is in relation to Cairo and other surrounding districts.

Site Analysis

The site is 600 square feet by 1,000 square feet. Located near the district, Mansheya Nasir and commercial shops which include fast-food, photography studios, a large underground cave church, and small green spaces. There are three main roads that border the site, Al Moqatem Road, Uptown Cairo Road, and Street 33.

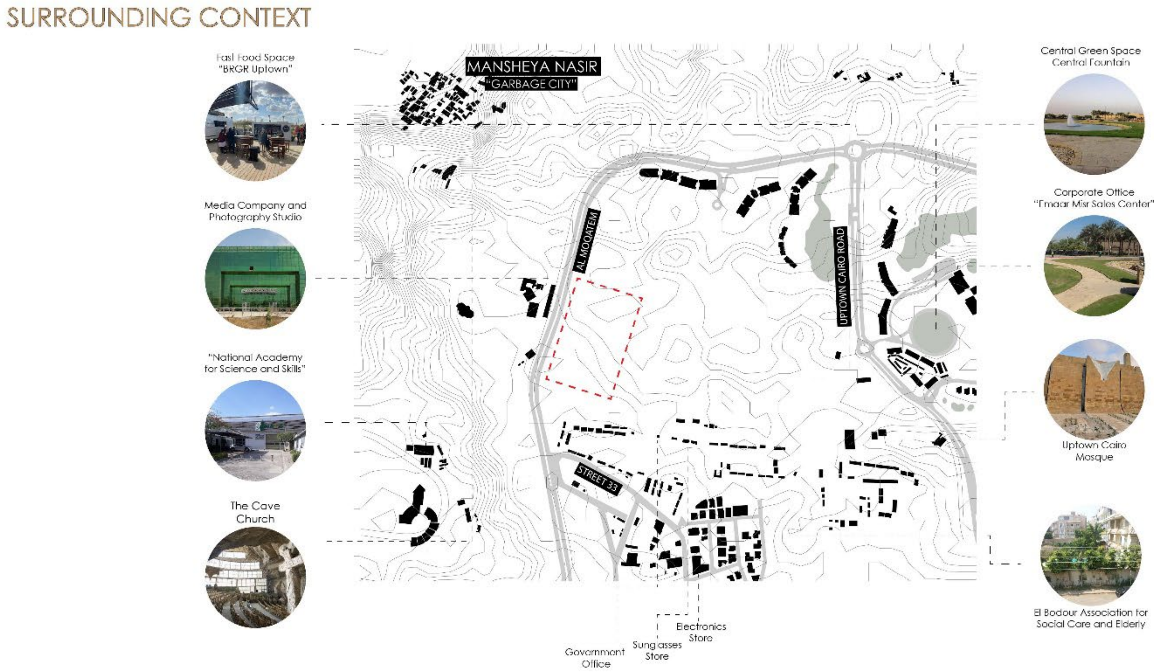
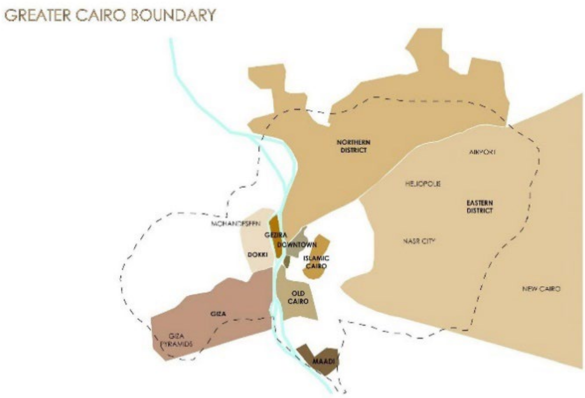


Figure 29: A surrounding context illustration to show the surrounding context of the selected site.

The site is also very accessible by bus, metro, and car. The closest bus stop is only a half mile away. Al Moqatem Road is the main road that will be used for everyone to access the site whether it is by car or by walking. Mansheya Nasir is a district of the Greater Cairo boundary.



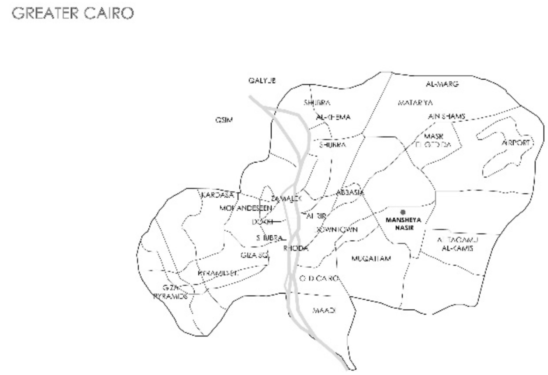


Figure 30 (left) The Greater Cairo boundary. Figure 31 (right) The districts within the Greater Cairo Boundary

There are over 270,000 people who all play a role in the waste to energy process. There is a good combination of male and female, 48% are females and 52% are males. Although Mansheya Nasir is considered the garbage city it still has all the same characteristics that a normal district or city would have. This includes schools, hospitals, apartment complexes, and more. The site has a lot of topography and underneath all this topography is a large cave church.

SITE DEMOGRAPHICS

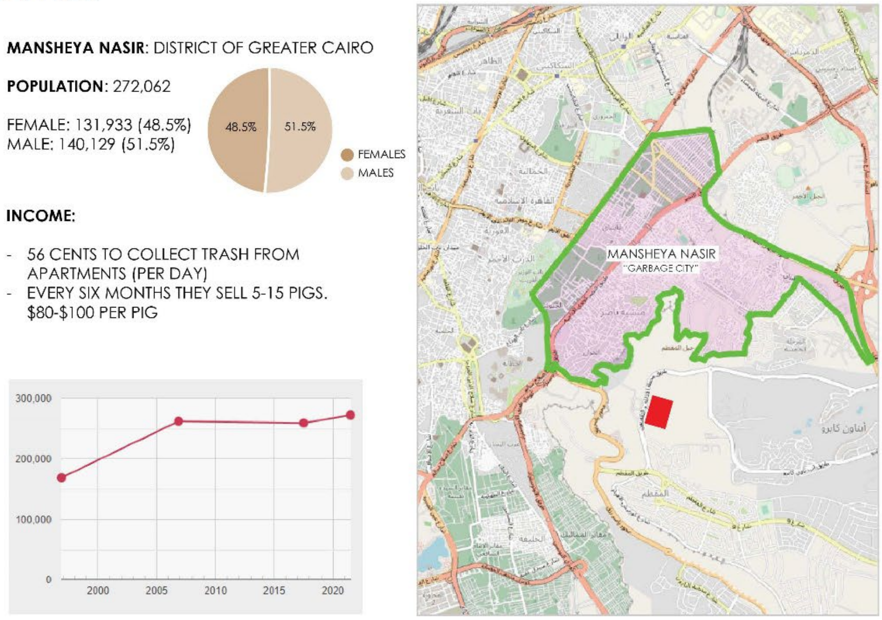


Figure 32: The site demograhics of the selected site and Mansheya Nasir.

Chapter 8: Program

Waste to Energy Facility

Process

Waste to Energy facilities use trash as fuel for generating power/electricity. Other power plants might use coal, oil, or natural gas. [66] The previous chapters have explained the process of how a waste to energy faiclity functions and the different steps it goes through to produce electricity. Keeping in mind that once the trash trucks bring in the trah they are dumped into a pit and goes through the sorting process. From there it then goes into the combustion chamber to burn the wste and that “burning fuel heats water into steam that drives a turbine to create electricity.” [67] This process can reduce a communitys landfill significantly, it can reduce it by up to 90 percent. [68] Figue 32 is

[66] “Waste-to-Energy: How It Works,” *Deltaway*, last modified August 5, 2018, accessed December 13, 2022, https://deltawayenergy.com/2018/08/waste-to-energy-how-it-works/
[67] *Deltaway*, 2018
[68] *Deltaway*, 2018

another representation of the oveall process, one can also reference figure 8 that is shown above in chapter three.

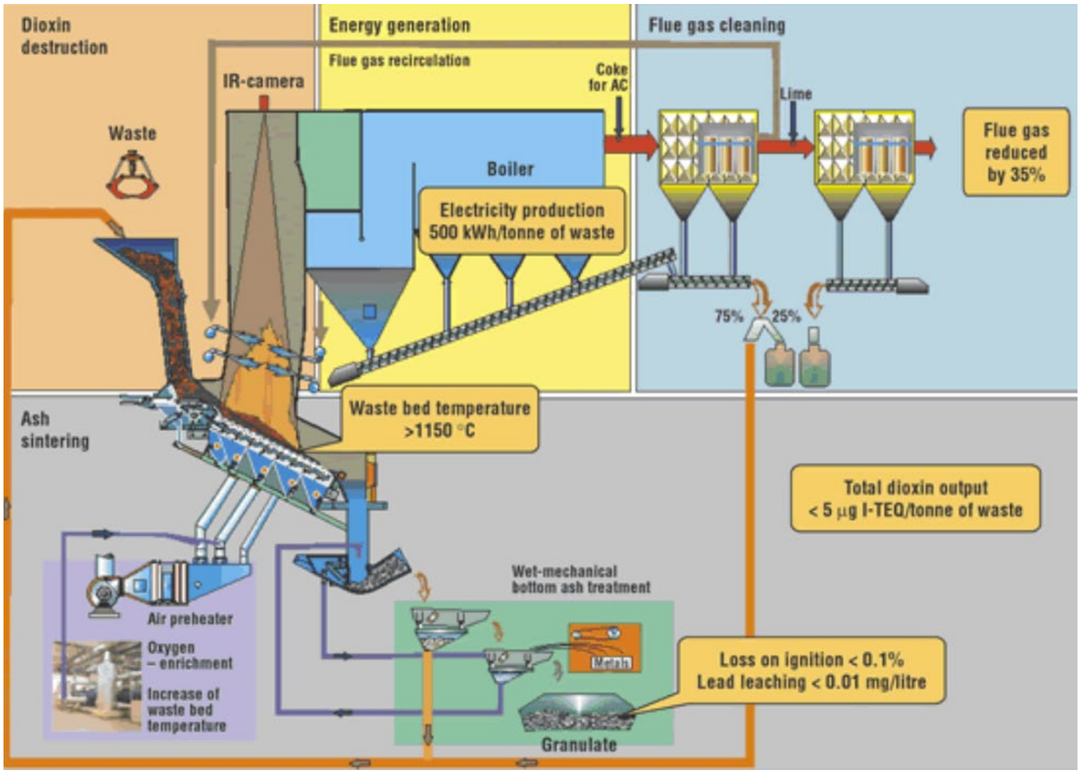


Figure 33: Overall process of a waste-to-energy facility.

Layout (Amager Bakke)

After referencing and studying other waste-to-energy facilities and plants around the world, one that stuck with this thesis specifically was the Amager Bakke plant located in Copenhagen, not only because of its overall function but because of its landscaping and exterior components. The energy plant has a park on the roof level enabling skiing and other recreational facilities.[69] The sections in figures 33 and 34 show an overall idea of how a waste to energy facility is laid out vertically. There is a simplified section and then one that is in much more detail.

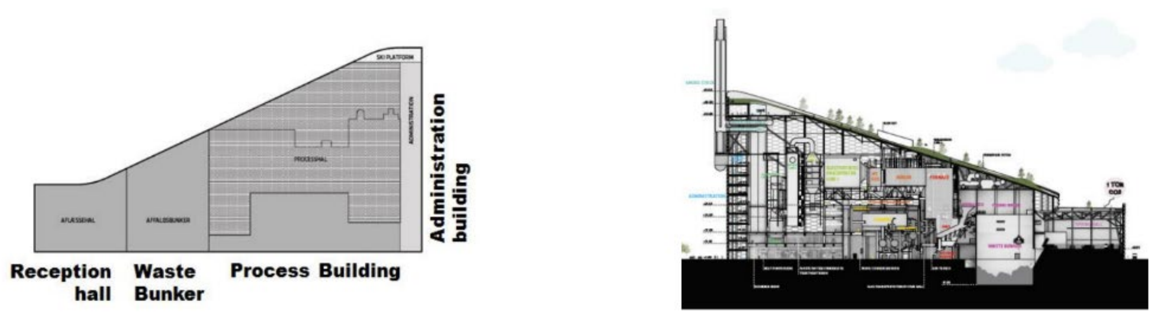


Figure 34: Sections of Amager Bakke showing the vertical connection between the spaces.

[69] Peter Nordestgaard and Casper Arndt, "Amager Bakke: A Steel Building with the Design," *Wiley Online Library*, last modified September 16, 2019, accessed December 13, 2022, https://onlinelibrary.wiley.com/doi/pdf/10.1002/cepa.1156, 151.

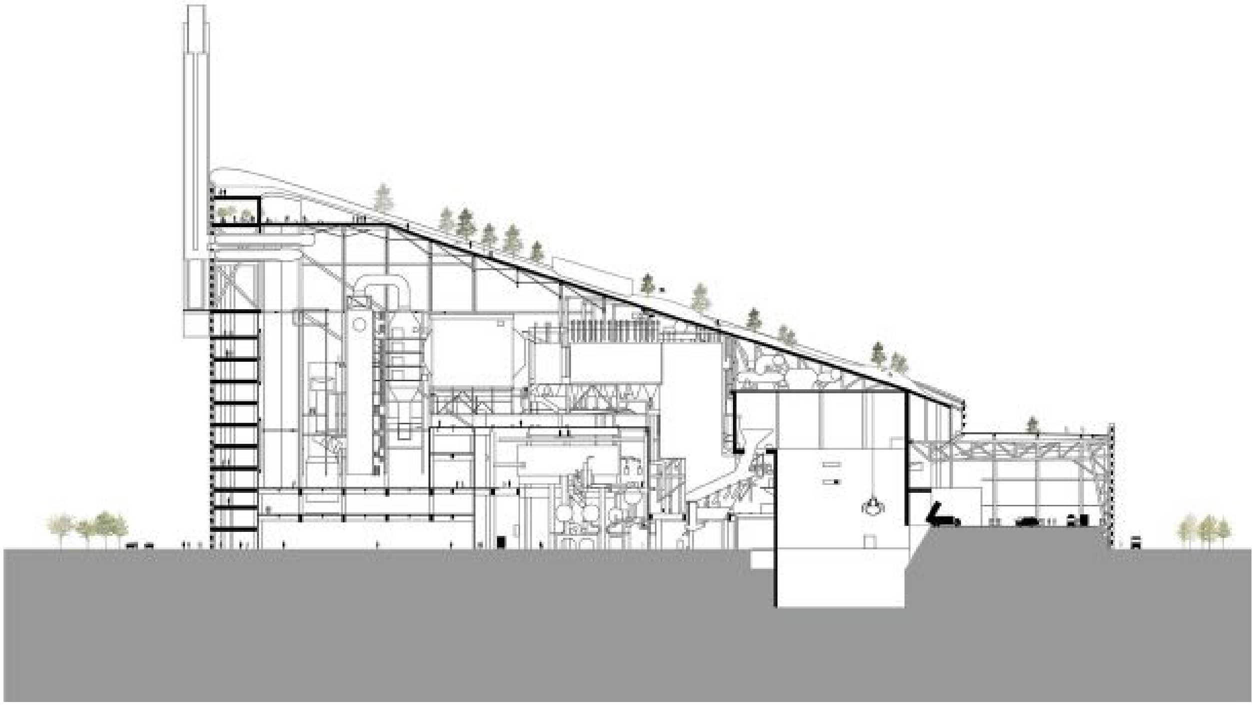


Figure 35: Blown up section of Amager Bakke, representing the interior functions.

Amager Bakke has a large sloping roof for its visiotrs to utilize. The intended program within this waste to energy plant includes all the necessary rooms and functions which are, smoke stack, waste bunker, feeding hooper, hopper deck, crate, furnance, boiler, turbines, heat pumps, condensor room, waste control room, furnance area, condensor and pump room, heat pump room, and truck ramp/access. Other programmatic components that are included are offices and other outdoor recreational facilities. Figure 35 shows the layout of one of the existing floors while figure 36 is an exploded axonometric representing all the levels within the Amager Bakke. Lastly, figure 37 is the roof plan for this precedent.

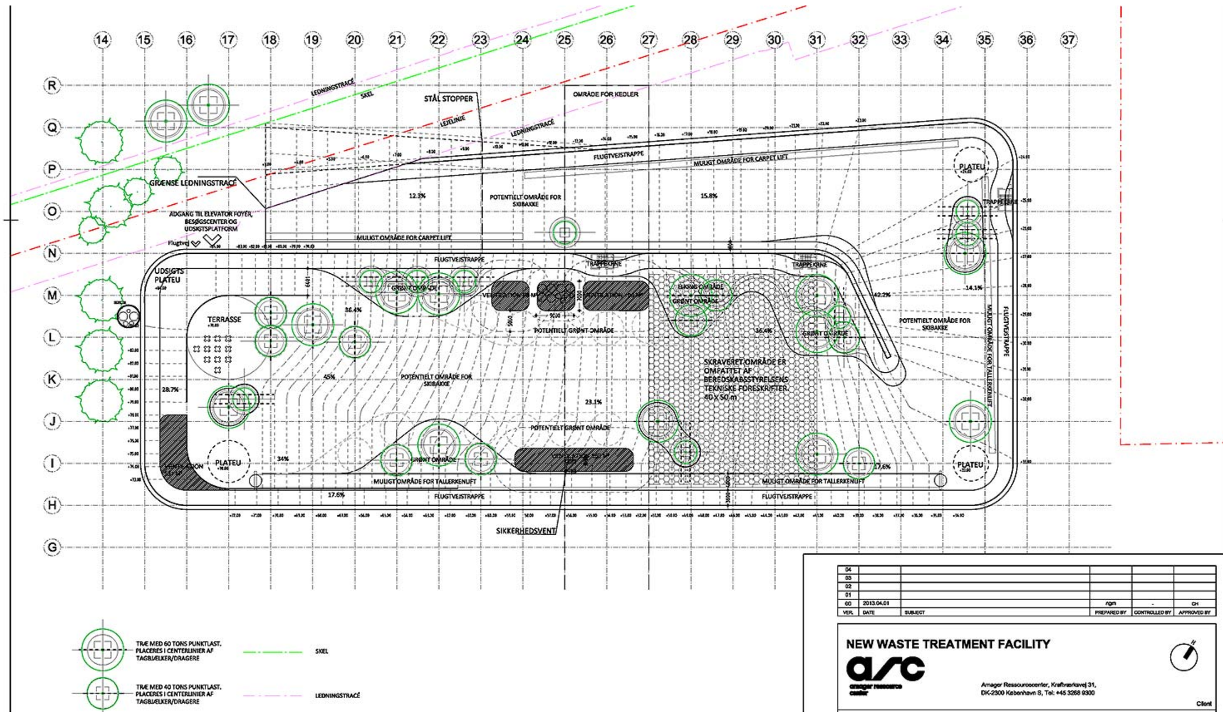


Figure 36: Floor Plan of Amager Bakke

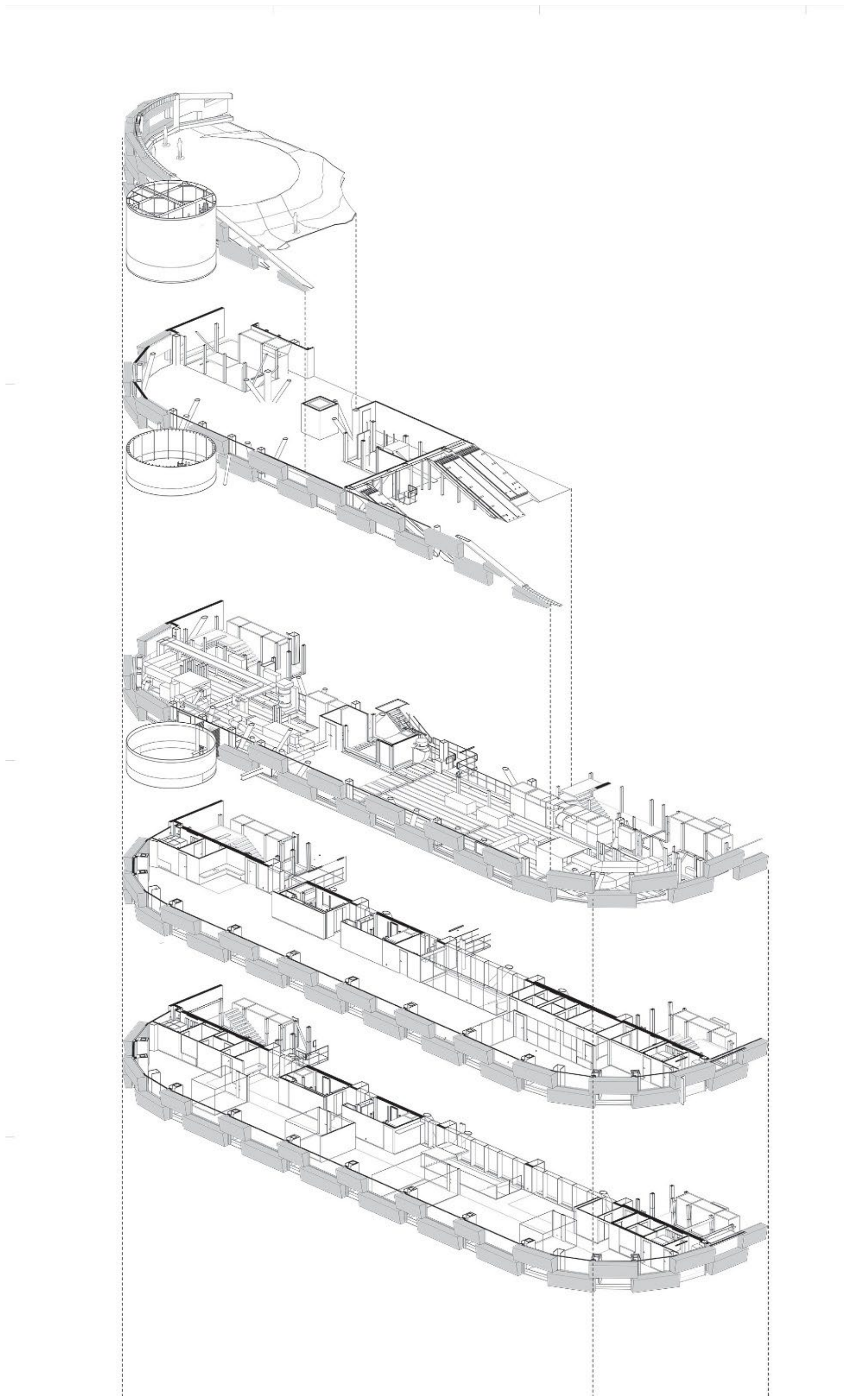


Figure 37: Exploded Axonometric of Amager Bakke

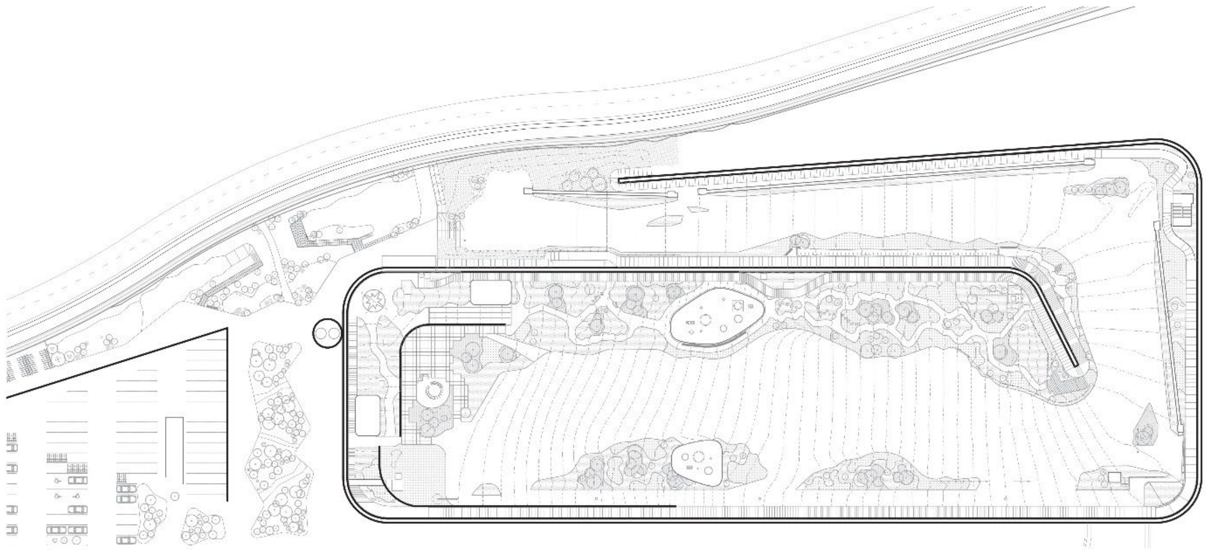


Figure 38: Roof Plan of Amager Bakke

Program Tabulation

After analyzing precedents and looking into the process of a waste to energy facility, there were many factors that went into picking which program made the most sense to have a functional facility. A program tabulation was designed in order to get the exact square footages, grossing factor, total square footage, and net square footage. The table below breaks down the program required for a waste to energy facility.

WtE PROGRAM:	AREA (SQ.FT.):
Weight Station	11,800
Storage Pit	13,500
Control Room	600
Furnace	14,400
Economizer	14,500
Flue Gas Filtering	32,000
Turbine Room	3,900
Generator Room	3,900
Sampling Station	2,000
Emissions Control Room	2,000
Smokestack	2,500
Ash Conveyor Belt	8,000
Ash + Metal Processing Plant	110,000
Operation	8,000
Maintenance	8,000
Office Building Parking + Storage	1,000
Tipping Floor	11,390
Waste Bunker	21,000
Boiler Room	7,950
Generator	500
ID-Fan Structure	3,400
Net Sq. Feet:	280,340 Sq. Feet
Grossing Factor:	1.07

Figure 39: Program tabulation for the waste-to-energy facility including gross and net square footage and grossing factor.

This program was based on the amount of waste being produced in the selected area, each room square footage is equipped to handle about 25,000 tons per day which is more than needed. The selected site area, the citizens produce about 15,000 tons per day, and this can rapidly grow. Making sure that this waste to energy facility can serve the community for years in advance. Figure 38 breaks down the program and its square footages none of which include the educational component. The following program tabulation will break down the educational component which are the interior public features along with all outdoor features. The last portion will also include the necessary building services.

ADDITIONAL PROGRAM:	AREA (SQ. Ft.):
Outdoor Features:	
Classroom Courtyard	5,200
Office Courtyard	1,100
Interior Features:	
Offices	300 x 10
Classrooms	1,300 x 8
Lobby	1,700
Cafe	2,740
Observation Deck	10,000
Break Room / Kitchen	330 x 2
Office Bathrooms	220 x 2
Atrium	5,800
Souvenir Store	1,500
Exhibit Viewing	2,500
Exhibit Walk	10,000
Bathroom	510 x 2
Bathroom	275 x 2
Sorting Station	8,100
Sorting Facility Bathroom/Showers	1,150 x 2
Sorting Facility Break Room/Kitchen	1,330
Net Sq. Feet:	68,340
Building Total:	348,680

Figure 40: Additional program tabulation.

Chapter 9: Transitions

The thesis has changed tremendously over the past year. Originally this thesis did not include the Zabaleen as much in the beginning but now this facility is really being designed as an assistance to them to help them sort their waste more efficiently. Not only will this now be more efficient for them, but it will also keep their district clean, and they will be in a safer environment while sorting through the waste. This thesis was also going to include a large community garden to utilize organic waste for composting since 55% of the waste produced is organic. But now after realizing that the Zabaleen's main source of income was the selling of their pigs, and they use the organic waste to feed their pigs, this changed since we did not want to mess with their income. The thesis was designed to help the Zabaleen while not having their income be affected. Another thing that changed over time was the addition of the sorting facility. Before the thesis was designed to only have the waste to energy facility with an educational program added to it but after seeing some of the conditions that the Zabaleen have to work in, the thesis later added a sorting facility to provide a cleaner and safer way for the Zabaleen to sort through the waste. Over time a lot more research was done to include the Zabaleen in the thesis as long as making sure the program of the facility fit the needs of the citizens.

Chapter 10: Design Approach

Selected Site

The design started with choosing a site that would be in close relation with not only the Zabaleen but also the citizens of Cairo as well. Mansheya Nasir is approximately 15 miles from Cairo and the overall selected site is only a 15-minute drive from the garbage city. The size of the site was a little less than 14 acres, estimated to be 13.8 acres large. Although Mansheya Nasir is considered the garbage city like mentioned before something to keep in mind is that it still has a lot of the same characteristics as a normal city or district would. Meaning it includes schools, churches, apartment complexes, hospitals, and more. Around the site there are mosques, corporate offices, fast food places, commercial stores, and a huge underground cave church. There are three main roads that border the site, Al Moqatem Road is the main road that will be used to access the site. The site is also accessible by bus, train, and metro. The closest bus stop is a half mile away.

Design Introduction and Background

Egypt is known for its rich historical elements like the pyramids, sphinx, the Nile River, and much more. It is located on the African continent. Bordered by the Mediterranean Sea and the Red Sea. Adjacent countries are Libya, Sudan, and Saudi Arabia. This thesis is located in Cairo, the capital of Egypt. It is the biggest city in Egypt followed by Alexandria. The Nile River runs right through Egypt and through Cairo.

Figure 41: Map locating Egypt and Cairo and showing the surrounding countries.

As of today, Egypt's population has reached 112 million people and is estimated to have 200 million people by the year 2080. After Nigeria and Ethiopia, Egypt is the most populated country on the African continent. Alexandria and Giza are the second and third largest cities in Egypt. The median age in Egypt on average is very young.

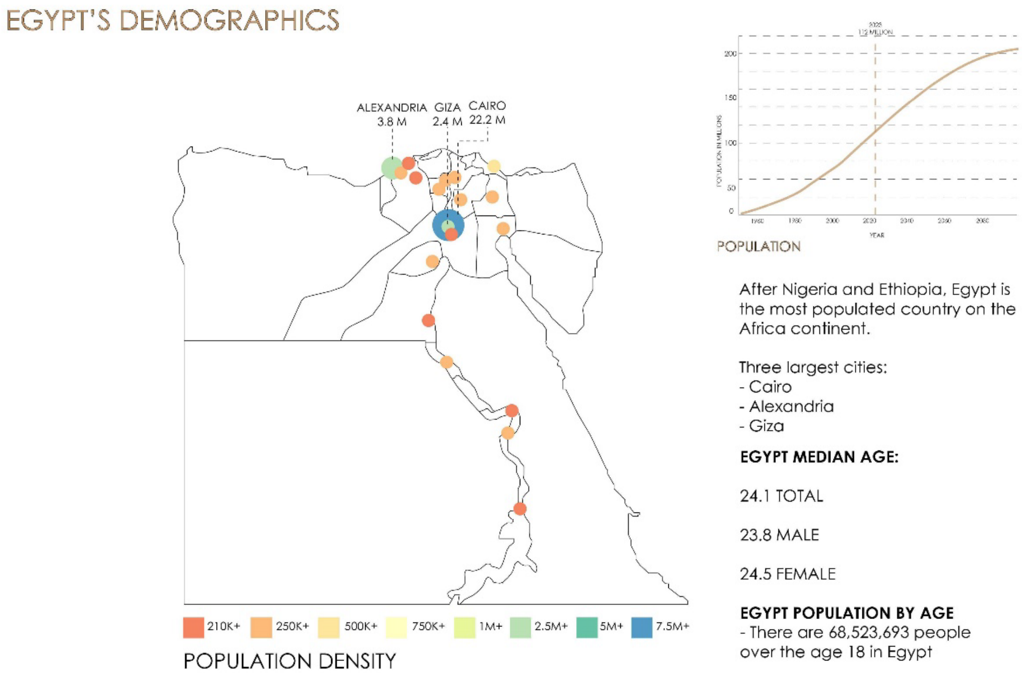


Figure 42: A diagram representing the population and its density in Egypt through the years.

Within Egypt there is the Greater Cairo Boundary that is made up of many districts. Here are the districts that fall into that boundary, specifically pointing out Mansheya Nasir, which is now referred to as the “Garbage City.” Anyone living in this district plays a role in Cairo’s waste management process. I will talk more about this throughout the presentation. Looking into Cairo, before the year 2000 the population was less than 10 million people as of today it has reached 22.2 million, nearly doubled, and is estimated to be 25.5 million people by 2030. Cairo continues to grow, and it grows at a 1.99% rate. The main language in Cairo is Arabic but others speak French as well. There is a large young population in Cairo. About 90% of the population practices the Muslim religion and only 10% of them are Christians or Coptic Christians.

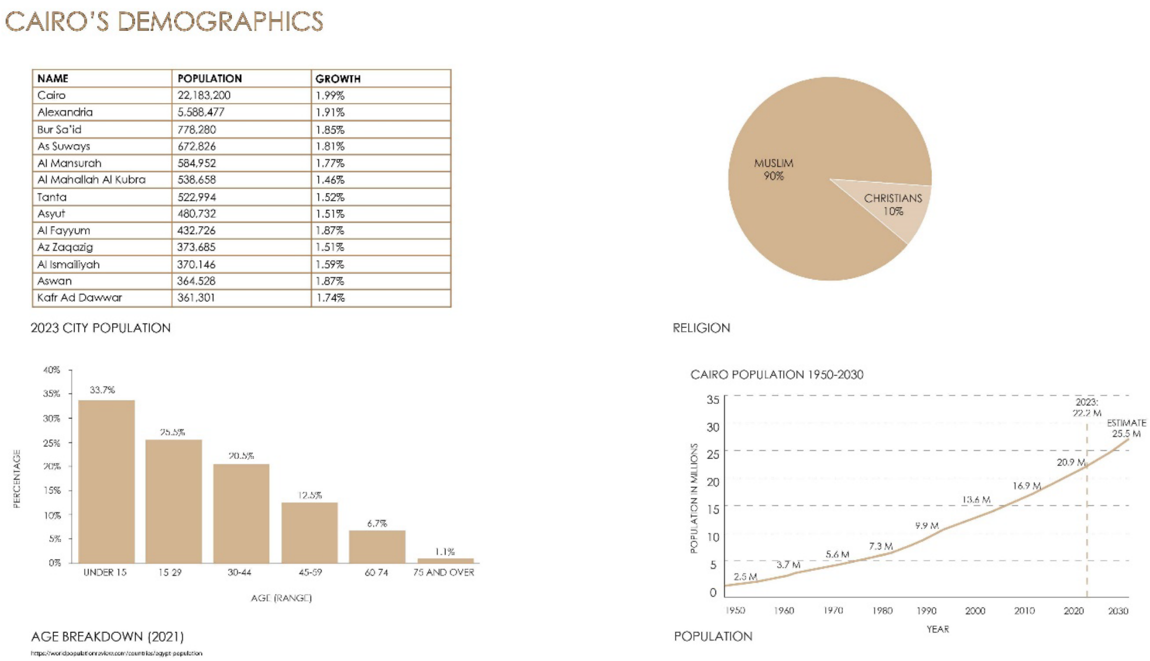


Figure 43: Representing the population growth in Cairo.

So, what is the problem here? Currently, Egypt produces 90 million tons of solid waste at a rate of 55,000 tons per day. Cairo alone produces 15,000 tons of garbage daily. Comparing Cairo to New York, the average person in New York produces about 3 pounds of garbage per day while a citizen in Cairo produces a little less, 2.42 pounds.

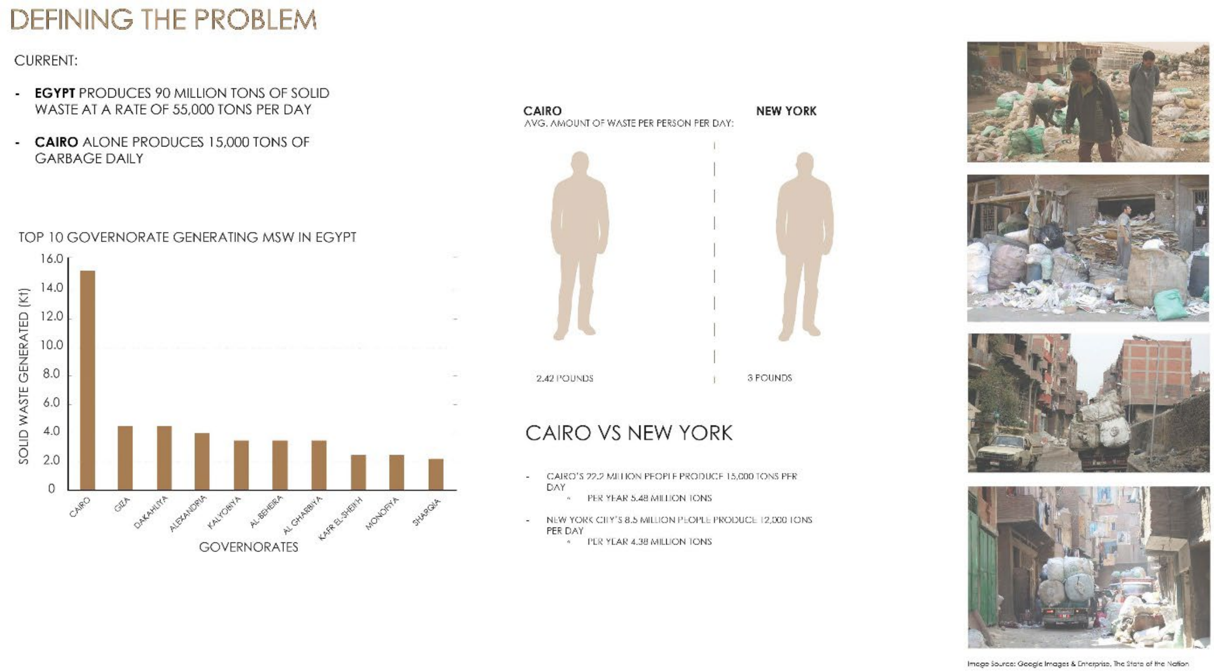


Figure 44: Defining the problem and showing how much waste is being produced in Egypt and Cairo and comparing it to New York.

There are different types of municipal solid waste in Cairo, 55% of it is organic, 16% is plastics, 14% is paper/cardboard, and 2.5% is glass. There is more organic waste than any other type of waste. Organic waste can be used to educate the citizens on composting and agriculture through an educational portion of the facility.

AMOUNT/TYPE OF WASTE

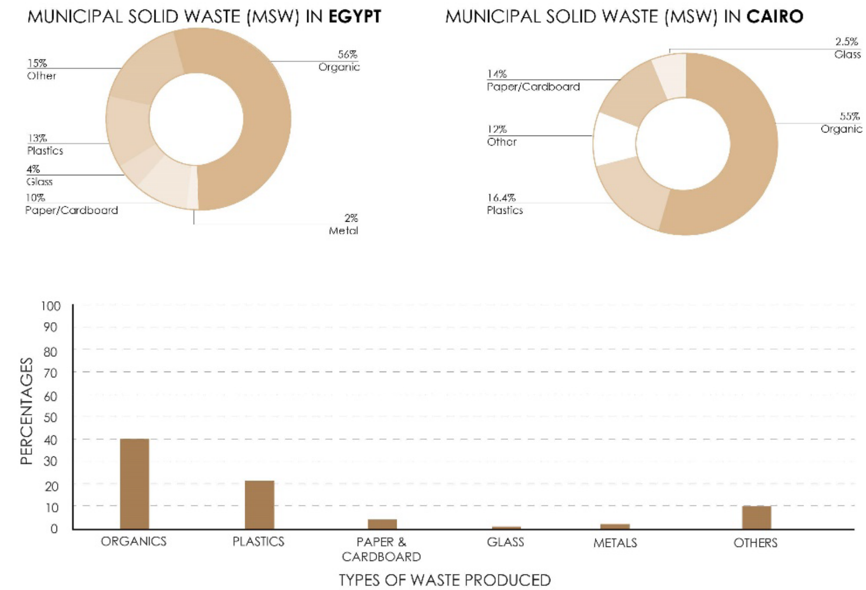


Figure 45: The types of municipal solid waste in Egypt and Cairo.

What does all this mean? Is Cairo drowning in waste? No! On the outside skirts of Cairo lies a district named Manshetya Nasir, where a group of people who have named themselves the “Zabaleens” which translates to the garbage people have roamed the streets of Cairo and picked up the trash on the streets. They then bring it back to Manshetya Nasir and do all the functions of a waste-to-energy facility by hand which includes the sorting and the burning of waste. The government has tried to handle the waste by pulling out loans and grants from many organizations and agencies to help pay the private sector, those all fell through eventually leaving the Zabaleens to collect all the waste in Cairo.

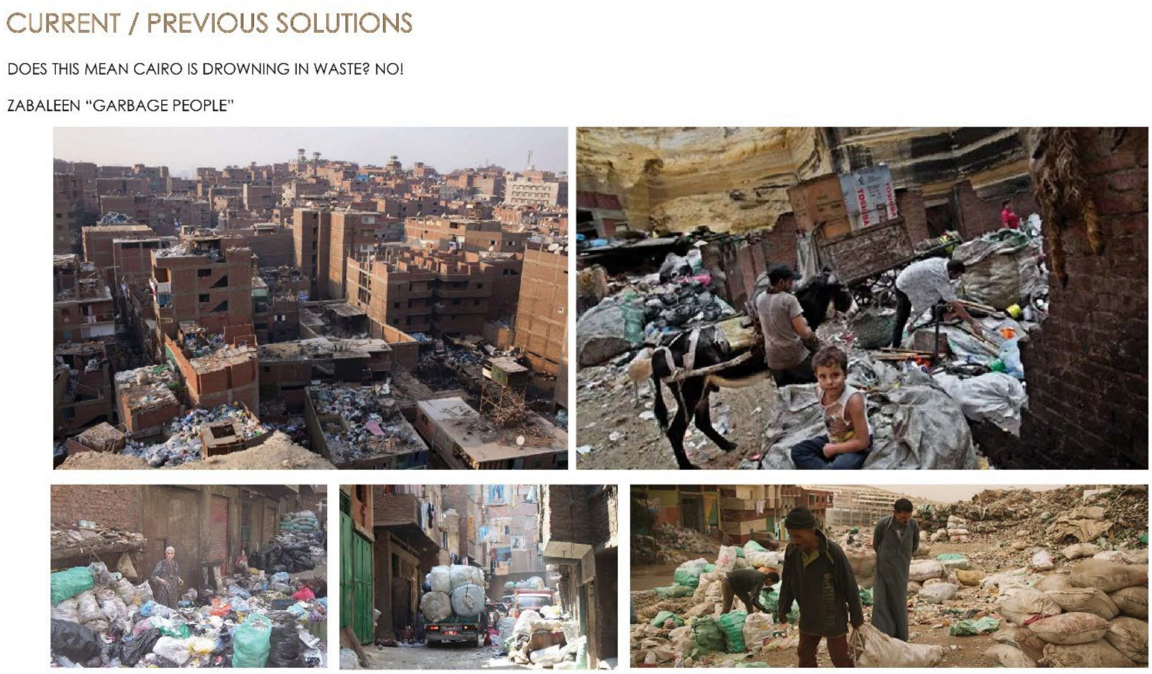


Figure 46: Images showing the conditions of Mansheya Nasir.

This thesis is proposing to engage and educate the community about the waste, while still having the Zabaleens continue to do their job which is to collect the trash from the streets of Cairo but instead of bringing it back to their district, Mansheyta Nasir, they will now bring it back to the facility to go through the sorting process. The organic waste will still be fed to their pigs to keep their income steady. But now this will keep trash out of their district, speed up the sorting process, and allow them to continue with their daily jobs and not have their income be affected.

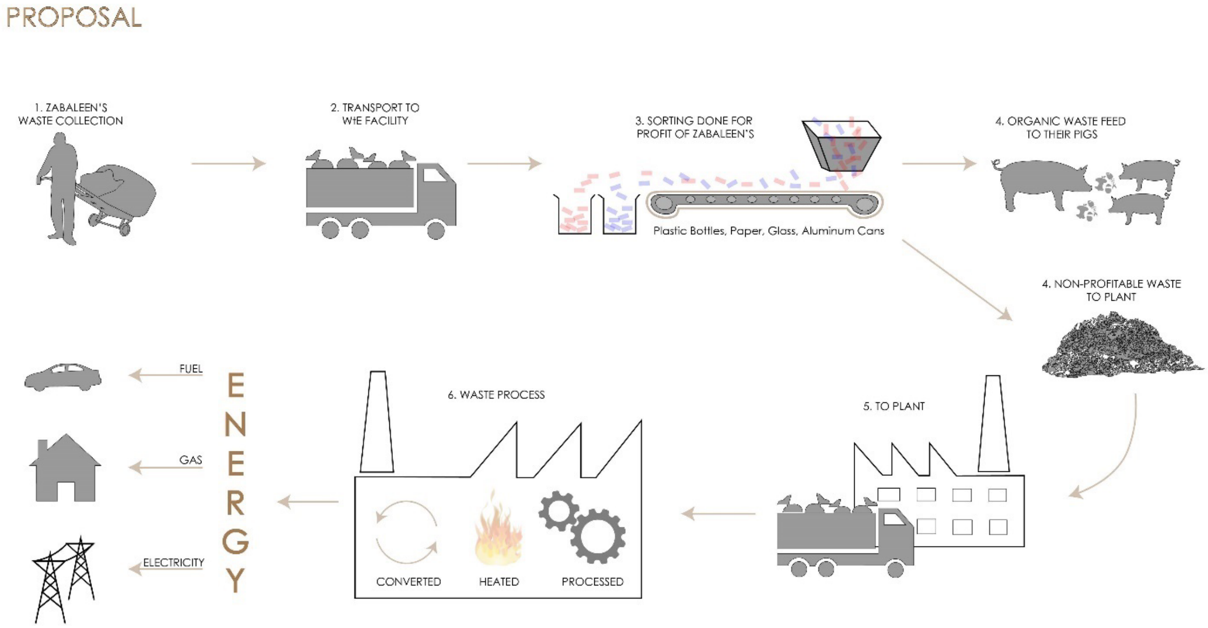


Figure 47: Proposal diagram representing the cycle of how waste will now be produced and handled in Cairo.

This facility will not cause more pollution in Cairo as through the facility a lot of toxins and harsh chemicals are controlled within the facility, so water vapor and clean flue gases are the only things being released into the air.

WASTE-TO-ENERGY PROCESS

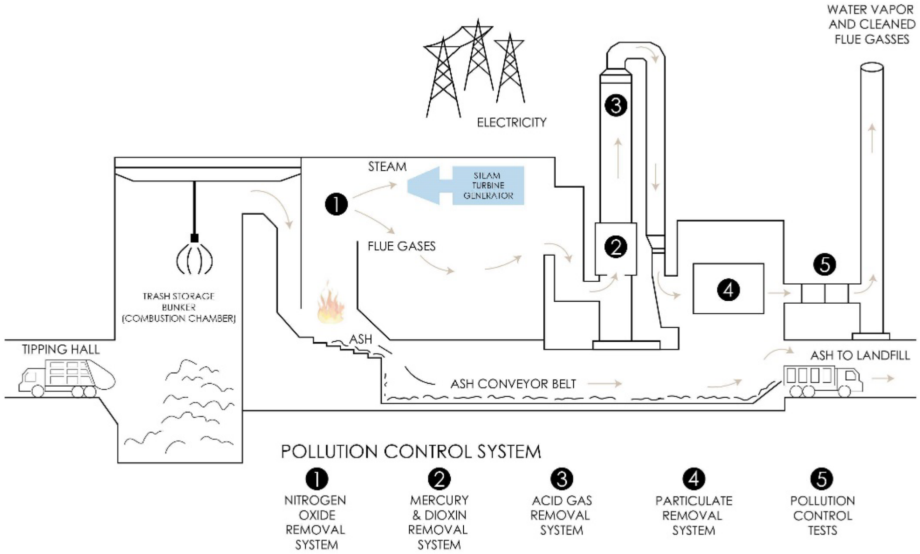


Figure 48: A diagram showing how the pollution is to be controlled within the facility.

Site Approach

Mansheyta Nasir was chosen because it is considered a garbage city, and this is where the Zabaleen live. The selected site is roughly 13.8 acres and about a 15 min drive from Mansheya Nasir. Mansheya Nasir is a district in Greater Cairo, it has a population of over 270,000 people that all have a role in the waste management process. The Zabaleen receive 56 cents to collect trash from apartments per day and make about $100 per pig sold.

SELECTED SITE

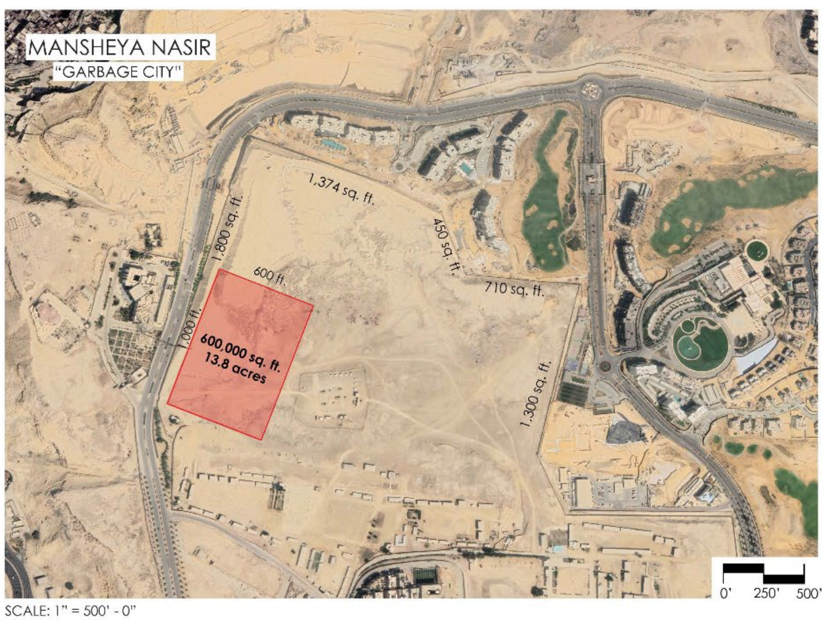


Figure 49: The selected site and its size.

The Zabaleen have really identified a niche in Cairo's infrastructure to capitalize on. As a family effort they collect, transport, sort, and dispose of waste inefficiently by hand. Family members are exposed to harmful waste, bacteria, and possible injury in order to make a living. The new facility takes danger out of the equation. Members would continue collecting and transporting waste, but now they will transport it to their new facility where waste can be sorted and disposed of efficiently and safely while still retaining profit.

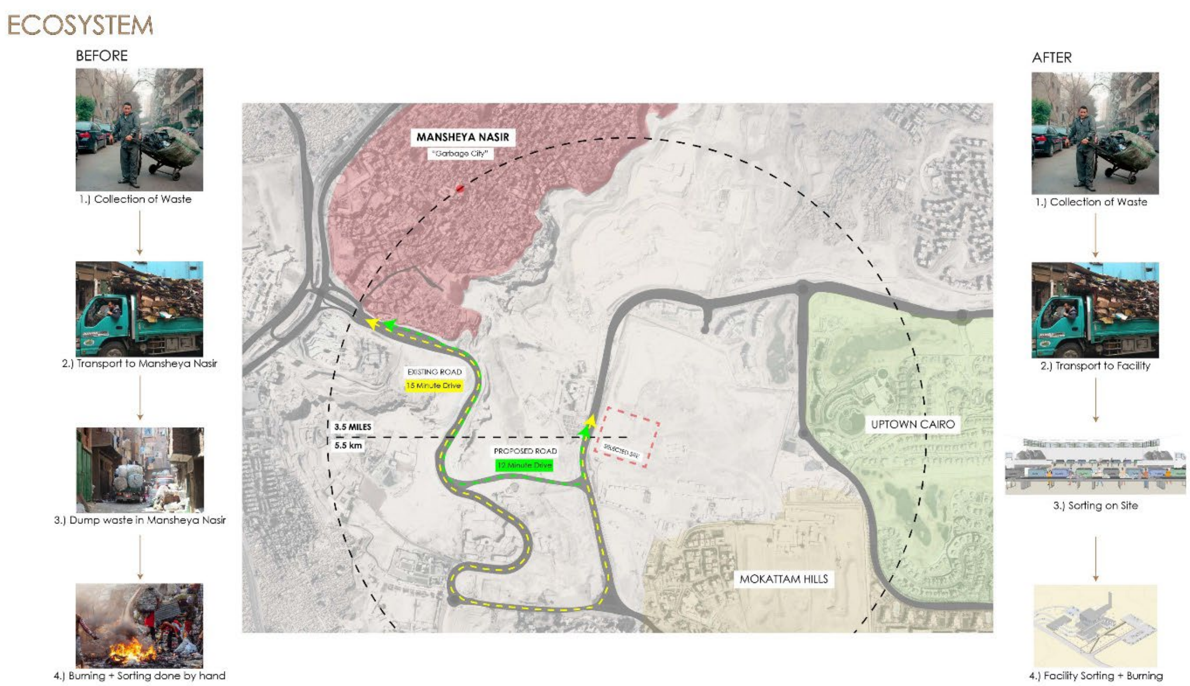


Figure 50: An overall site plan view representing the location of the selected site and its relationship to the surrounding districts along with a before and after of an ecosystem for the Zalableen.

Starting off with the site plan, it shows the different zones which include the sorting facility, waste to energy facility, the public program, xeriscaping/park, and three parking lots. The first parking lot is for overnight trash truck parking, the second parking lot is for bus stops for when there is a field trip to the facility, and the third parking lot is for visitors and workers. The xeriscaping was designed as a park to bring a sense of greenery to a location that is considered a subtropical desert.

Figure 51: A color coded site plan to show the different proposal zones on site.

Program

Diving into the program, it is divided into four categories. First the waste to energy facility, second the education about waste, third the environmental education, and fourth the sorting of valuable waste. Including an educational program into the facility will represent a better way to reuse, reduce, and recycle waste. Environmental education will be used to educate citizens on compositing and agriculture. The sorting of valuable waste will be used by the Zabaleen's to have a cleaner and more efficient environment to sort the waste. The four program categories are laid out throughout the massing of the building. The building is a two-story design that intersects the waste to energy facility with the educational program so while visitors are flowing through the space, they get views of the waste management process as well.

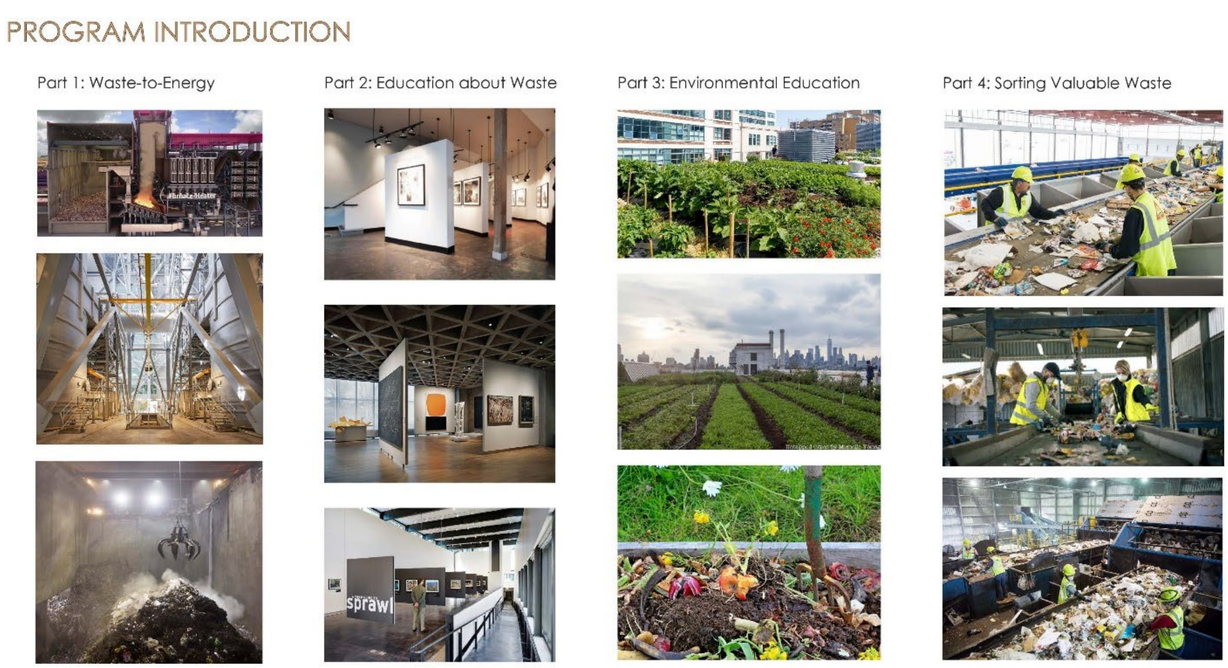


Figure 52: The program is represented in four categories. 1. Waste to Energy 2. Education about waste 3. Environmental Education 4. Sorting of Valuable Waste

Architecture

As mentioned above the building is a two-story design. Starting with the ground floor, it includes a main exhibit walk and seating spaces that give views of the facility and its two main programs which are the tipping hall and the waste bunker. The tipping hall is where the trash trucks come in, tip over, and dump the trash into the waste bunker space where the trash is then sorted. Visitors can learn this process and be able to view it throughout their walk. There are also classrooms at the end of the walk, and these were envisioned as large open spaces that lead to the outdoors and allow visiting students to learn about composting and agriculture.

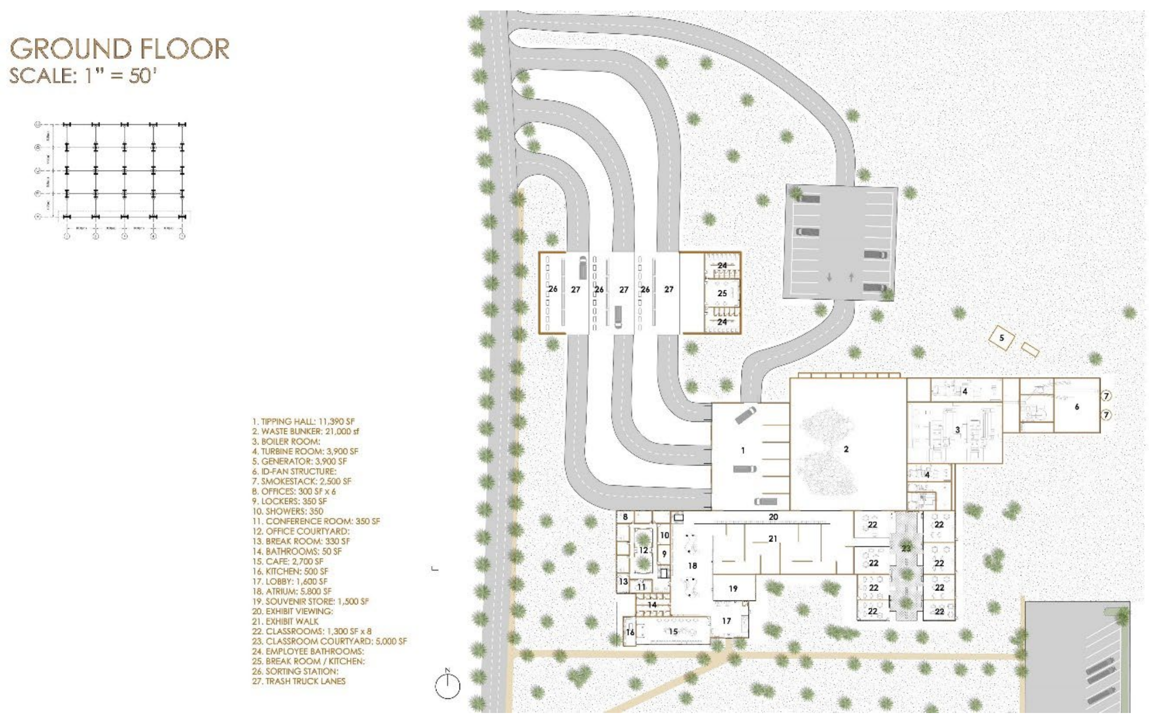


Figure 53: The overall ground floor plan at a 1” = 50’ scale.

The second floor is mainly an observation deck, and it gives visitors a view of the waste bunker, this differs from the ground floor because here you can actually see the crane in action.

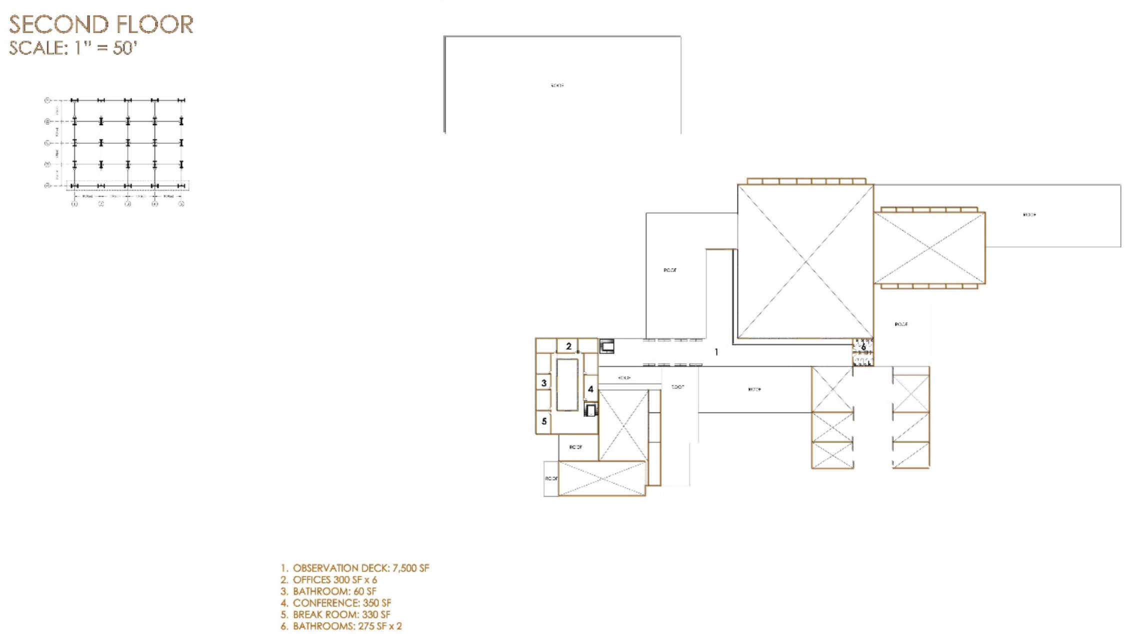


Figure 54: The overall second floor plan at a 1” = 50’ scale.

The facades are designed using limestone brick, a metal panel skin, and glazing. The limestone brick stops at 15 feet to match the surrounding context. Limestone brick is a very common material that is found and used in Cairo’s residential and commercial buildings. The limestone brick wraps around the entire facility. These two sections cut through the main spaces. The west-east section cuts through the tipping hall, exhibit walk, souvenir store, and lobby. The north-south section cuts through the public program which includes the offices for works, the whole exhibit walk, the classrooms, and the classroom courtyard.

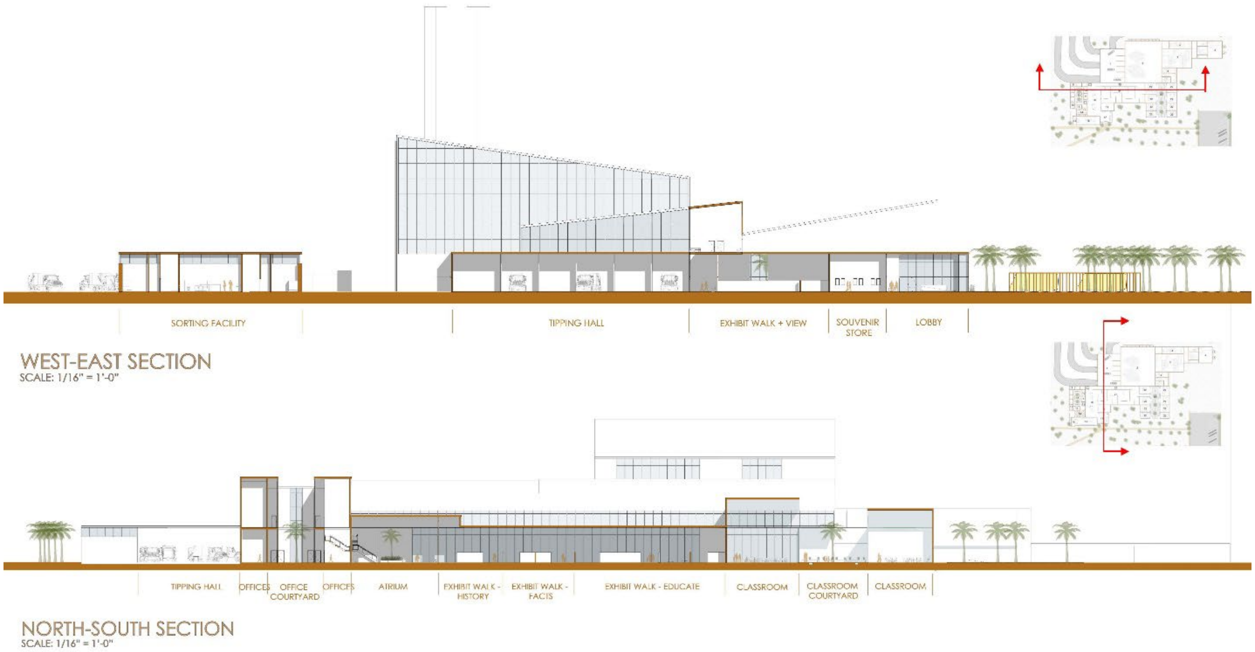


Figure 55: Two main sections, west-east section and a north-south section cutting through some of the main spaces in the building design.

The exhibit walk on the ground floor is broken up into three categories, a historical background of the Zabaleen, a factual space that shows visitors how much waste is being produced, and an educational space that educates visitors on how waste can be beneficial to them.

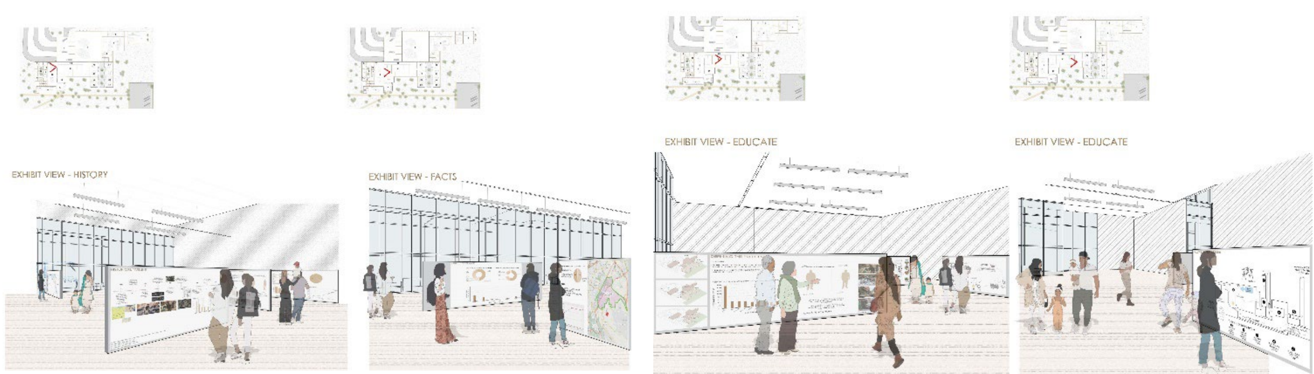


Figure 56: Small vignettes from the ground floor showing the experience through the exhibit walk. The first is history, the second facts, and the third education.

Chapter 11: Conclusion

In conclusion this thesis was designed to provide a space of recreation, educate the citizens of Cairo, propose a new way of viewing waste, and have a cleaner and safer waste management system not only for the Zabaleen but for all of Cairo. This thesis represents a prototype for Cairo, knowing that the propsed design will not be able to handle all the waste that is currently being produced in Cairo but it is a start to show the citizens of Cairo that there is a safer and cleaner way to handle waste.

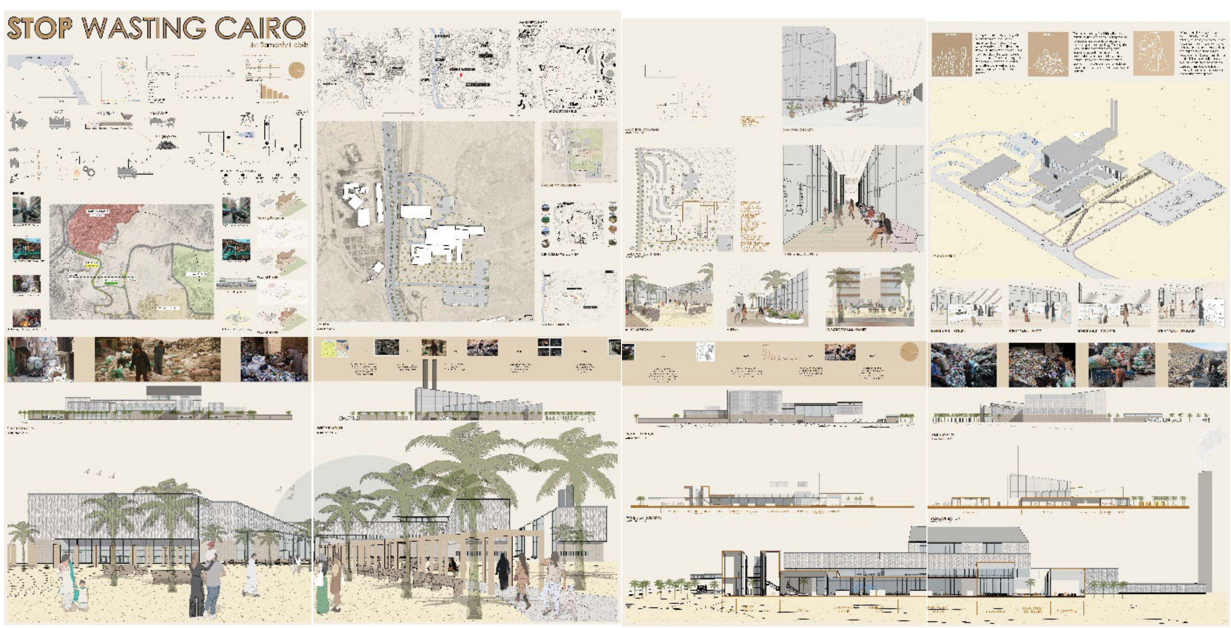


Figure 57: Final four presentation boards.

Figure 58: An overall exterior perspective view of the facility.

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