STRIVING TOWARDS ZERO WASTE THROUGH LANDSCAPE DESIGNS AND PROGRAMS IN U DISTRICT

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ABSTRACT

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This thesis presents a research-based design for Seattle's University District that aims to make the district cleaner, generate less waste, and reduce its ecological footprint. The key strategies proposed are based on an examination of the history and present conditions of the district, as well as future plans for Seattle's solid waste management. The proposed design is also based on five case studies, and a literature review of zero waste cities and the factors that impact waste-related behaviors. The design proposes four types of interventions to make the U District localize its food lifecycle, reduce food waste generation, and divert food waste from landfills. Three sites were chosen as testing sites for these interventions to experiment with their feasibility and effectiveness. Lastly, the thesis suggests potential sites for future expansions of these interventions.

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CHAPTER 1 INTRODUCTION

This chapter explains why I chose to examine waste management in the University District (U District) for my thesis. It also introduces the main research questions, and how the proposed design aims to address those questions.

1.1 Why I chose this topic

My interest in waste-related landscapes started when China banned foreign plastic imports five years ago. At that time, I learned that exporting waste is a common strategy among many developed countries (Zhang, 2020). Developing countries like China in the 1980s, imported solid waste to alleviate the shortage of raw materials (General Office of the State Council of the People's Republic of China [State Office], 2017). However, developing countries often lack technologies or policies to protect their environment from imported waste (Zhang, 2020). Learning about the global waste flow made me interested in waste management.

It was 2019, the last week of class at Penn State University, and the garbage cans in libraries were filled with styrofoam boxes and Starbucks cups, with some of the trash falling into adjacent recycling cans. The smell of food permeated the room. It was understandable as we students were preparing for final exams and papers, but I was struck by how much waste we generated, and I was dismayed to think that most of it would end up in a landfill. While takeout and food delivery make our lives more convenient, many containers are not recyclable or compostable and have "significant economic, social, and environmental cost" (Moss & Grousset, 2020, p. 3). I wanted to make a change and so I joined student councils and other organizations to spread awareness about waste and waste management. Through working with people from different industries, I realized the town needs a systematic change in legislation, facilities, and business partnerships to reduce waste generation and increase the diversion rate (percent of garbage composted or recycled of total generated).

COVID-19 led to an increase in waste volumes and a decrease in diversion rates (Forlani & Njie, 2022). At the pandemic's beginning, the community where I lived in Center County, Pennsylvania returned to the 1950s' "throwaway" lifestyle. The grocery stores there stopped accepting reusable bags and selling coffee in personal containers.

In 2022, the third pandemic year, I joined the master's program in Landscape Architecture at the University of Washington (UW) in Seattle. Here, I participated in Catherine De Almeida's Waste Relations design studio and learned about the circular economy and ecological footprint. The ecological footprint refers to the degree to which one's lifestyle uses resources. Some understand it as a balance between humans' consumption and nature's regeneration of natural resources (Wackernagel & Beyers, 2019). In this studio, I did a case study on Kamikatsu, a small rural Japanese town with an 80% recycling rate. I also researched Seattle's waste management system and designed an educational program with two teammates to support the development of a community-led biodigester in South Park, Seattle.

In the summer of 2022, I continued researching waste management practices in the United States (U.S.) and Kamikatsu with an eye toward pursuing this in some way for my capstone project. The research I conducted uses Kamikatsu as a case study to find strategies, programs, policies, and designs that are applicable to cities in the United States that initiated zero-waste goals. I compared the waste quantity of three U.S. cities (New York, Boston, and San Francisco) that Chinese scholars acknowledge for their zero-waste programs and designs (Ling, 2021; State Office, 2019; Zheng, 2021) and Seattle. The comparison revealed that, on average, a Seattle resident generates more waste than the other three cities (New York, Boston, and San Francisco).

All of these experiences made me very interested in waste management and how landscape architecture can support zero-waste strategies. I therefore chose the study of waste landscapes as my thesis topic to pursue my interest in creating clean, healthy, and low-ecological footprint designs.

1.2 Why I chose U District

I chose the University District in Seattle because it is a convenient location and is a mixed-use urban neighborhood in Seattle with some waste management issues, like litter on streets and overflowing dumpsters. According to Mathis Wackernagel and Bert Beyer's 2019 text, *Ecological Footprint*, wealthier regions typically have more significant ecological footprints and consume more resources than poorer regions. As the U District develops, I want to reduce its ecological footprint and find ways for it to develop sustainably.

Seattle is moving towards zero waste and had a diversion rate of about 52% in 2021 (Schwenger, 2022), which means over half of Seattle's waste is recycled or composted. Still, the remaining 48% is transported to the Columbia Ridge Landfill in Oregon daily (Seattle Public Utilities [SPU], 2023e). On average, a Seattle resident generates 5.5 lbs of waste per day (Schwenger, 2022), meaning a person weighing 150 pounds would generate waste heavier than themselves in less than a month.

At the time of this thesis (2022-23), the University District is an urbanizing area (based on U.S. Census Urban and Rural Classifications, 1996) with close to 60 developments proposed, underway, or completed less than a year ago (Phelps-Goodman, 2023). The ongoing development is causing gentrification, driving up land value in the neighborhood, and making living unaffordable to many existing residents (Peng et al., 2020). The district also has a young (city-data.com, 2022; Land Econ Group, 2019a) and diverse population (Seattle Department of Neighborhood, 2018) composed of students, workers, tourists, and families (Yan & Wu, 2022; see Figure 1).

The zero-waste concept is suitable for this neighborhood because it promotes repairing and reusing materials rather than throwing them away and purchasing new things. These practices can help residents to save money and strengthen the neighborhood's circular economy. For example, Crossroads Trading, Goodwill, and U District Youth Center are successful businesses and institutions that divert waste from landfills and assist low-income residents. The proposed strategies can work in tandem with those efforts.

1.3 Critical Stance & Research Questions

Our health, ecosystem, and economic systems have been, and continue to be, damaged because of improper material management. We only have one earth, and people across various industries are

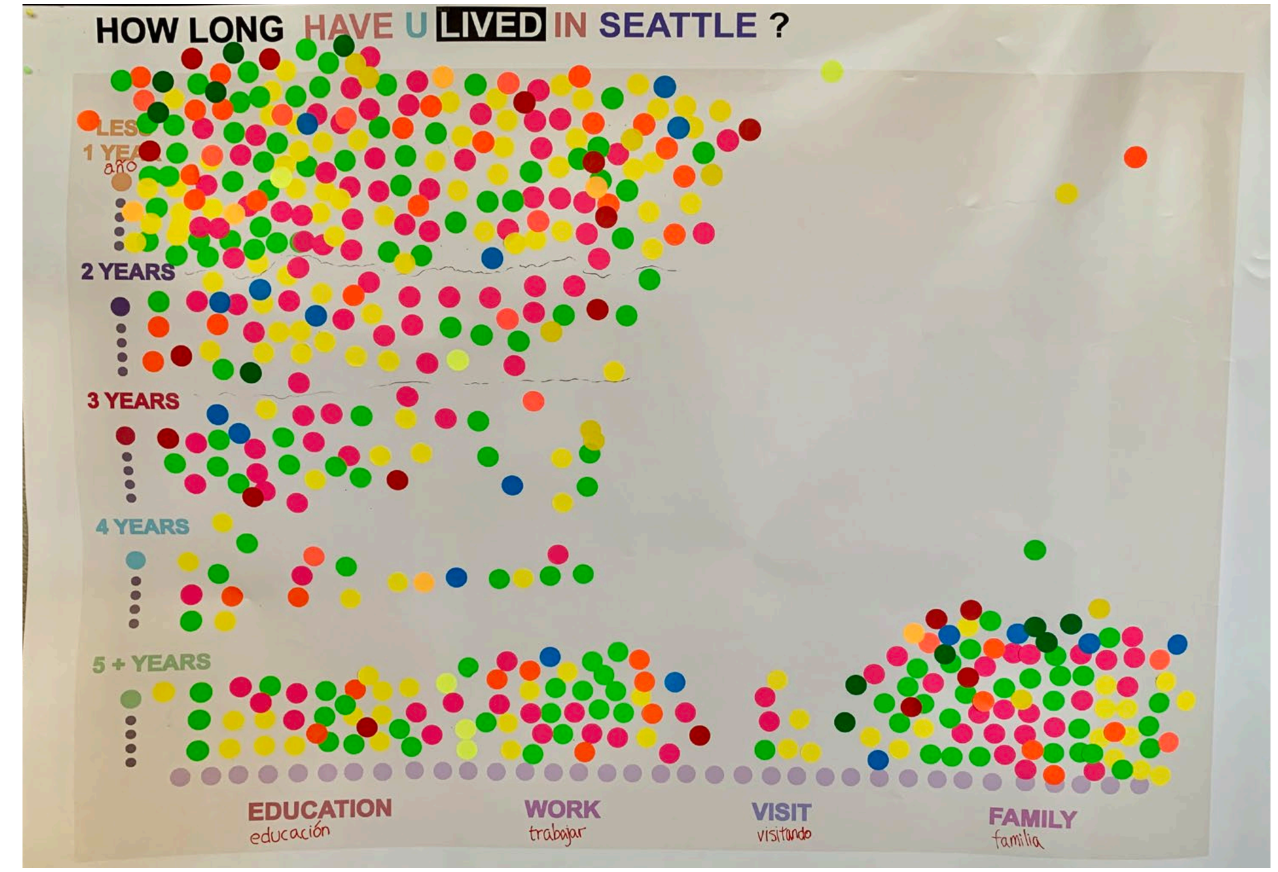

Figure 1. 2022 Fall U District Food Walk Demographics Survey. (Yan & Wu, 2022)

gradually shifting their practices to acknowledge this. This thesis aims to explore innovative landscape design possibilities in the U District to make it cleaner, generate less waste, and reduce its ecological footprint under the framework of Zero Waste, the Waste Behavior Model developed by researchers, and relevant design codes and guidelines while also serving as a precedent for other parts of Seattle.

To create innovative design solutions for the U District community, this thesis answers the following question:

Main Question:

- What landscape interventions (e.g., amenities, facilities, programs) can be developed for Seattle's U District to become cleaner, generate less waste, and reduce its ecological footprint?

In order to answer this main, overarching question, I have researched the following sub-questions:

1. What are Seattle's solid waste management (SWM) practices today?
2. What waste management practices has Seattle tried thus far, and how well did they work?
3. What design and waste management precedents can help Seattle or U District achieve zero waste? What are the advantages and disadvantages of those interventions?
4. How can other neighborhoods in Seattle apply the programs, design concepts, and facilities?

These questions will be answered in the following chapters. Chapter 2 introduces the history, present condition, and plan for Seattle's solid waste management. Chapter 3 reviews the literature on zero waste, and the factors that impact waste-related behaviors. It also studies five cases to inform the design. Chapter 4 analyzes the demographics and present waste environment in U District to identify suitable interventions for it to become cleaner, generate less waste, and reduce its ecological footprint. Chapter 5 describes the design interventions and how they respond to Seattle's plan and my thesis goals. Chapter 6 reflects upon the advantages and disadvantages of the design approach, identifies future opportunities, and summarizes what landscape architects can do to help a city become zero waste.

1.4 Methods

This thesis presents a research-based design. Three key strategies have been identified through an extensive review of literature, including Seattle Public Utilities' 2022 Solid Waste Plan, the zero waste city model and Zero Waste Index by Zaman and Lehmann (2013), three factors that impact behavior suggested by Stewart Barr (2007), three factors suggested by Hans-Joachim Mosler et al. (2008), and two factors by van der Werf et al. (2021). The design also uses the U District Station Area Mobility Plan (U District Mobility Group, 2018), U District Design Guidelines (Design Review, 2019), and development proposals from the Seattle In Progress website (Phelps-Goodman, 2023) to understand the U District context.

Based on the understanding of the circular economy and today's food lifecycle in the U District, three specific locations in the U District were designed as pilot sites for four types of interventions to reduce food waste. These include the integration of food waste processing systems, the implementation of local food production and distribution networks, the creation of educational spaces, and the design of community engagement initiatives.

CHAPTER 2 PAST, PRESENT, AND FUTURE OF SEATTLE'S WASTE MANAGEMENT

This chapter reviews governmental publications and scholarly articles on city-scale waste management to understand how Seattle's municipal solid waste management evolved to today's form. Seattle Public Utilities (n.d.) defines solid waste as "all the garbage, yard waste and recyclables that residents and businesses set out for collection or haul to a City Recycling and Disposal station" (para. 2). Seattle Public Utilities (SPU) also explains what zero waste is, and how Seattle plans to achieve zero waste in the future. These resources are to help me determine the design strategies.

2.1 Histories of Waste Management in Seattle

According to Phelps et al. (1978), before the 1900s, waste in Seattle was dumped into the sea for tidal action to carry it away. At the beginning of the 20th century, private collectors carried people's garbage into dumping grounds and kept small fires to burn combustibles. Seattle began landfilling in the beginning of the 1900s and fed hogs with some kitchen waste. Seattle gradually built four brick incinerators (formerly referred to as destructors) from April 1908 to July 1912 to solve the landfill space crisis. Though the incinerators saved much space, they gradually closed due to expensive costs and air pollution concerns (Phelps et al., 1978).

Seattle's landfills changed into sanitary landfills in the 1920s to reduce environmental damage (Long, 2001). Sanitary landfills are garbage dumps that are covered with 10 to 12 inches of soil per day during operation, so that they can be reclaimed after years of use. Landfills were running out of space again in the 1950s and 1960s. The city took several actions to solve the crisis, including: (1) acquiring more land (inside the city) for landfills, (2) increasing garbage collection fees, (3) building a railroad to long-term landfills outside the city, and (4) looking for composting opportunities (Phelps et al., 1978). The primary landfill for the city switched to King County's Cedar Hills Landfill between 1986 and 1991 and eventually to Oregon's Columbia Ridge Landfill, which is still used today (SPU, 2022). This long journey of Seattle's search for disposal sites confirms that landfilling is not the ultimate solution to waste management, as the city cannot continue to search for new sites.

Seattle started recycling in 1988 to save on the costs of using landfills outside the city after its last landfill closed in 1986 (Bagby, 1999). Seattle's 1989 update on its solid waste plan set the target for "reducing, recycling, and composting 60% of all waste by 1998" (SPU, 1998, p. 1.2). The 1989 plan also banned yard waste from curbside garbage, set up a rate structure to encourage recycling, and created an education program to show citizens how to achieve waste reduction and recycling goals (SPU, 1998). The plan effectively made Seattle "a leader in solid waste management" (Weaver, 2013, p. 1-3).

Seattle started curbside food waste collection in 2005, and it became a requirement to throw food waste into compost cans since 2015 (SPU, 2023b). However, the enforcement of the codes remains a challenge -- there are still compostables in the garbage and recycling cans because of enforcement challenges, the availability of cans, and insufficient knowledge of residents and visitors. Based on a synthesis of Seattle's waste composition study, 17.1% of garbage is compostables, and 28% is recyclables (Cascadia Consultant Group [CCG], 2017, 2018, 2022) so further efforts to support the diversion of this would be helpful.

2.2 Seattle's Waste Compared to Other Cities

The curbside recycling and composting program successfully helped Seattle reduce waste from 7.8 pounds per person per day in 2007 to 5.5 pounds per person per day in 2021 (Schwenger, 2022), and increased the diversion rate from 28% in 1988 (Bagby, 1999) to 52.7% in 2021 (Schwenger, 2022). Though the diversion rate has since decreased from "58.8%" in 2016 (Schwenger, 2022, p. 3), Seattle is still a leader in diversion rate in the United States. To understand Seattle's achievements, I compared three cities in the United States that are globally acknowledged for their waste management strategies — San Francisco, New York and Boston.

San Francisco is recognized for its composting and community outreach programs (Zheng, 2021). New York is recognized for its district-scale programs and amenities (Ling, 2021), and Boston's short-term and long-term plans could help other cities set detailed zero-waste interventions (State Office, 2019).

When comparing Seattle to these other cities, Seattle's performance gets more complex. For example, despite Seattle's high diversion rate, Seattle residents are throwing away more waste per person than in San Francisco, New York, and Boston, whose residents only throw away 4.9 pounds, 3.3 pounds, and 2.1 pounds per day, respectively (See Figure 2; Recology Sunset Scavenger et al., 2021; DSNY, 2021; MassDEP, 2022). The comparison indicates that reducing the overall waste quantity and increasing the diversion rate are both critical to eliminate garbage going to landfills.

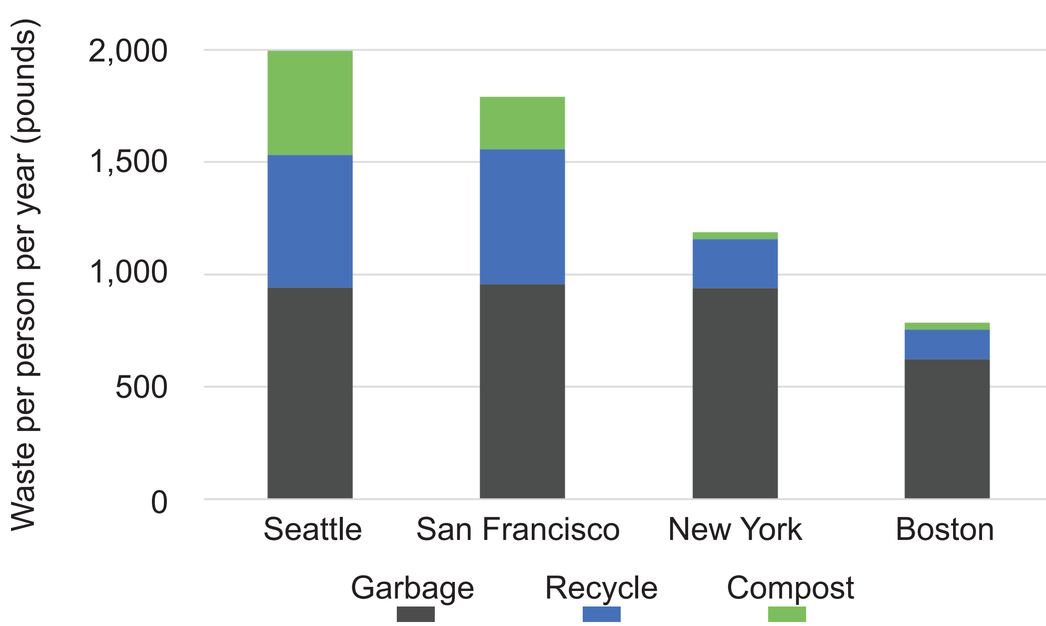

Figure 2. Annual Waste per Person (lbs.) In Seattle, San Francisco, New York, and Boston in 2021. (synthesized by author, information from Schwenger, 2022; Recology Sunset Scavenger et al., 2021; DSNY, 2021; MassDEP, 2022)

2.3 Seattle's Current Waste System

Today, Seattle's municipal solid waste is separated into three categories: garbage (gray as indicated in Figure 3), recycling (blue), and compost (green). In 2021, the City of Seattle had 737,015 residents and generated 735,182 tons of trash (Schwenger, 2022). Of this waste, 217,563 tons were recycled, and 170,070 tons were composted (2022). The diversion rate has fallen slowly since its peak in 2016 - 1.3% since 2020 and 6.1% since 2016 (see Figure 3).

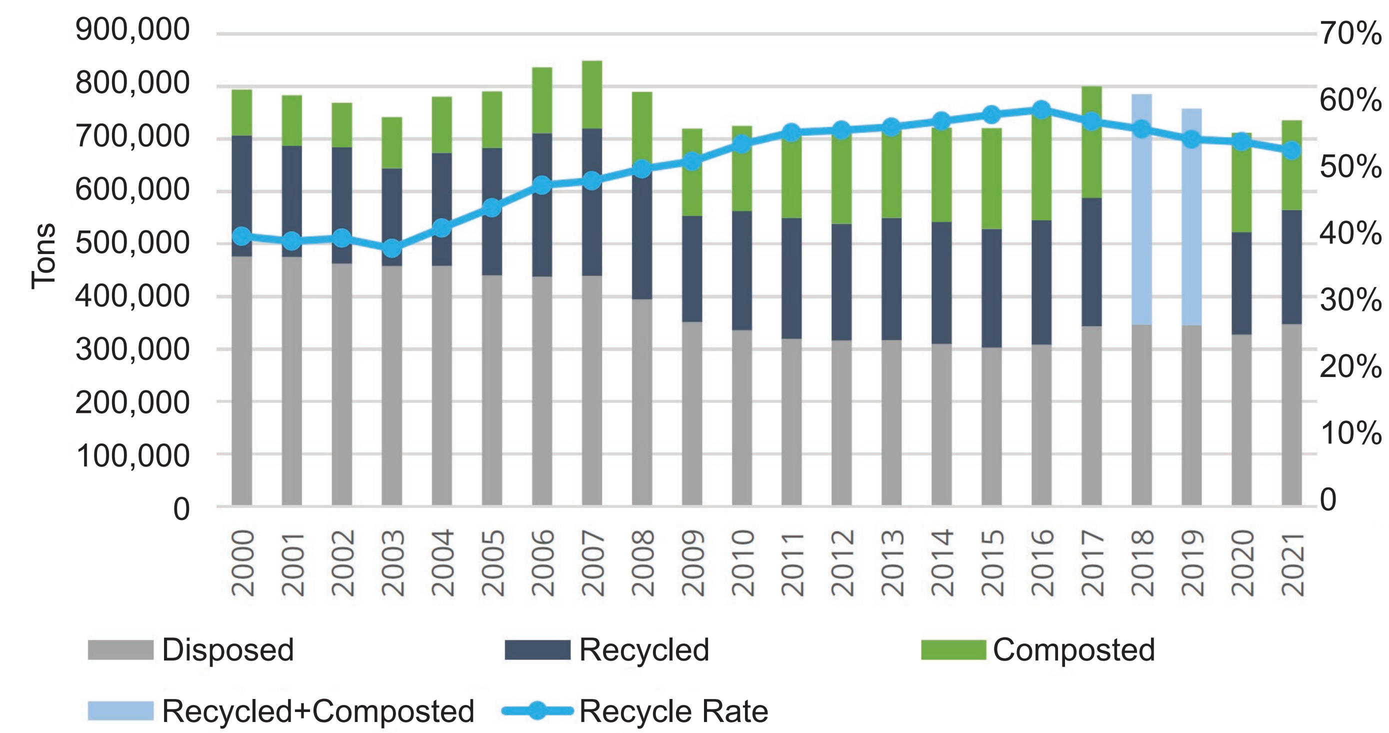

Figure 3. Seattle 2000-2021 Recycle Rate Trend. (Schwenger, 2022)

Recology and Waste Management are the two companies contracted to collect garbage weekly from Seattle residents and businesses and bring it to two transfer stations (SPU, 2022). Container trucks carry garbage from the transfer stations to the Union Pacific Railroad Argo Yard. From there, the 100-car train loads of garbage are shipped to the Columbia Ridge Landfill in Arlington, Oregon daily (See Figure 4 & Figure 5; SPU, 2023d).

Recyclables are transported from curbs to the municipal recovery facilities (MRFs) to sort and bale together. They are then sent to another set of facilities in Seattle, or sent elsewhere in North America and Asia to recycle. According to SPU, Seattle recycles 100% glass and metal (except aluminum), which is 28% of total recyclables, while plastics, aluminum, cardboard, and paper are sold across North America and Asian countries like Korea, India, Indonesia, and Thailand (SPU, 2023c).

SPU, Cedar Grove Compost, and Lenz Enterprises primarily collect compost. The latter two are private companies managing the greater Seattle region's food and yard waste (SPU, 2022). Besides

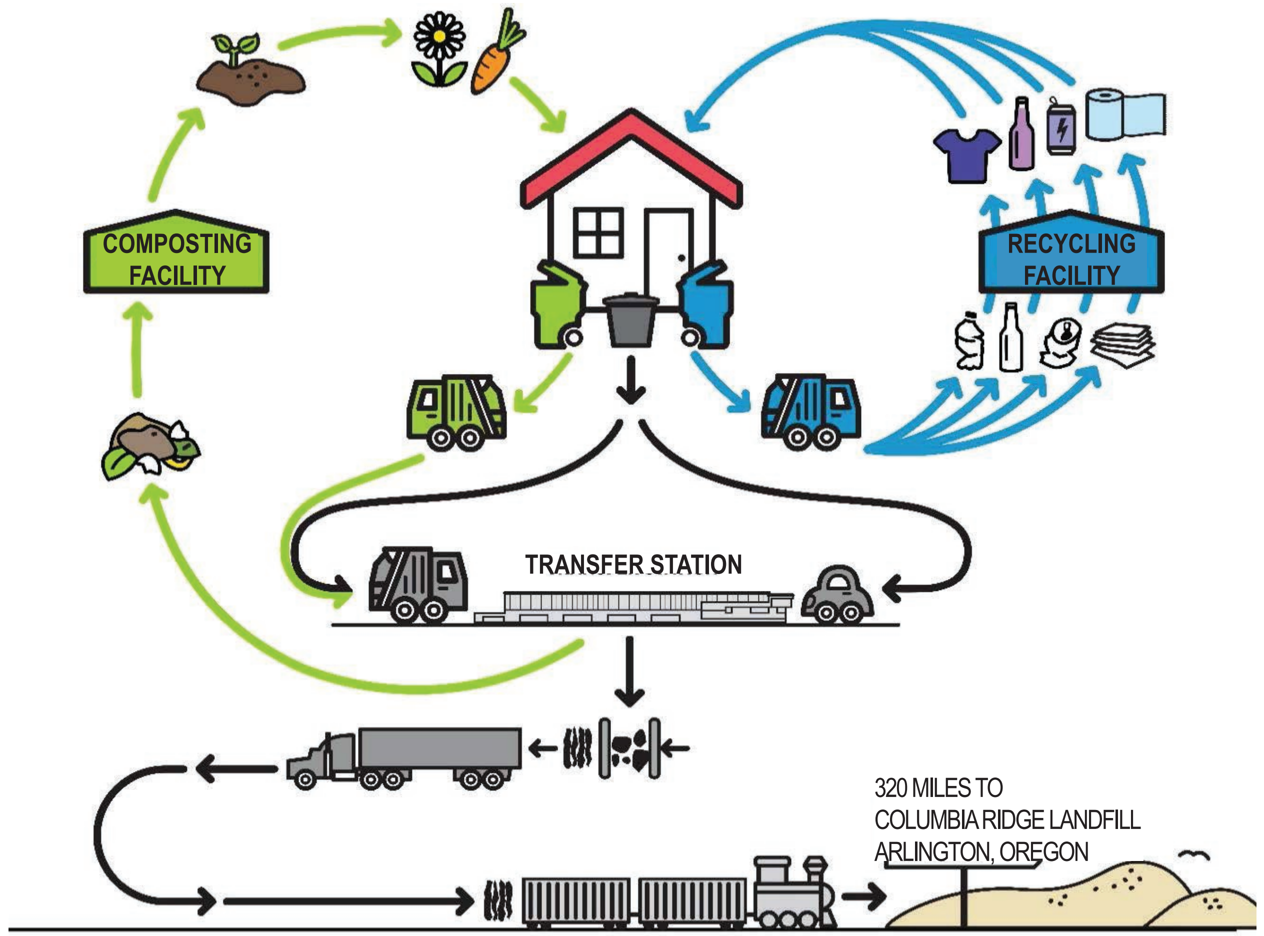

Figure 4. Seattle Solid Waste System. (SPU, 2022)

composting, Seattle also has multiple programs to divert food waste, such as the U District Food Bank and the Food Lifeline.

Compared with disposing of waste through small private companies, the centralized system is cheaper because of economies of scale. However, materials travel long distances through this system, emitting greenhouse gasses during transportation.

2.4 Zero Waste and Seattle's Future Plans

The current waste management system in Seattle can be improved to achieve zero waste and reduce the city's ecological footprint. The ways include: diverting recyclables and compostables from garbage cans, thinking about long material lifecycles in centralized systems, and reducing unrecoverable materials still being made. Furthermore, for every product thrown into a landfill after use, new natural resources from the earth are required to produce that product again (Wackernagel & Beyers, 2019). To make this linear-pattern sustainable, the circular economy concept emphasizes the importance of regarding waste as a resource (Stahel, 2016) so that we can "conserve natural resources" and "prevent pollution" (SPU, 2021, p. 13; see Figure 6).

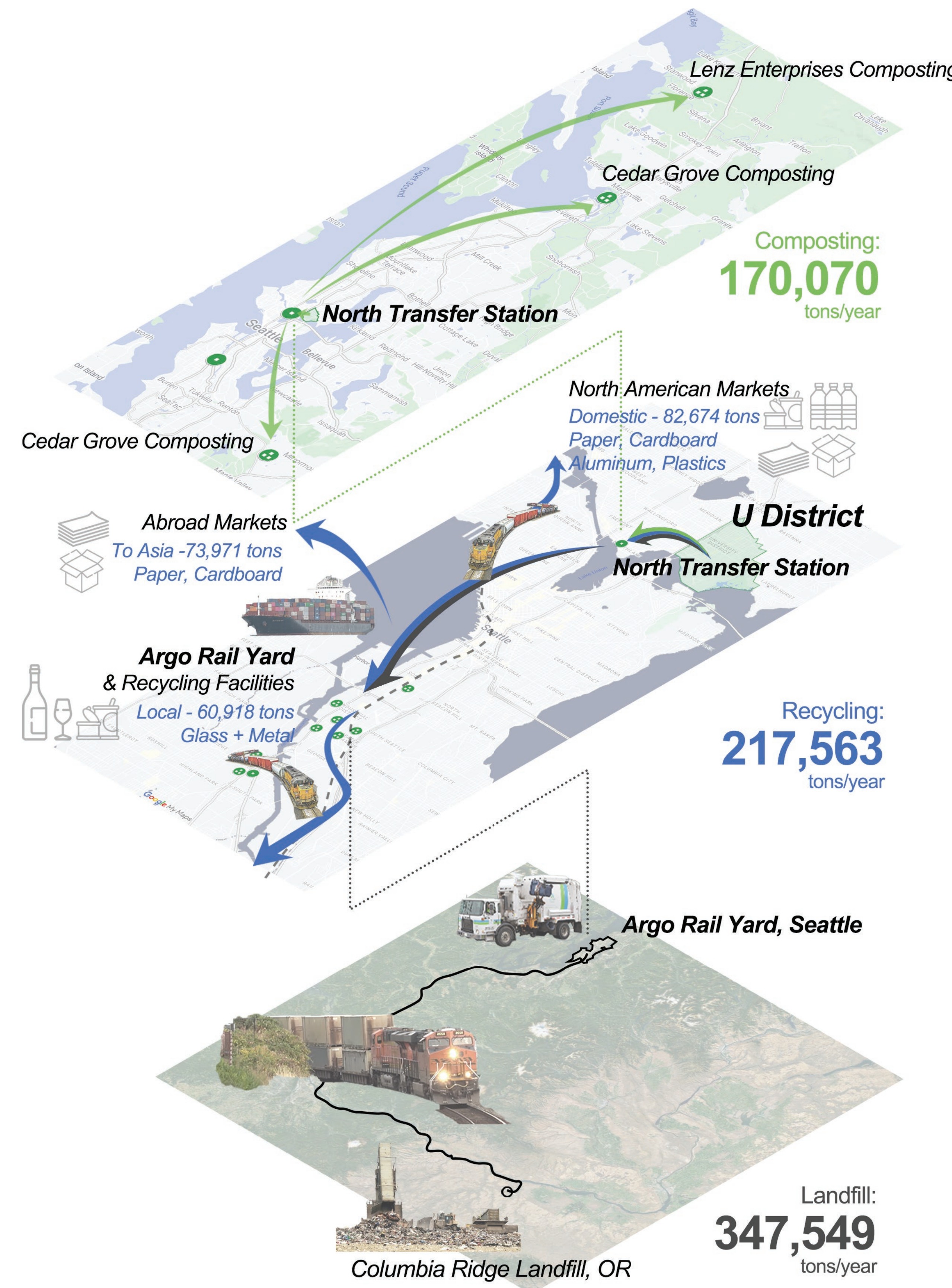

Figure 5. Seattle Solid Waste System Diagram. (graphic by author)

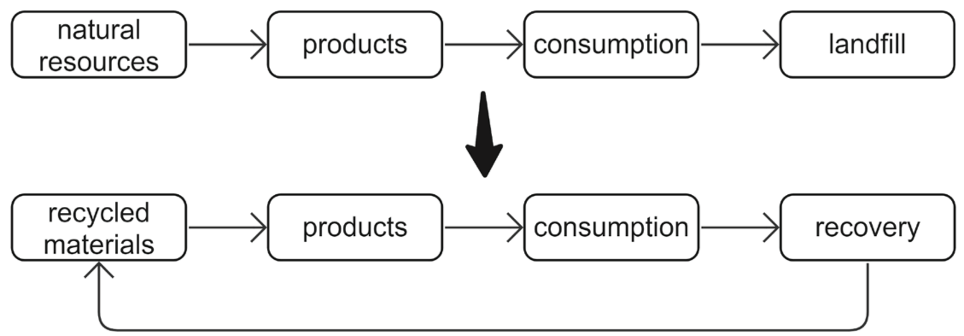

Figure 6. Material Stages of Landfilling vs. Circular Economy. (diagram by author)

The concept of Zero Waste is a cornerstone for building a circular economy. The term “zero waste” was first coined in 2000 by Warren Snow in Kaitaia, New Zealand, to describe the effort “to maximize materials recovery and minimize wasting by reusing, recycling, and composting everything currently being wasted” (Seldman, 2016, para. 2). Building on Snow’s definition, the Zero Waste International Alliance (ZWIA) defines zero waste as “the conservation of all resources by means of responsible production, consumption, reuse, and recovery of products, packaging, and materials without burning and with no discharges to land, water, or air that threaten the environment or human health” (2022, para. 3). This definition is referenced by many U.S. states, including California and Massachusetts (CalRecycle Office of Public Affairs, 2022; Keep Massachusetts Beautiful, 2022).

Zero waste is a trending topic across the globe. Many related targets and practices were developed to solve a diverse range of problems, including: (1) natural resource crisis, (2) landfill space crisis, (3) environmental pollution, and (4) dependence on imports (Bagby, 1999; Japan Industrial Waste Information Center, 2018; Wackernagel & Beyers, 2019). Zero waste is considered a philosophy (Connecticut Department of Energy & Environment Protection [CT DEEP], 2020; CalRecycle Office of Public Affairs, 2022), a design principle (CT DEEP, 2020), and an urban development model (State Office, 2018). Though many municipalities or organizations set the goal to eliminate all waste (CT DEEP, 2020; Kamikatsu-cho Town Hall Planning and Environment Division [KPED], 2020b; CalRecycle Office of Public Affairs, 2022), some places did not set a deadline for a 100%-diversion-rate, but declared more achievable milestones, like Seattle’s goal of a 70% diversion rate by 2022 and China’s ten trial cities by 2020 (Moorehead, 2007; State Office, 2018).

Seattle Public Utilities 2021-2026 Strategic Business Plan (2021) defined zero waste as “protecting the health and the environment through the conservation of all resources from production through consumption without burning or pollution to land, water, or air” (p. 13). The plan suggests “looking at the whole life cycle of materials so we can eliminate waste, prevent pollution, encourage product durability and reusability, conserve natural resources, and ultimately build a circular and inclusive economy” (2021, p. 13). Lastly, the plan provides two initiatives for achieving zero waste: “waste diversion” and “waste prevention” (SPU, 2021, p. 21).

So far I have outlined Seattle’s current waste issues: (1) compostables and recyclables in garbage containers, (2) unrecoverable materials are still made and sold, (3) the centralized system creates a

high amount of greenhouse gas emissions, and (4) the waste quantity per person is high compared to San Francisco, New York, and Boston. In response to these issues and Seattle’s 2021-2026 Strategic Business Plan’s waste diversion and waste prevention initiatives, I created three ways for the U District to become zero waste: (1) localization of material lifecycles, (2) diverting waste from going to landfills

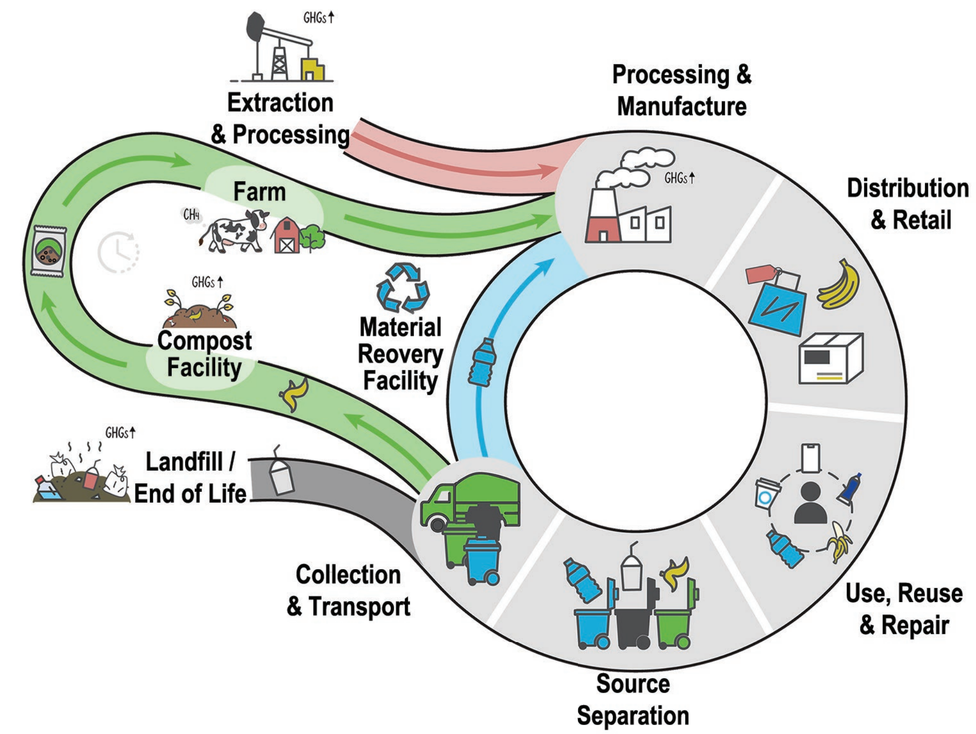

Figure 7. Today’s Consumption Lifecycle. (SPU, 2022)

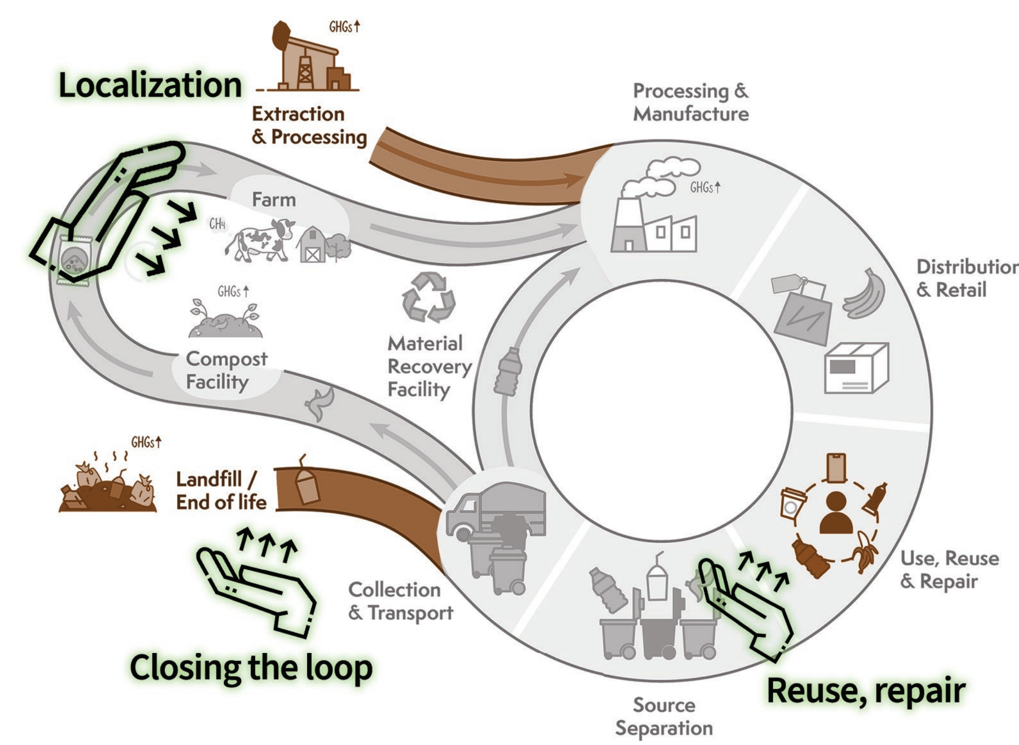

Figure 8. Three Zero-waste Strategies. (background graphic by SPU, illustrated by author)

(closing the loop), and (3) promoting reusing and repairing to prevent waste from going to landfills. (see Figure 7 & Figure 8).

To better explain the three ways, I simplified and renamed the stages in SPU's consumption lifecycle diagram into five steps: production, distribution, consumption, waste collection, and waste recovery (see Figure 9).

First, localization requires all five stages to be implemented. Through localizing material lifecycles, materials travel shorter distances from "cradle-to-cradle", thus reducing greenhouse gas (GHG) emissions. A localized lifecycle diverts waste from the centralized system and has materials reclaimed into nearby resources, reducing demand for imported materials. Second, diverting waste from landfills (closing the loop) would need consumers to sort waste correctly, manufacturers to use 100% recoverable materials, and recyclers to recover all the waste. Third, promoting reuse and repair is a waste prevention strategy. Because people's lifestyles are changing, products also need to be up-to-date. Repairing or repurposing an existing product prevents people from throwing it into landfills.

In conclusion, Seattle has been looking for sustainable waste solutions. Though Seattle incinerated waste in the past and is still landfilling garbage today, it established recycling and composting programs to shift away from landfills. The city currently can achieve zero-waste goals through localizing material lifecycles, closing the loop, and promoting reuse and repair. Knowing Seattle's history and current conditions of waste management and thinking about the various waste management strategies informed my design interventions for Seattle's U District.

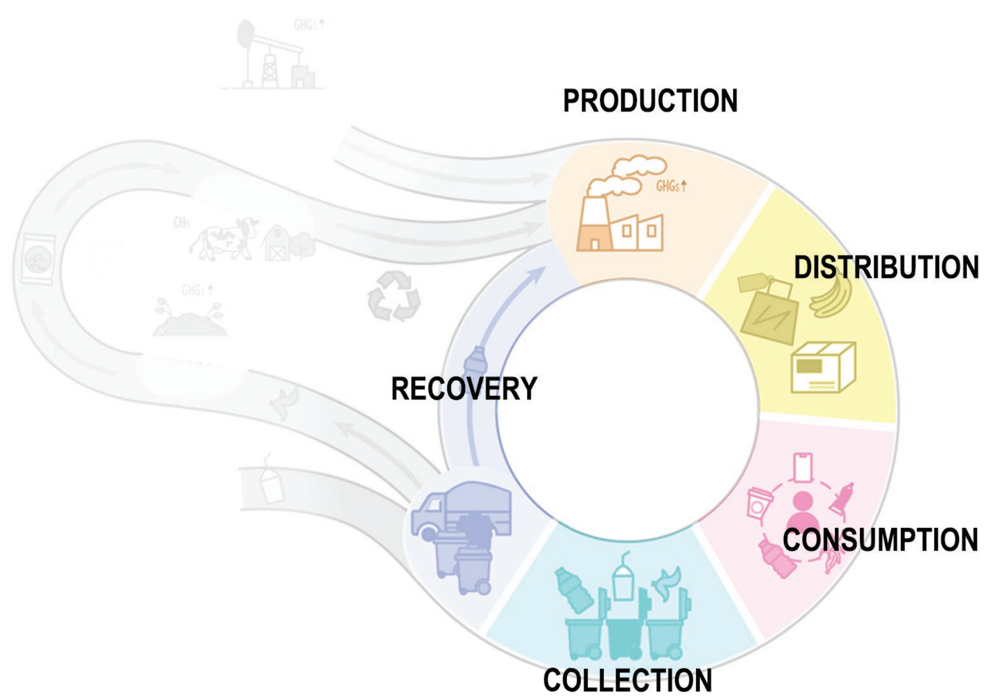

Figure 9. The Five Stages In a Closed-loop Lifecycle. (background graphic by SPU, illustrated by author)

CHAPTER 3 LITERATURE & CASE STUDIES ABOUT PREVENTING & DIVERTING WASTE

Transforming into a circular economy can be challenging because waste is "often understood as the opposite of 'value'" (Hawkins & Muecke, 2003:x, as cited in De Almeida, 2022, p. 183). This means changing social perception from waste as useless to waste as resource is essential to improving Seattle's waste management system. Therefore, in this chapter, I first review the literature on zero-waste cities and what factors impact waste-related behaviors. I then describe cases from Seattle, Kamikatsu (Japan), ASLA Education Animation, Shanghai (China), and Los Angeles to understand the mechanisms for making changes so that I may find potential strategies for my zero-waste designs in U District, Seattle. From the literature and case studies, I learned that landscape architecture has a critical role to play in helping cities achieve zero-waste goals.

3.1 Zero-waste Cities

Zaman and Lehmann (2013) proposed six drivers for transforming current cities into zero-waste cities (see Figure 10). These drivers encompass diverse aspects a city needs to change to become zero waste. The six drivers are: (1) awareness, education & research, (2) sustainable consumption and behavior, (3) transformed industrial design, (4) 100% recycling & recovery, (5) new infrastructure & system thinking, and (6) zero depletion legislation & policies.

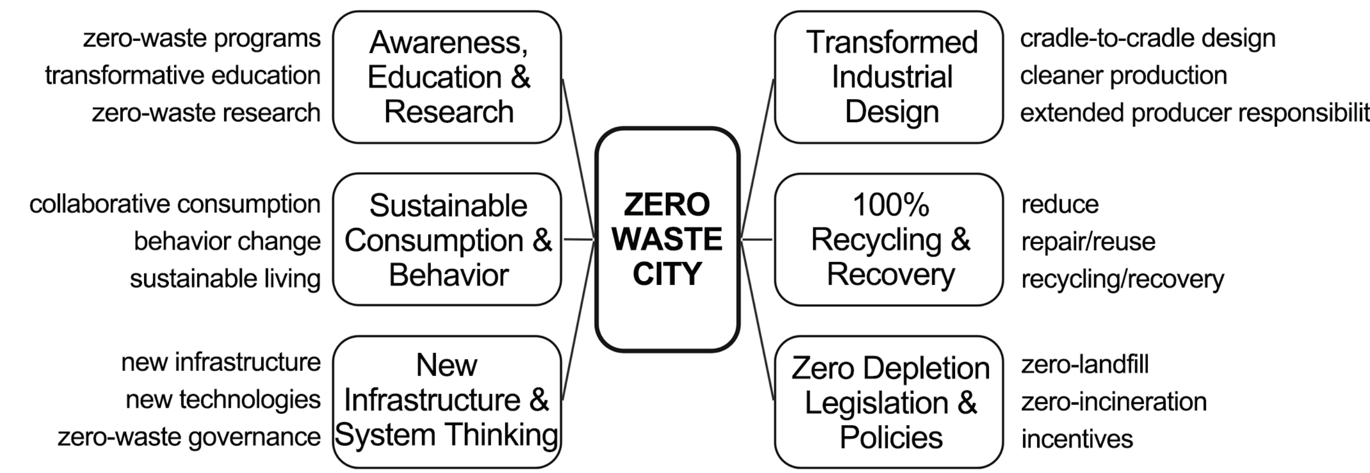

Figure 10. Drivers for transforming current cities into zero-waste cities. (adapted from Zaman & Lehmann, 2013)

The six drivers suggest that cities need to consider the entire lifecycle of materials, implement extended producer responsibility (i.e., producers take care of their products after they become waste to consumers; OECD, 2023), research new technologies and solutions, and educate the public to consume and purchase responsibly (Zaman & Lehmann, 2013). This model suggests that collaboration among government agencies, manufacturers, retailers, and customers is necessary for real change in waste management.

In addition, Zaman & Lehmann (2013) suggest a Zero Waste Index that measures how much resources "finally substituted for virgin materials and offset resource extraction" (p. 126). For example, a city with 50% of its plastic waste recycled would have a plastic recovery rate of 50%. Nevertheless, due to increased demand, recycled plastics only account for 40% of new product sources, so the substitution for plastic is 40%. This index may not work well for cities like Seattle that rely heavily on importing and exporting goods and waste because intercity trades complicate the measurement.

Regardless of this disadvantage, the Zero Waste Index can help a city understand waste composition and which material types need more effort to recover, and then take more accurate and practical actions. Based on Seattle's waste composition studies, compostable organics are the largest portion of the commercial (26.5%) and residential (30.4%) substreams (Cascadia Consultant Group [CCG], 2017; 2022). Moreover, according to the Washington State Food Security Survey Wave 4 (Otten et al., 2023), 49% of households experienced food insecurity between December 2022 and January 2023. These survey and composition studies indicate that Seattle can start with food and food waste to move towards a circular and inclusive economy effectively.

3.2 Factors Impacting Waste-Related Behaviors

To understand the mechanisms to transform cities to zero waste on an individual level, this section reviews four pieces of literature on how psychological and environmental factors impact waste-related behaviors.

Stewart Bar (2007) identified three factors that contribute to people's disposal behavior: (1) environmental values, (2) situational variables, and (3) psychological factors. Environmental value refers to how much one values the natural environment or one's attitude towards the environment. Situational variables refer to the influence of the context over people's behavior, such as accessibility to infrastructure, sociodemographic, and personal knowledge and experiences. Psychological factors refer to personality characteristics and perceptions of one's behavioral impact.

First, Barr's (2007) study confirmed that environmental values are the most substantial factor to impact waste-related behaviors. Similarly, a study by Meneses and Palacio (2005) also supports the impact of ecological values on recycling behavior. The study identified different social roles in the waste management system: "(a) the influencer; (b) the initiator; (c) the decision maker; (d) the vendor…; (e) the persuader; (f) the enforcer…; and finally (g) the rejecter" (p. 838), and connected the roles with age, gender, and educational level. Their findings show that those in the reluctant to recycle group tend to be middle-aged (46-60) persons with lower-than-high-school education levels. The authors suggest that educating on environmental issues and creating social norms could effectively motivate this group to change (Meneses and Palacio, 2005). Moreover, Barr (2007) agrees that specific demographics "young, female, single-family dwelling, high-income earning, well-educated, and politically liberal individuals" (p. 439) are somewhat associated with waste behaviors, though this association is stereotypical and is sometimes based on spurious relationships in the data.

In my opinion, targeting a specific group to educate may sound non-inclusive, but knowing that those in different demographic groups might respond to policies and landscape designs differently can help us

to educate the public more effectively. This concept is supported by Powell et al. (2019), who advocate for speaking in the language of different audience groups to communicate a shared goal better. These arguments imply that raising environmental awareness in multiple ways can positively improve U District's waste-related behaviors.

Second, Barr (2007) notes that "environmental and behavioral knowledge has been found to play a significant part in shaping waste management behavior" (p. 439), which could explain why specific groups are more active than others. Because the specific groups are exposed to waste-related knowledge more often, they are likelier to "behave in an appropriate manner" (Selman, 1996, as cited in Barr, 2007, p. 442). This section indicates that since knowing how to do the right thing is a prerequisite for appropriate waste-related behaviors, Seattle, a top tourist destination, would need programs to guide visitors. The public open spaces in high-pedestrian-traffic areas have great potential for increasing the public's knowledge of waste management and environmental values, guiding the public to take action, and supporting the public with incentives.

Third, Barr's study (2007) indicates that when pro-environmental behaviors become a norm, people are more likely to change their environmental behavior to match that norm. Interestingly, the study finds that those who recycled before the introduction of curbside recycling programs are more likely to reduce and reuse than those who only recycled after the program was introduced. Barr theorizes that people who did not recycle before the curbside program may feel they have fulfilled their social responsibility through participating in recycling, and felt no need to reduce and reuse (2007). In my opinion, another possible explanation is that those who recycle only after the introduction of a curbside recycling program do not feel reducing and reusing behaviors are convenient enough. These findings confirm that education, supportive policies, and convenient programs and infrastructure are essential to waste-related behavioral changes, especially when moving towards more complex and challenging behaviors.

A study by van der Werf and colleagues (2021) affirm Barr's point: Both guidance and supportive programs are indispensable. Their study sampled 139 households in The City of London, Ontario, Canada, to test the effectiveness of food-waste reduction interventions. The interventions sent to households included food storage containers, a "Reduce Food Waste, Save Money" postcard with tips to reduce food waste, a refrigerator magnet version of the postcard, and food waste reduction tools including an explanatory letter, freezer stickers, and a grocery list pad. The postcard guides participants on reducing waste; the other items provide supportive tools to reduce food waste. This intervention reduced the treatment group's food waste by 31%, compared to a 1% increase for control households who did not receive the materials (van der Werf et al., 2021). This study confirms that providing infrastructure to support waste reduction programs is effective to guide the community to reduce food waste.

A study in Cuba researched associations among three factors (perceived reputation, perceived difficulty, and attitude/psychological factor) and recycling, composting, and reusing behaviors (Mosler et al., 2008). Composting was new to Cuba, and the article suggests having neighborhood organizations host activities and assemblies to engage communities in composting practices, which could increase people's awareness of how and why to compost and reduce participation difficulty. Secondly, this study finds little connection between reuse and perceived reputation because reuse behaviors mainly were done indoors and privately, making it hard to create a social norm. The article suggests that establishing communal centers for reuse might be a more effective strategy. This could be enhanced by additional strategies such as exchanging tools and knowledge about repairing used objects so that reuse behaviors can have social values as well (Mosler et al., 2008).

In Figure 11, I synthesized the literature above into a diagram to understand the relationship between different impacting factors and the mechanism of consumer waste-related behaviors). This diagram integrates the following impacting factors into the cost-value evaluation mechanism that Mosler et al. (2008) describe. The factors include environmental values such as pollution caused by landfills (Barr, 2007; Meneses & Palacio, 2005), environmental barriers such as availability of a trash receptacle (Barr, 2007), knowledge barriers such as not knowing where to compost (Barr, 2007; Werf et al., 2017), social values or social barriers such as positive and negative social attitudes toward composting (Barr, 2007; Meneses & Palacio, 2015), and financial values such as money saved by preventing food waste (Werf et al., 2021; Mosler et al., 2008). In addition, the diagram also incorporates the social norm mechanism described by Barr (2007), Mosler et al. (2008), and Meneses & Palacio (2015).

This diagram illustrates that personal and environmental factors can influence people's waste-related behaviors (such as reusing, recycling, and composting). I classified the factors into personal costs that prevent individuals from desired behaviors (e.g., recycling) and personal values that encourage individuals to take desired actions. Environmental factors also impact personal costs and personal values. For example, composting infrastructure was not available, accessible, or convenient to residents in 20th-century Seattle. While today, in many restaurants in Seattle, there are compost cans, sinks, and public restrooms. The infrastructures, technologies, and supportive programs reduced the cost and increased the value of composting. As a result, Seattle's compost rate increased from 11% in 2000 to 23% in 2021.

The mechanism illustrated in this diagram is a feedback loop: An increase in personal values or decrease in personal costs would propel individual changes; when a social norm formed from multiple individual changes, the social value factor increases, thus driving more people to change. Group activities and special events are helpful ways to power the feedback loop. They can increase people's awareness of the environment, waste, and zero-waste lifestyles, thus making a neighborhood cleaner, generating less waste, and reducing its ecological footprint. This mechanism also indicates that designers and the district need to provide guidance and support instead of relying on consumers alone because inconvenient programs can increase an individual's cost to recycle correctly.

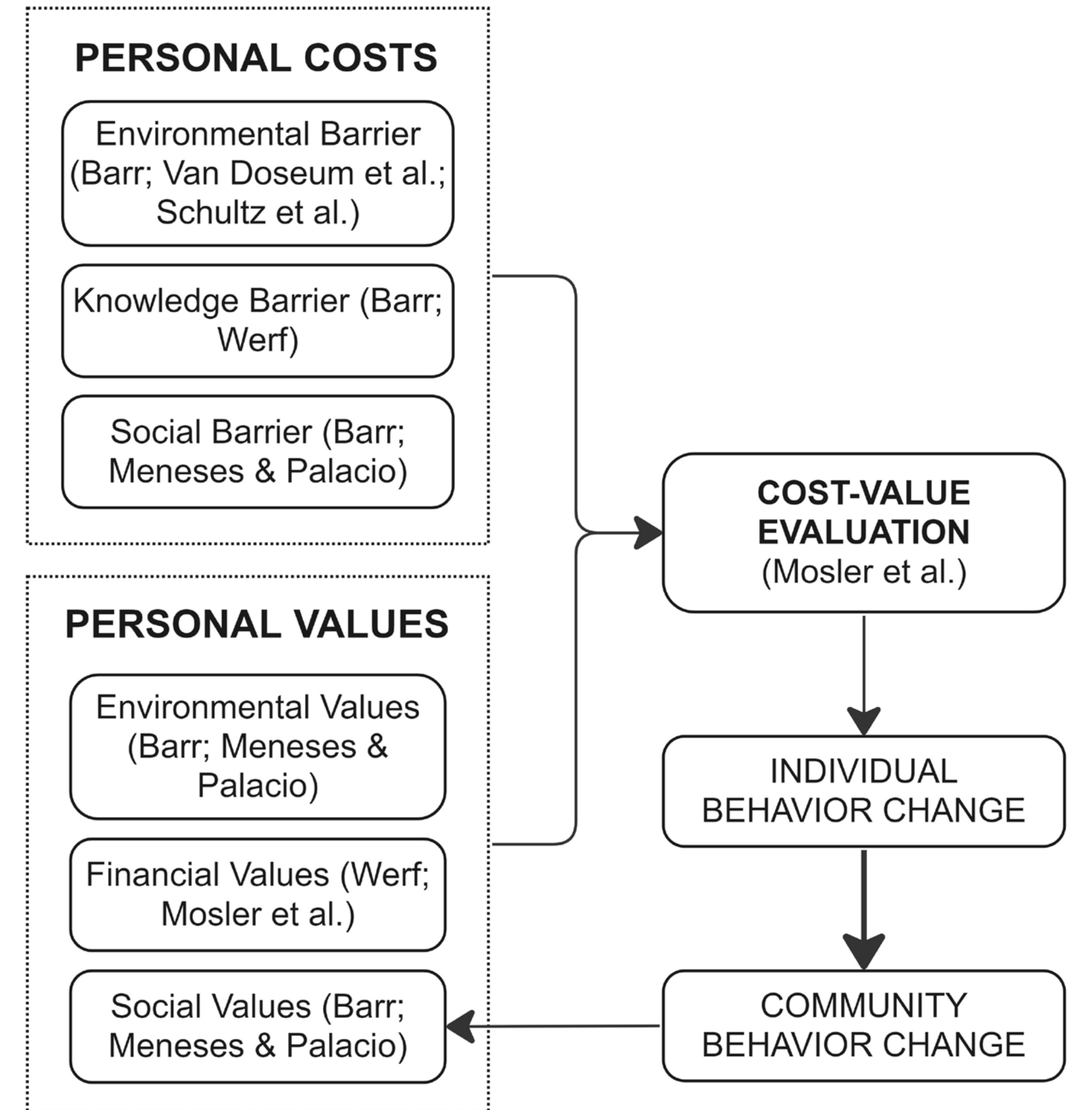

Figure 11. Waste Behavior Model. (diagram by author, a synthesis of research findings)

3.3 Case Studies

In this section I describe five case studies from Seattle, Kamikatsu (Japan), American Society of Landscape Architects (ASLA) Education Animation, Shanghai (China), and Los Angeles that provide potential landscape solutions to make the U District cleaner, generate less waste, and reduce its ecological footprint. These were a key source of inspiration for my designs in the U District.

3.3.1 Reclaimed & North Transfer Station, Seattle

The North Transfer Station is located in the Wallingford neighborhood, Seattle, at 1350 N 34th St. It has two buildings to take recyclable materials, garbage and compost from individuals and commercial haulers. The waste is dropped off on the ground floor, then pushed to holes by forklifts. Beneath the holes are container trucks, which will carry different kinds of waste to a new destination. The station also has a community room to educate the public about waste sorting and reusing tips, the station's history, and its functions.

In 2016, artist Jean Shin designed a sculpture with reclaimed steel rebar at this Transfer Station (Figure 12). The rebar is salvaged from the old transfer building on this site. The sculpture showcases the artistic reuse of abandoned materials. Its shape represents the natural landscape before Seattle's first transfer station was built. This sculpture commissioned by SPU (2016) advocates for visitors to reuse and repurpose and "consider our impact on the environment both past, present and future" (see Figure 13).

The sculpture is placed between the street and the North Transfer Station's front entrance, which leads to an educational community room (see Figure 14). This placement increases the exposure of the sculpture and its educational impact.

However, the sculpture does not allow climbing or interaction. Upon my visit, two children were comprehending the sculpture through climbing, but were told to get off by their mom. This story indicates that educational public art can be more welcoming if it allows for some degree of interaction. For example, the miniature transfer station in the community room encourages children to learn about the flow of materials by playing with toy cars (see Figure 14). The viewing window (upper left of Figure 14) lets people watch how waste are treated at the station. The scene of waste getting dropped off and carried away invites the public to care about their waste's destinations. The eight flippable double-side boxes (upper right corner of Figure 14) provide tips on how to reduce, reuse, and recycle. These interactive educational tools are telling the community that their waste have values.

Figure 12. Sculpture Reclaimed by Jean Shin. (photo by author)

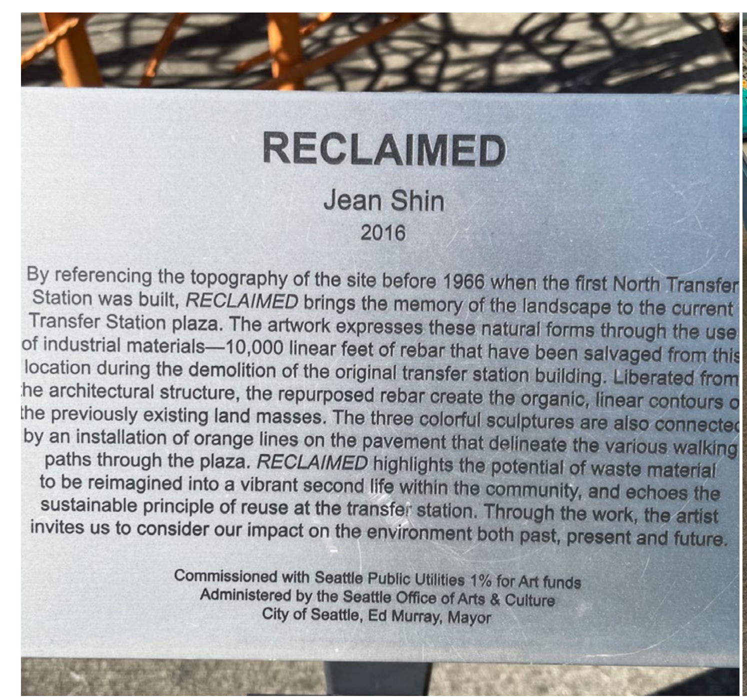

Figure 13. Reclaimed Sign. (photo by author)

Figure 14. North Transfer Station Community Room. (photo by author)

3.3.2 Building A Park Out Of Waste

The ASLA has published an educational animation made by Daniel Tal (2017) that illustrates how demolition waste can be used in constructing new parks. For example, concrete and glass can be processed on-site to make porous pavings, steps, and walls. Reclaimed wood and steel can be used as site amenities like benches, lights, and bike racks and the remaining wood can be used as wood chips for plantings (See Figure 15).

This case study suggests that the interventions in U District should prioritize using and reusing locally sourced materials. In addition to using reclaimed materials in new developments, there are more ways to expand its benefit, such as using signs or cards to make people aware of the reuse and repurpose processes, especially on outdoor furniture. This way, we can carry the reusing and recycling concept from outdoors to indoors.

Furthermore, by visualizing the drastic contrast between abandoned materials and their repurposed products, residents and visitors will be encouraged to explore the value of all kinds of waste, including food waste.

To see the original video, visit the link below: https://www.asla.org/sustainablelandscapes/vid_waste.html

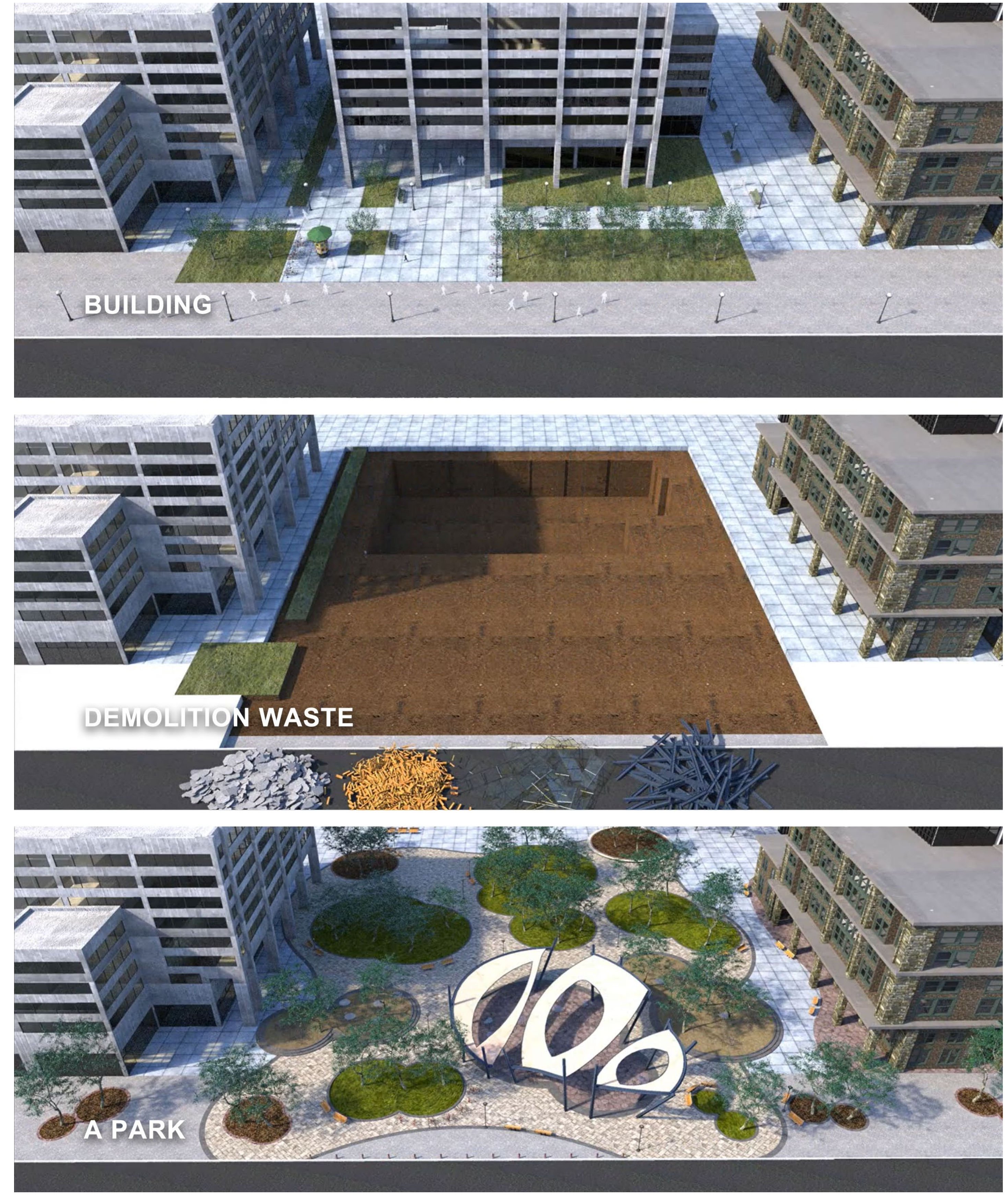

Figure 15. Screenshots from video Building a Park Out of Waste. (Tal, 2017)

3.3.3 Zero Waste Center in Kamikatsu (Japan)

The Zero Waste Center (ZWC) in Kamikatsu, Japan was completed in 2020 and is located in the heart of this rural Japanese town with 1,500 residents (Kamikatsu Town Hall, 2022). The town is known for its 80% recycling rate and scenic landscapes (Kamikatsu Public Sector, 2019). The new sorting center designed by Hiroshi Nakamura & NAP utilizes locally grown cedar wood for its structure. It also utilizes abandoned and donated household wastes for its furniture and decorations (Nakamura, 2022). For example, a chandelier in its item-exchange store is made of empty glass bottles, and a wall is made of colored plastic trays (see Figure 16).

The new waste center is a renovation of the old garbage station. Because the town has a low population density (33.45 people/square mile; Kamikatsu Town Hall, 2022), its residents have to carry their waste to the waste center and do the sorting themselves. This system made the old garbage station a place to meet others and socialize. The new waste center takes advantage of its location and incorporates community services and tourism. The facility has a sorting area with more than 40 baskets, a workshop where people can exchange second-hand items for free, a lounge with reclaimed furniture, a meeting room for people to collaborate and innovate, and lastly, a hotel for visitors to experience a zero-waste lifestyle (see Figure 17).

The waste center has a few features that help reduce Kamikatsu's waste generation. First, its usage of locally sourced used-materials, arts, and technologies gives useless waste value and advocates for reuse. Second, the community areas attract residents for other activities besides disposing of garbage, indirectly increasing people's exposure to the circular economy and zero-waste concepts. Third, its

Figure 16. Plastic Tray Wall & Bottle Chandelier at Zero Waste Center. (photo by Koji Fujii / TOREAL)

Figure 17. Zero Waste Center Features and Location. (photos from Nakamura N&P & Koji Fuji/ TOREAL, combined by author; KPED, 2020c; Nakamura, 2020a)

reuse/repair workshop (known as “kuru-kuru” workshop) faces the center’s entrance, making reusing second-hand items more convenient than buying new products and throwing them away. Fourth, the center provides reusable tableware for group events to reduce single-use items (KPED, 2020c).

Kamikatsu Town has other programs that contribute to its increase in diversion rate. First, the town subsidized at-home composters in the late 20th century, and 97% of households adopted them (Kyōko et al., 2018). This move reduced the garbage station’s burden and odor, proving that financial incentives could effectively encourage pro-environmental behaviors. Second, the town’s multi-stream recycling (13 streams and 45 substreams) increased awareness of the waste-to-resource concept, thus prevented mis-sorting and increased recyclables’ purity and value.

However, these two programs can be challenging to implement in Seattle. Kamikatsu increased its sorting categories from nine in 1997 to 45 in 2016 (see Figure 18 for details). If such a degree of sorting were required in Seattle, it might cause confusion and push back. In addition, subsidizing at-home composters may not be economically attractive compared to the existing centralized system. Instead, Seattle can gradually increase its sorting categories and place community-scale composting machines in public spaces.

Lastly, Kamikatsu still has 20% of its waste unrecoverable due to technology and financial limitations such as rubber products, face masks, and animal litter (KPED, 2020a). The unrecoverable products are still being manufactured and sold. Therefore, a circular economy cannot rely on consumers alone and need collaborations with all roles in materials’ lifecycles.

Figure 18. Kamikatsu Waste Sorting Categories and Timeline. (synthesized by author; KPED, 2020a, 2020c; Matsuoka, 2018)

3.3.4 Humans and Birds in a Cycle

This 2021 ASLA student award project was designed by Shuyu Hou, Linfeng Huang, Ruiyang Li, and Xiaofeng Zhang and advised by Yufei Ding, Zhicong Zhao, and Rui Yang. It proposes a sustainable waste stream and habitat network planning for aves in Shanghai. The project aims to save birds threatened by the hazardous waste in Shanghai's landfills, restore bird habitats occupied by waste treatment facilities, and increase citizens' bird protection awareness.

The project first designed a system that utilizes food waste and leachate at four types of waste-related landscapes: trash cans, transfer centers, landfills, and habitats (see Figure 19). It then identified the types of spaces needed for the new system (see Figure 20), and locations for designs, including an intersection of Shanghai's Inner Ring Road, a transfer center, a landfill, and a vacant space between the transfer center and the Inner Ring Road. The design 1) utilizes vacant spaces along Shanghai's urban Avenues to create green corridors, 2) uses artificial intelligent (AI) trash cans to automatically separate food waste that is safe for birds to eat, 3) uses anaerobic bio-digestion to turn leachate and struvite from the landfill into bird habitat's fertilizers, and 4) uses specific plant species to grow food for birds (see Figure 21).

The designs in this project align with SPU's zero-waste strategies, such as localizing waste treatment and raising environmental awareness to divert toxic waste from landfills. The workflow for this project (material cycle system -> spaces and programs -> designs at specific sites) can be applied to this thesis. Integrating artificial intelligence and anaerobic digestion can also be used in Seattle's U District to process food waste locally and encourage learning through interactive designs. Feeding birds food waste through AI trash cans in Seattle may not be ideal, as they may attract birds and rodents, litter the street and increase maintenance costs. Nonetheless, a trash can that provides bird food periodically can attract birds to gather towards the can and away from regular trash receptacles.

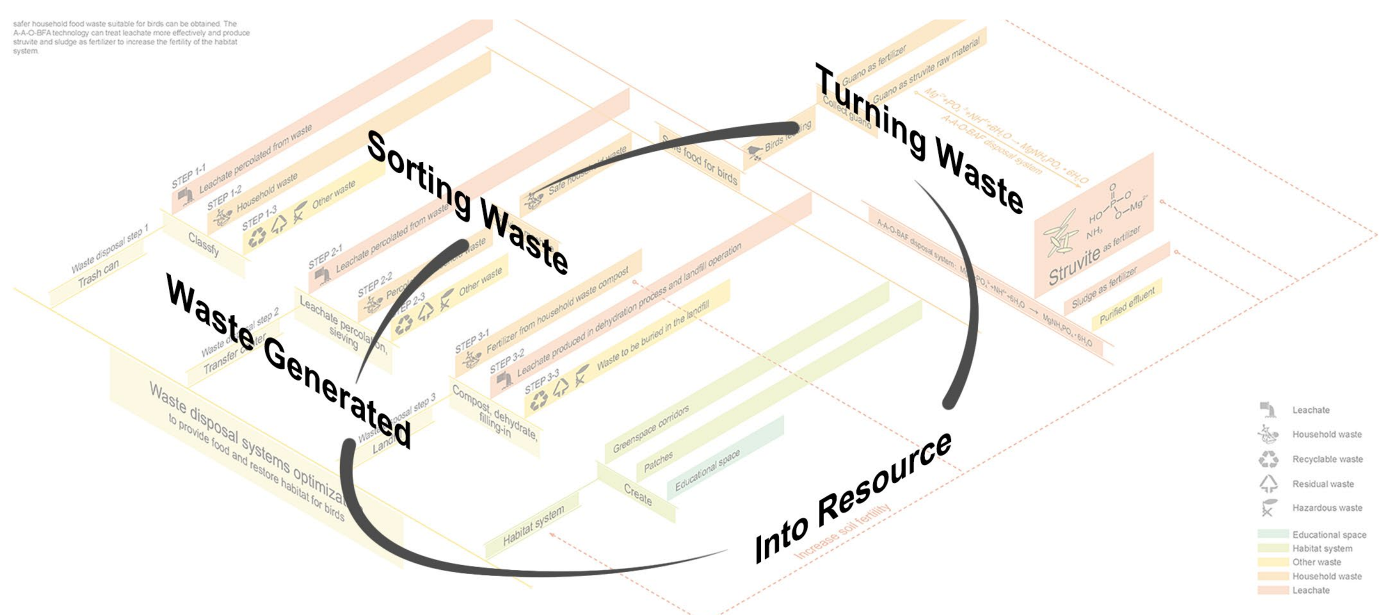

Figure 19. Proposed Shanghai's Bird-friendly Waste Disposal System. (Hou et al., 2021, image from ASLA). Image is illustrated to increase legibility. See https://www.asla.org/2021studentawards/3535.html for the original image.

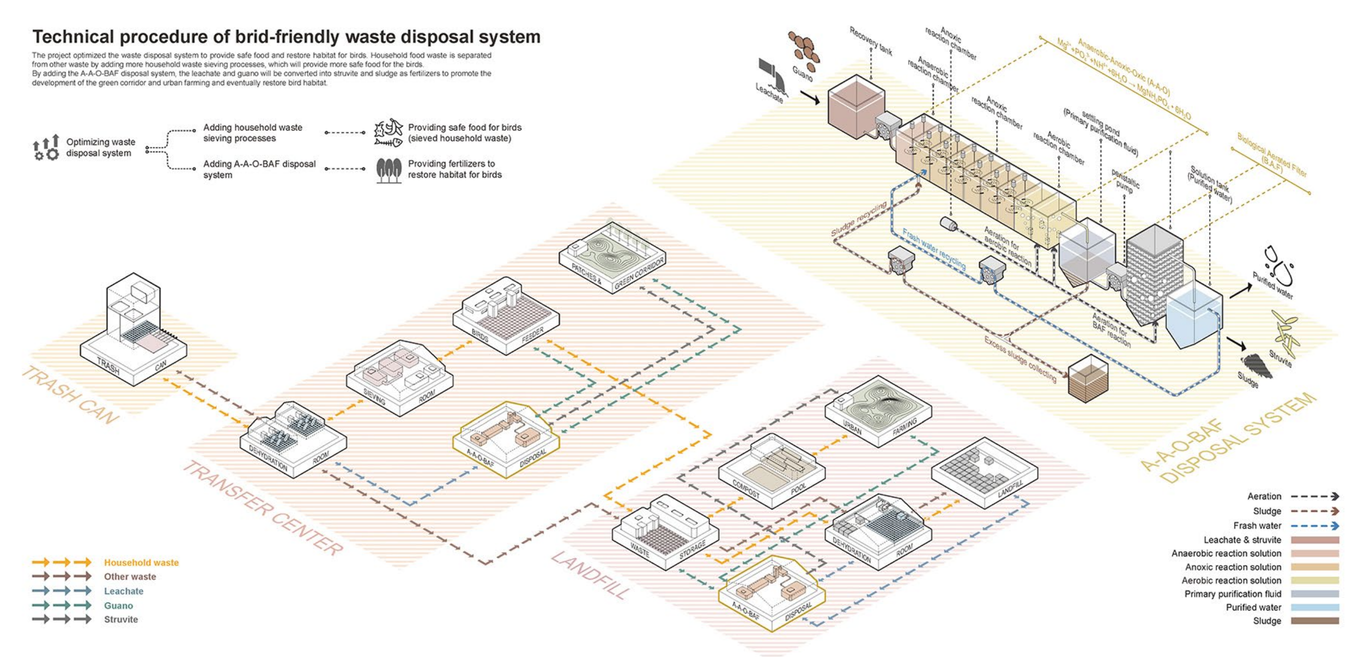

Figure 20. Humans and Birds in a Cycle - Types of Space Needed for the Proposed Waste Disposal System. (Hou et al., 2021, image from ASLA)

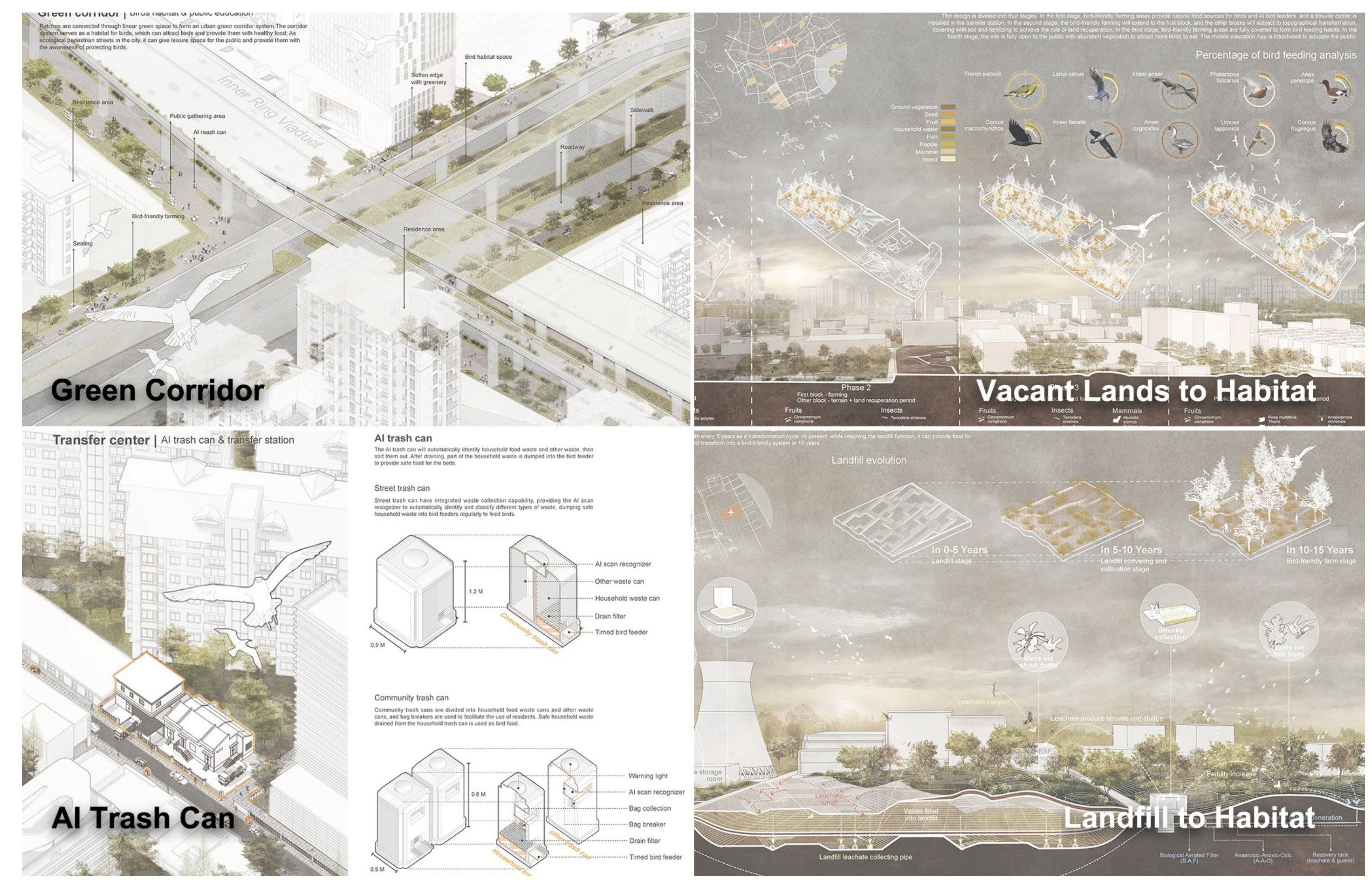

Figure 21. Proposed Site Designs & Interventions in Shanghai. (Hou et al., 2021, images from ASLA). Images are illustrated to increase legibility. See https://www.asla.org/2021studentawards/3535.html for the original image.

3.3.5 Rehousing the Homeless and Optimizing Waste Streams

This 2021 ASLA student award project was designed by Chao Zhou, Yangjin Jiang, Lyuyuan Jia, Leixi Qian, and Kexin Wang and advised by Lin Qing and Xiangrong Wang. The design team developed strategies to turn household waste from housed residents into homes and necessities for the unhoused population in vacant spaces in downtown Los Angeles. The strategies that they suggested involve using cardboard and metal for houses, repairing furniture and clothing to new furniture and clothing, and using food and yard waste for organic fertilizers. The project mapped the hot spots of homeless gatherings, accumulation of waste, and parking lots to determine potential places for interventions (see Figure 22). The team also developed community programs that everyone can join to improve community bonds (see Figure 23). Unlike Kamikatsu, this project's waste reuse and community programs are dispersed into different locations (see Figure 24).

This project in Los Angeles aligns with Seattle Public Utilities' goals. The design reduces waste generation by hosting flea markets and item-exchange programs in public spaces. By building an environment for the homeless, the design diverts household waste away from landfills through reuse, repair, and repurposing. Furthermore, the design localizes material cycles and reduces GHG emissions by keeping furniture and appliances inside the region.

The U District also has unhoused people living on the streets. Therefore, the U District can take some of its waste diversion and prevention programs and strategies, such as shared activities to increase community cohesion, urban gardens to provide affordable and healthy food, and multiple sites with diverse functions forming a network to complete the materials' cycles.

In conclusion, public spaces, such as parks, streets, shops, places of worship, and even parking spaces, can assist cities in achieving zero waste and catalyzing change in people's lifestyles, industries, and local economies. Therefore, as a landscape architecture thesis, the design will use U District's public open spaces to develop a circular food economy and catalyze the shift towards zero waste. Based on the lessons from the articles and case studies above, Seattle can utilize a network of urban public spaces to develop interventions and community programs to guide and support the public to reduce food waste generation, prevent food waste in public garbage cans, and partially localize the food lifecycle. Chapter 4 describes existing programs and interventions in the U District, and Chapter 5 identifies the locations and designs piloting sites to complete U District's food lifecycle.

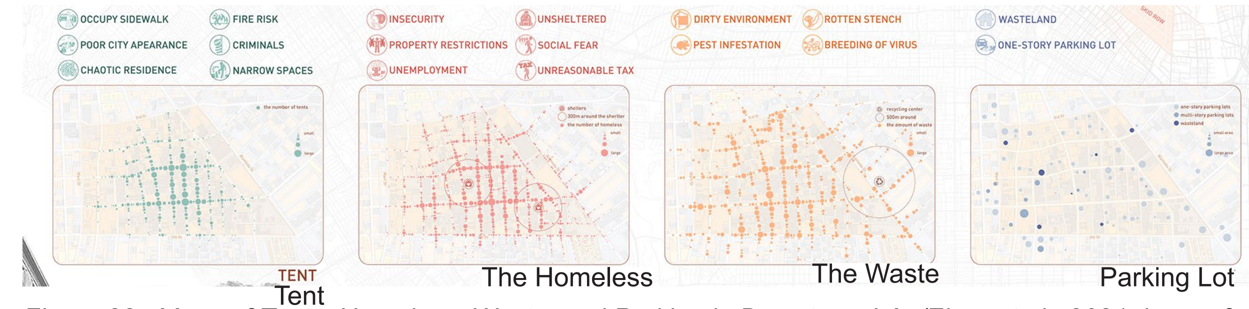

Figure 22. Maps of Tents, Homeless, Waste, and Parking in Downtown LA. (Zhou et al., 2021, image from ASLA)

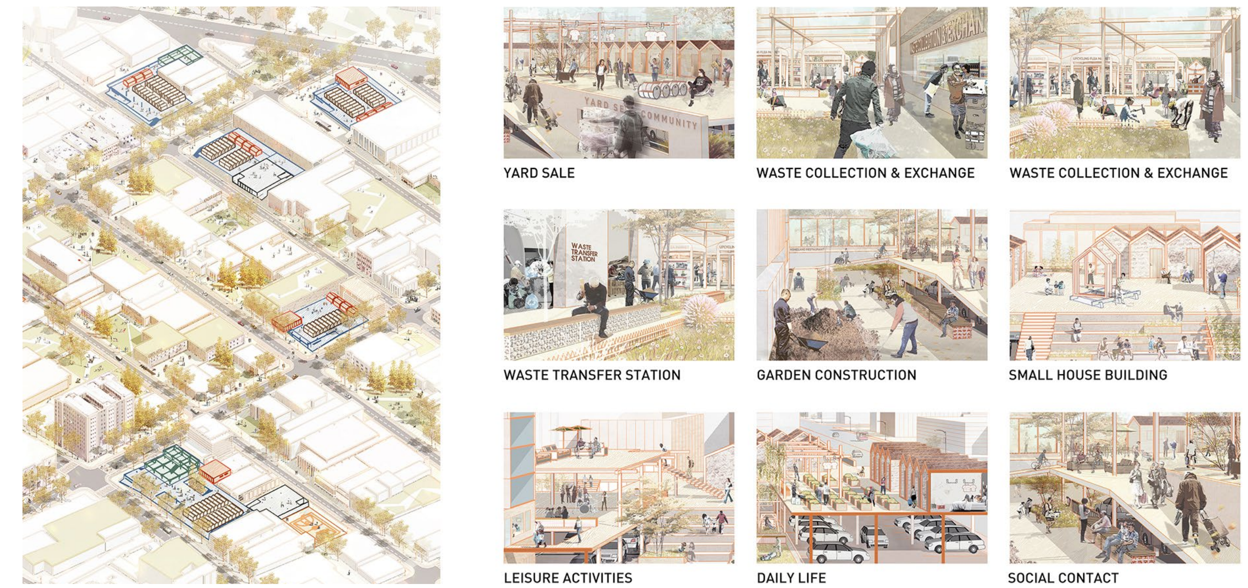

Figure 23. Proposed LA Waste-Related Community Programs. (Zhou et al., 2021, image from ASLA)

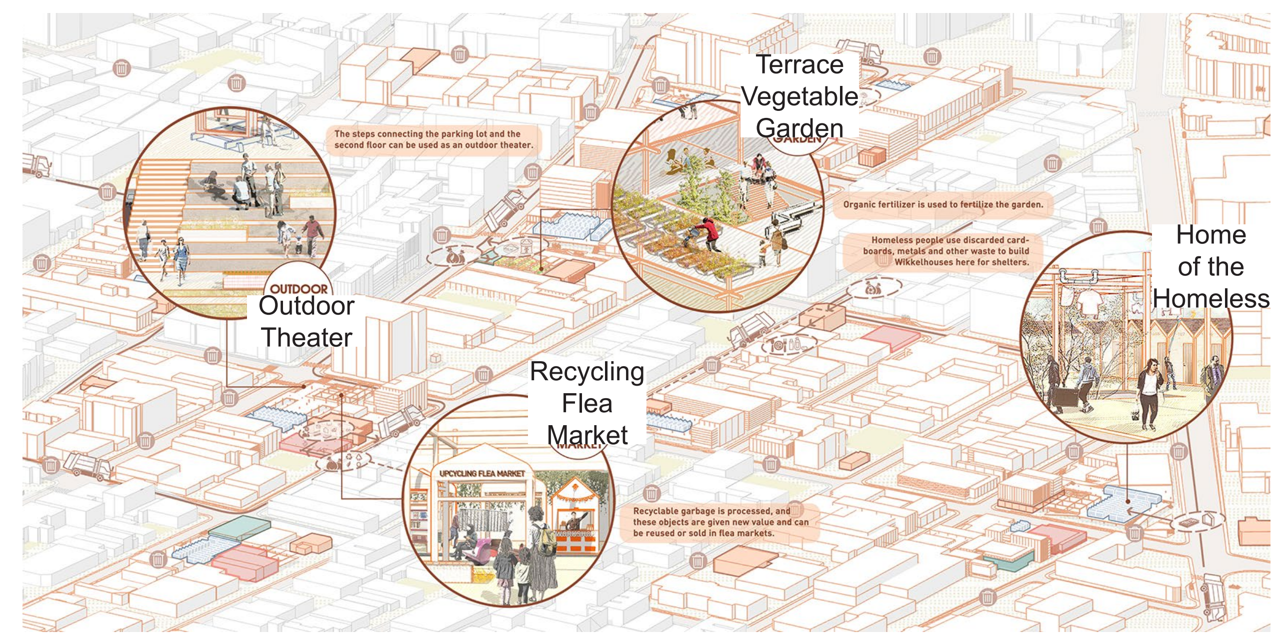

Figure 24. Proposed LA Waste-Related Community Program Network. (Zhou et al., 2021, image from ASLA)

CHAPTER 4 U DISTRICT

To understand the existing programs and future needs of the U District, I analyzed its demographics, economy, spatial structure, district plans, and existing waste reduction programs. This information is summarized in this chapter.

4.1 Demographics

The U District is a growing neighborhood in Northeast Seattle. According to the Seattle Housing growth report (2023), the U District had 9,951 housing units and 47,678 jobs in 2015, with an estimated capacity for an additional 8,406 units and 10,284 jobs. Since then, another 3,769 units have been built, with another 1,001 issued, not yet complete since Seattle Comprehensive Plan’s adoption in 2016 (see Figure 25). In addition, according to Seattle In Progress, 59 recently completed and proposed developments in the district will add more than 6,000 rooms (not including single-family homes and projects that do not go through design review; Phelps-Goodman, 2023; see Figure 26).

The increasing population will lead to more waste generation. Zero-waste interventions such as localizing material cycles, diverting waste away from landfills, and promoting reuse and repair can help the district generate less waste, become cleaner, and reduce its ecological footprint.

The U District is a diverse and young neighborhood. According to a report by Land Econ Group (2019a), there were 31,194 residents as of 2018. Of these, 56% are White, 32% are Asian, 3% are Black, 7%

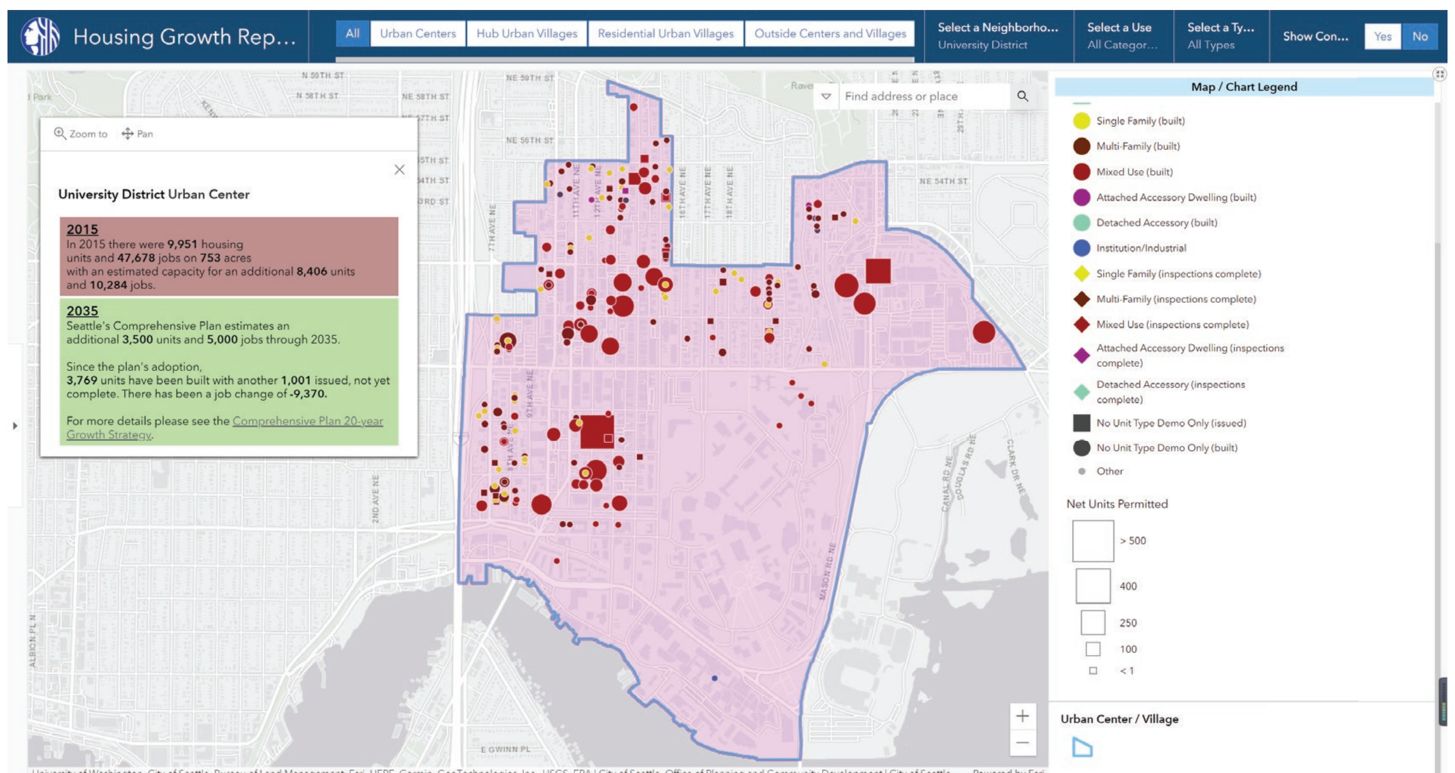

Figure 25. Screenshot of University District Urban Center Housing Units Projection. (Seattle Housing Growth Report, 2023)

Figure 26. Map of U District Future Developments. (diagram by author, information based on Phelps-Goodman, 2023)

have two or more races, and 6% have a Hispanic origin (2019). According to the Seattle Department of Neighborhoods (2018), 26 languages are spoken in the U District. The U District Partnership's website entails that the student population is the primary consumer group in the district (Land Econ Group, 2019b). This claim is also supported by the U District's low median age (22.6 according to Land Econ Group, 2019a; 25 according to city-data.com, 2022).

The UW school season significantly impacts the district's demographics and user groups. According to my interview with Maya Lu from a U District restaurant named Boba Up, her restaurant has different customer groups during school seasons vs. summer breaks (personal communication, May 22, 2023). "During school seasons, there are more school-related customers: orders from UW departments for meetings, club events, and elementary school field trips. During summer breaks, there are more tourists, UW students' families, and corporate catering" (M. Lu, personal communication, May 22, 2023). In addition, some other restaurants, like Supreme Pizza, have fewer orders during summer breaks (Supreme Pizza employee, personal communication, March 21, 2023). This means some restaurants may generate less food waste in summer.

The U District's unique characteristics bring challenges and opportunities for waste management. A typical UW student stays in Seattle for 2-5 years, though some of them remain in Seattle after graduation. Data indicate that both domestic non-resident and international student populations have been growing in the last three academic years (UW Office of Planning & Budgeting, 2023). This suggests that in the future, there will be more U District residents coming from areas with different recycling policies than Seattle. Like anyone, those students may dispose of waste incorrectly due to insufficient knowledge, guidance, and support. The student population also brings waste-to-resource opportunities and ideas, such as the student-initiated all-compostable serviceware program (Blasco, 2008; UW Sustainability, 2009). In addition, they may bring U District's zero-waste strategies across the country and abroad when they reunite with their families.

Besides students, the U District is also used by employees working in and outside the district, tourists, and people who live on the streets. They are all stakeholders in U District's material lifecycles.

4.2 Economy

U District residents face financial challenges with 18.85% inflation in living costs since 2019 and a 7-19% increase in rental prices (U.S. Bureau of Labor Statistics, 2023; Browning, 2023). A circular economy can ameliorate U District residents' financial burden. By cycling materials within the district, its residents and businesses can reduce the costs of purchasing new materials outside the district. For example, reducing consumption, selling/purchasing used items, and growing vegetables at home can help the community reduce their financial burden without compromising comfort.

4.3 Spatial Structure

This section analyzes three major areas and four major streets in the U District for potential zero-waste intervention sites. The selection of these places are based on the zones determined in the U District Design Guidelines (Design Review, 2019), the streets analysis in the U District Station Area Mobility

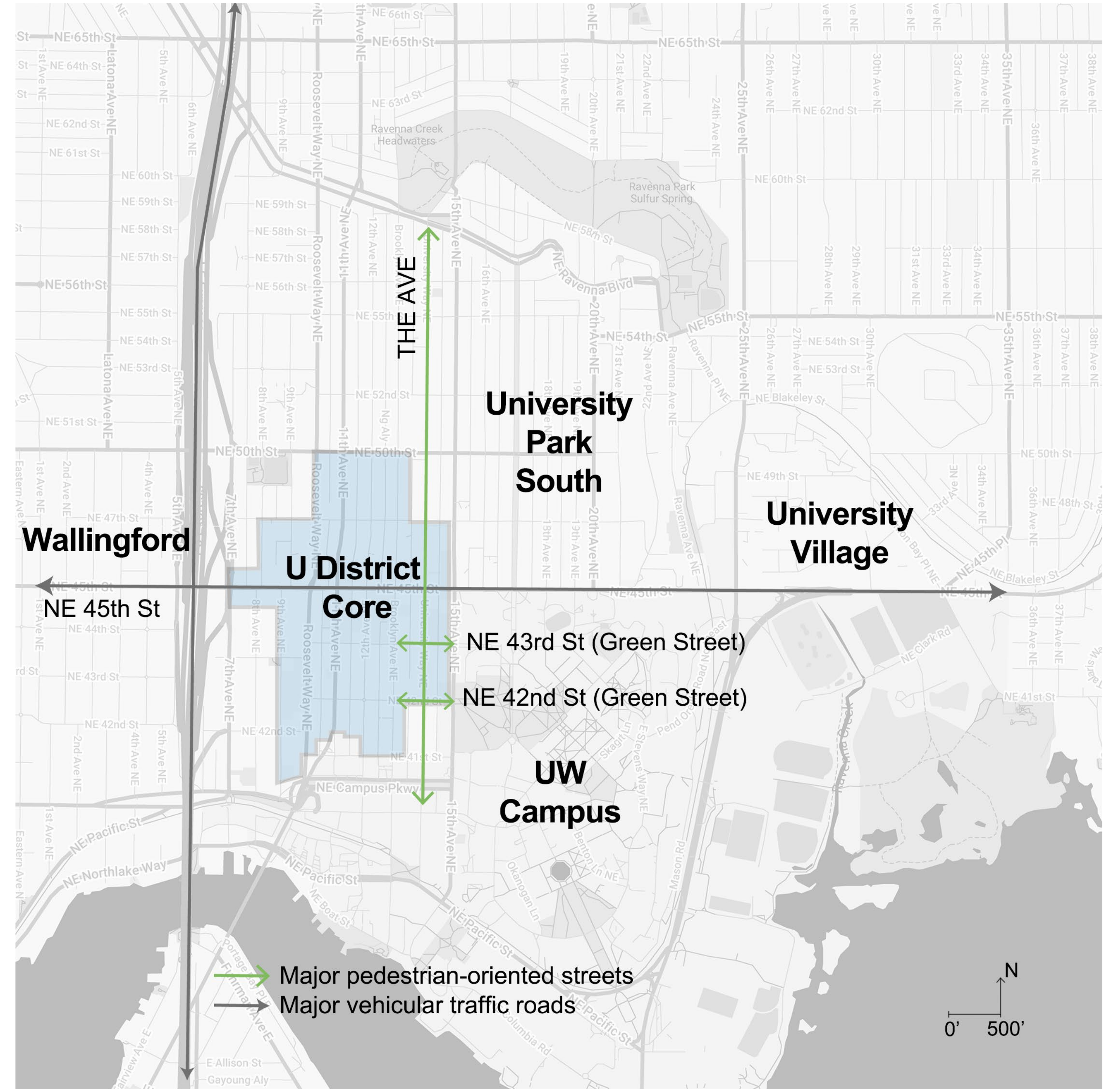

Figure 27. U District Spatial Structure. (diagram by author, based on Google Map, U District Design Guidelines 2019, U District Station Area Mobility Plan 2018, and U District Green Street 2023)

Plan (U District Mobility Group, 2018), and recent green street projects (U District Advocate, 2023). The three major areas are: (1) U District Core, with high-rises from 240' to 320'; (2) UW Campus, an academic institution with many students, faculty, staff, and tourists; and (3) the residential areas, which have a mix of houses and low- to mid-rise residential buildings. There are four major streets in the U District: (1) University Way, known locally as "The Ave," which is a commercial strip connecting UW west campus with Ravenna Park; (2) NE 45th St, crossing East-West through the district, connecting Wallingford with U District Core, UW Campus, Greek Row, and University Village (UV); (3) NE 43rd St, a green street connecting the Link Light Rail Station on Brooklyn Ave and UW Campus; and (4) NE 42nd St, a proposed green street project to connect Brooklyn Ave NE with the UW Campus (U District Advocates, 2023; see Figure 27).

The Northeast forty-third street is a one-way road with a bike lane, wide sidewalk, seating areas, and rows of plants. Because of its proximity to the Link Light Rail Station, interventions on this street can utilize its high pedestrian traffic to increase environmental knowledge and spread U Districts' zero-waste designs to other areas.

Northeast 42nd Street's Green Street Project may also have high pedestrian traffic as it connects the high-rise apartments in U District Core with UW Campus. A vacant lot waiting for development is on the southeast corner of its intersection with the Ave. In addition, University District Design Guidelines' PL3 encourages human interaction and activity at the street level (Design Review, 2019), providing vacant lot opportunities for ground-level landscape interventions.

4.4 Food Waste

Food can be wasted for various reasons and during different stages (harvest, transportation, distribution, and consumption) from farm to table (Buzby et al., 2014). For example, animals, microbes, and weather can damage vegetables at farms; spillage, abrasion and excessive trimming can cause food waste in the distribution stage; and personal preference, insufficient food preparation and storage knowledge, and technological barriers can cause food waste at the consumer level (Buzby et al., 2014).

4.4.1 Issues

The U District has many waste issues. There are compostables in garbage receptacles (CCG, 2017, 2018, 2022), which could result from lack of compost cans, food scraps packaging littered on the ground, and large amounts of food waste generated by residents and visitors. Food containers are also prevalent types of litter in alleys. For example, on May 23, 2023, there were eight pieces of compostables and fifteen pieces of recyclables out of thirty pieces of garbage in an alley in U District (see Figure 28). According to the Waste Behavior Model (see Chapter 3, Figure 11), these phenomena indicate that food and container waste may not be valued enough to be placed in compost and recycling receptacles.

Besides humans, crows and rodents may also litter alleys and streets. Some apartments near University Way have garbage collection receptacles outside. When they are full with food waste, the receptacles attract crows and rodents that carry the food along with their packaging into alleys and streets. So it is

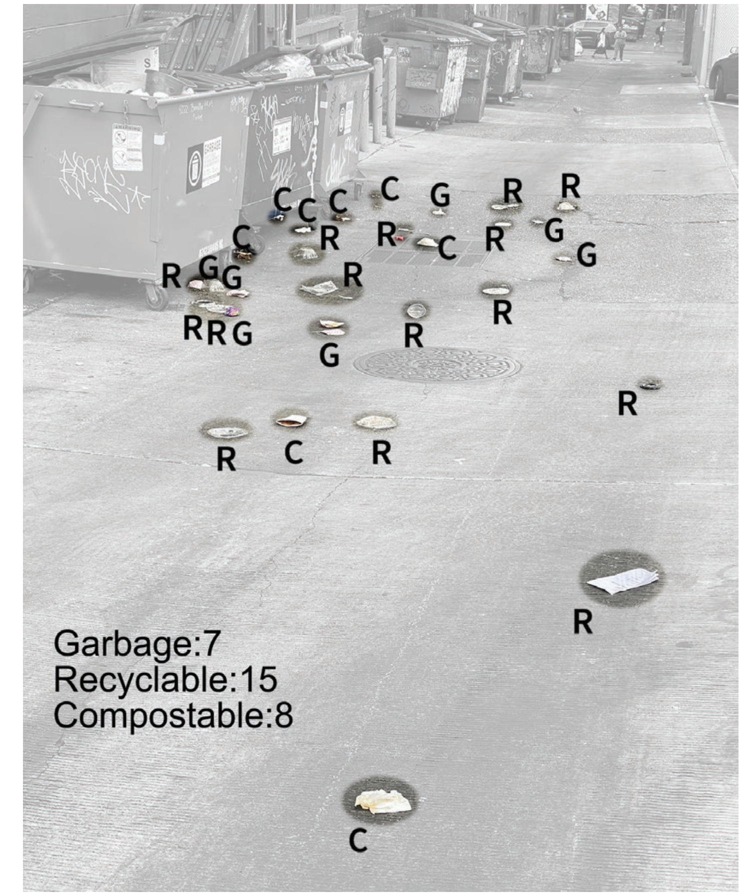

Figure 28. Litter in Alley. (photographed and illustrated by author)

critical to prevent dumpsters and cans from overflowing by reducing waste generation and disposing of food waste properly.

Building a circular food economy can make values of food waste more visible to the public. Besides, food is integral to people's lives. It is tangible, universal, and allows creativity. Through proper education and guidance from local organizations, the provision of physical amenities and policy support from the city, and active participation from local and regional businesses, the public can gradually notice the value of waste and reduce waste generation.

Landscapes and programs like urban farms, food waste processors, and community kitchens can increase people's knowledge on how to reduce and dispose of food waste, create more job opportunities, reduce dependence and costs on regional and global supply chains, and create a circular and inclusive economy.

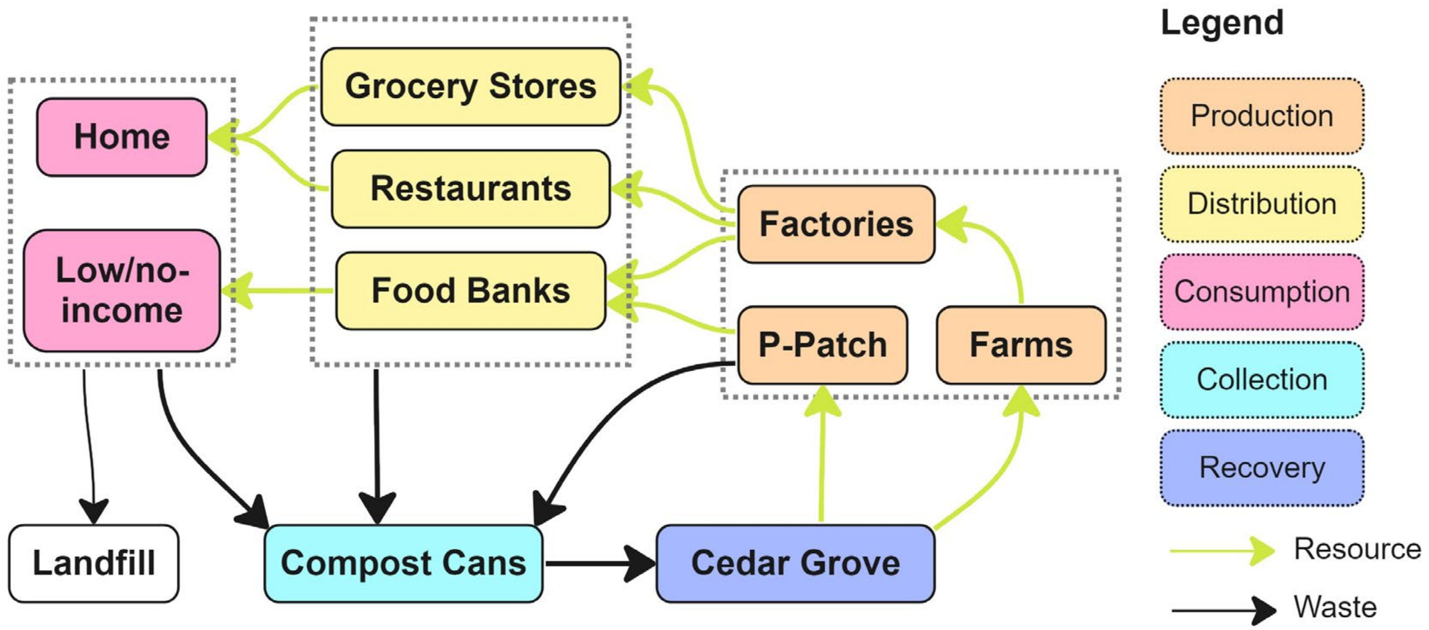

Figure 29. U District Food Lifecycle Diagram. (made by author)

4.4.2 Today's Food Lifecycle

The current food lifecycle in the U District includes producers (community garden/P-Patch), retailers (grocery stores, restaurants, food banks), consumers (general public), and waste collection crews (see Figure 29). The district needs more producers, public compost cans, and food waste recovery facilities to localize the food lifecycle.

In Figure 29, there are two primary cycles. In the first cycle, regional and global farms send produce to factories, where agricultural produce is turned into packaged food and sent to grocery stores and restaurants. Residents purchase food from grocery stores and restaurants to consume. Though most of the district's food waste is thrown into compost, some are thrown into garbage cans due to insufficient knowledge, lack of enforcement, and the unavailability of public compost cans. The food waste sent to compost cans is transferred to Cedar Grove Composting Facilities, which sells fertilizer to residents and farms across the state (Cedar Grove Composting, 2023).

In the second cycle, some P-Patch (community garden for residents and food banks; Seattle Department of Neighborhoods, 2021) gardeners buy fertilizer from Cedar Grove Composting and deliver food to food banks in the U District. Food banks provide free or affordable food to low and no-income residents in the region. Unhoused individuals are more likely to dispose of food waste and containers in garbage cans or on the street because of insufficient environmental knowledge, guidance on waste disposal, and available programs to make "desired behaviors" more convenient and accessible. In addition to the two primary cycles, all stages create food waste, so three arrows in Figure 29 lead toward the compost cans (food waste collection).

4.4.3 Food Lifecycle Inventory

This section uses Google Maps, OpenStreetMap, Apple Map, Seattle P-Patch website, Seattle GeoData, and personal observations to understand the locations and quantities of the existing food lifecycle elements in the U District.

As of May 2023, there are six grocery stores in the U District: Trader Joe's, Safeway, Target, H Mart, two District Markets on the UW campus, and 154 restaurants (including cafes and bars), selling food to residents in 248-acre area (Seattle GeoData Private Member, 2022; see Figure 30).

In this map, grocery stores are spread across the district, while the restaurants tend to cluster along The Ave, NE 45th St, and NE 50th St. Residential areas are primarily outside the U District Core and UW Campus.

The district also has four P-Patch gardens: Shiga's Garden, University Heights, Ravenna, and University District (more than 21,600 square feet [sf] in total), giving food to local residents and five food banks: UW Food Pantry, University District Food Bank, Blessed Sacrament Food Bank, Teen Feed, and University District Youth Center (see Figure 31). The five food banks serve different groups. For example, the UW food pantry is for "students, staff, and faculty who are having a hard time putting food on their plate" (UW Food Pantry, 2023), while Teen Feed and University Youth Center target youth and young adults (University District Youth Center, 2022; Teen Feed, 2023). Though many meals are consumed indoors, there are seven outdoor dining areas managed by local businesses in U District, and twenty-nine pairs of garbage and recycling cans along The Ave to collect waste (see Figure 31). Street cans are emptied daily at night by Recology. Due to lack of compost cans on the streets (see Figure 32), the food lifecycle is broken at the collection stage.

In summary, the U District has a generally young and diverse student-dominated population that fluctuates throughout the year. Increasing housing prices in the district create a burden for residents, especially low and no-income residents. A localized food lifecycle can ameliorate some financial difficulties and reduce waste going to landfills. The U District Core can utilize its high-traffic flow to initiate the interventions and extend their impacts to help the district become cleaner, reduce waste generation, and reduce its ecological footprint. As the elements are gradually implemented to complete the food lifecycle and showcase how food waste is turned into resources, the interventions and programs can expand to more places outside the U District Core, forming a district-scale food lifecycle network. See the next chapter for detailed designs and programs.

Figure 30. The current locations of Grocery Stores, Restaurants, and Residential Areas in U District. (diagram by author)

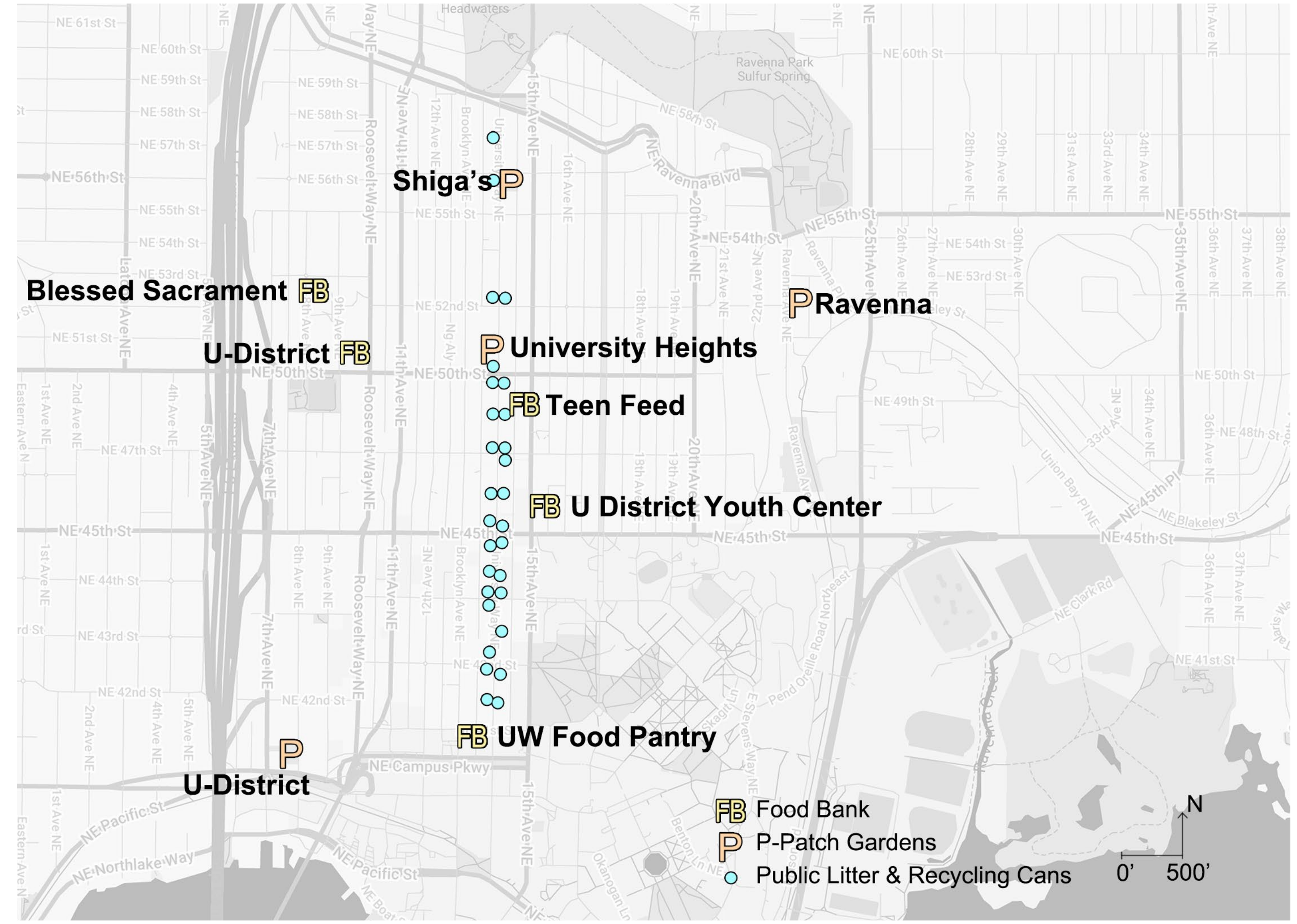

Figure 31. Current locations of P-Patch, Food Banks, and Public Trash Cans in U District. (diagram by author)

Figure 32. A Typical Pair of Public Litter & Recycling Cans in U District. (photo by author)

CHAPTER 5 DESIGN

This chapter describes three site designs I propose to localize food lifecycles in the U District to prevent food waste from going to landfills and to reduce food waste generation. These are a biodigester plaza, a rooftop garden, and a community kitchen. I will first identify the interventions still needed in the U District to reduce waste (i.e., biodigesters, roof gardens, community kitchens, and compost cans). I also chose the food-bank cycle and the restaurant cycle, from the food lifecycle diagram (see Figure 33 and Figure 34) as my design focus. The four types of interventions are incorporated into three sites in the U District Core close to the UW Campus to test the landscape interventions and design strategies. Lastly, this chapter identifies potential sites for future expansions for the four types of interventions.

5.1 Proposed Food Lifecycles

To complete the food lifecycle, I remodeled today's U District Food Lifecycle (see Chapter 4 Figure 29) into a zero-waste system, in which all food wastes are recovered, and the processes are localized as much as possible (see Figure 33).

The proposed system is color-coded based on the stages of a material lifecycle (see Chapter 2 Figure 8). It identifies four elements that the district needs (bolded and underlined in the diagram) to achieve a localized circular economy that collects, repurposes, and reuses food waste locally:

- Public compost cans to reduce the public's cost of composting outdoors, preventing compostables from garbage streams.
- A biodigester machine to process food waste locally in an urban area. Compared to a regional composting facility, a biodigester takes less time to process and less space to install.
- Roof gardens to use the fertilizer from biodigesters to keep the materials in the district.
- Community kitchens to make raw food edible and meals tastier, thus reducing waste generation in food preparation and consumption.

The Proposed Food Lifecycle Diagram (Figure 33) has three primary cycles. In the first cycle, P-Patch Gardens produce food for food banks. The food banks bring food to the proposed community kitchens to turn food ingredients into meals. Then, food waste from community kitchens and food banks is carried to the proposed biodigesters, which produce fertilizers for P-Patch gardens.

In the second cycle, the proposed roof gardens produce fresh vegetables, fruits, and herbs for residents (who grow the plants), restaurants, and potentially grocery stores. The restaurants and grocery stores sell prepared meals and food to workers, visitors, and residents, who would dispose of food waste in the proposed public or at-home compost cans. Those compost cans are collected regularly to send to the proposed biodigesters, which turn food waste into fertilizer for the roof gardens.

Because of the limit of available arable land, not all food that U District needs can be produced locally, so there remains a regional cycle. In this food lifecycle, food waste is composted at Cedar Grove Composting facilities and is used at regional farms. Food is redistributed from farms to grocery stores,

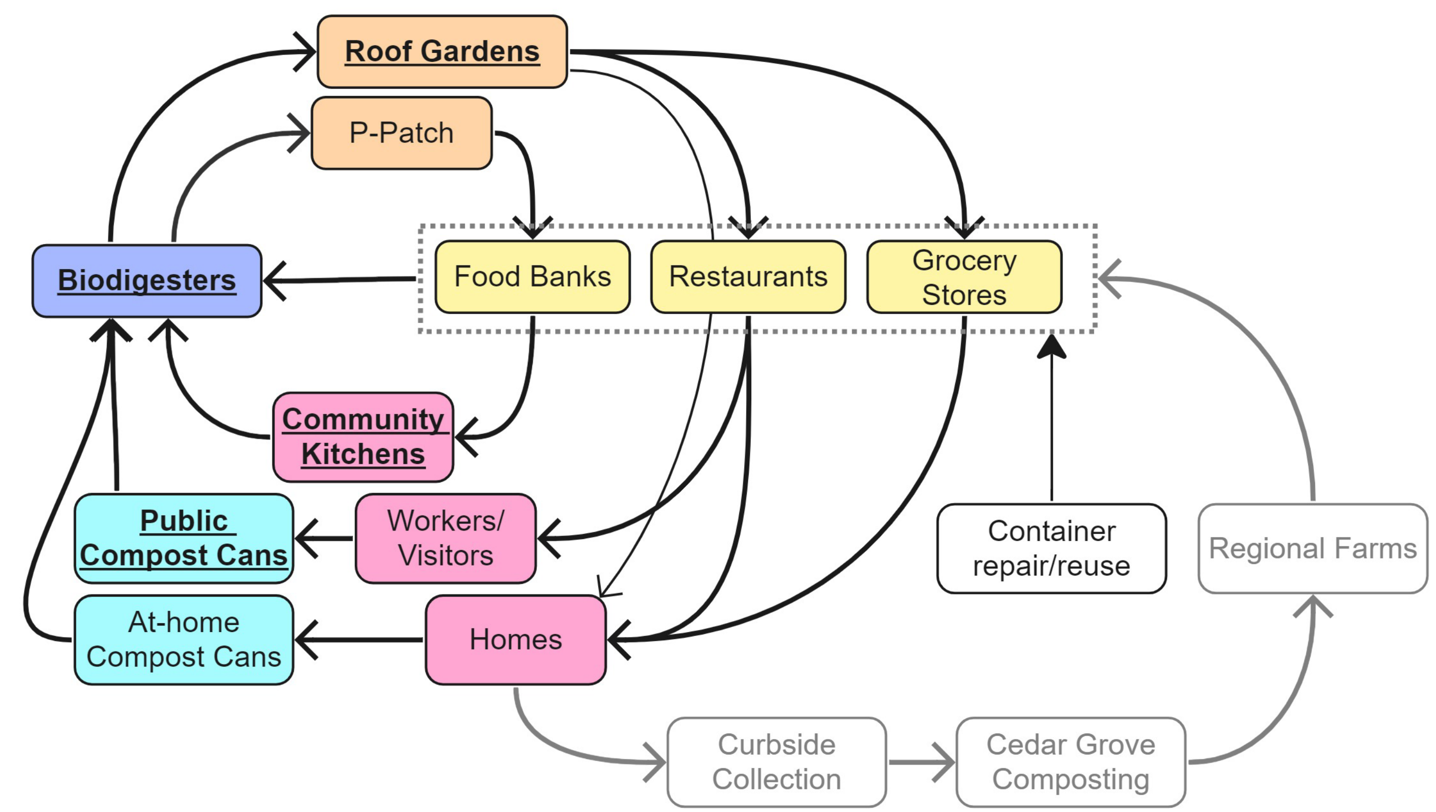

Figure 33. Proposed Food Lifecycle Diagram. (image by author)

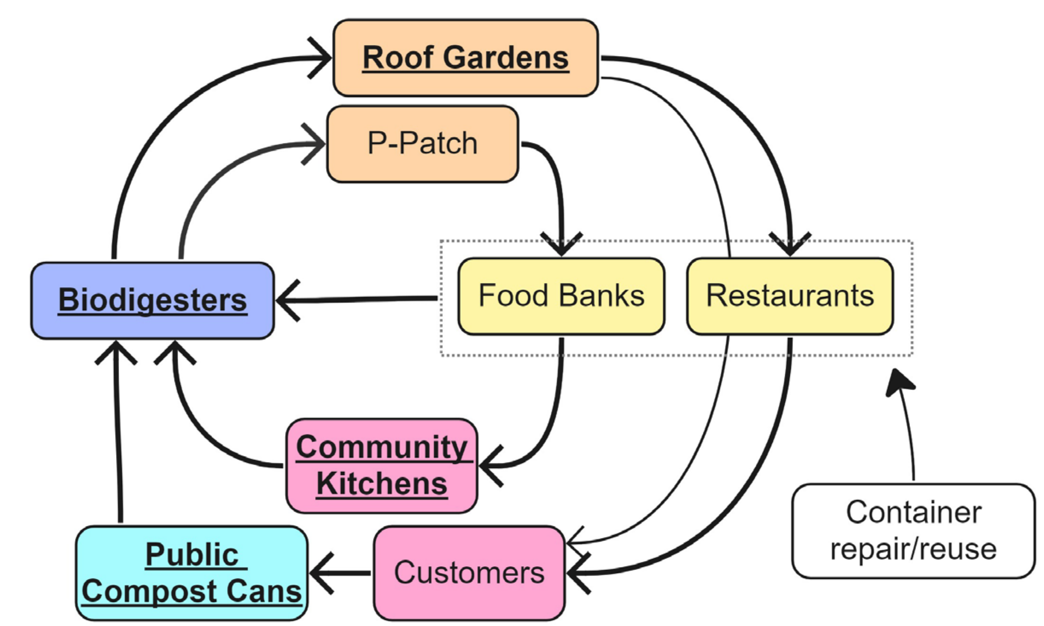

Figure 34. Simplified Food Lifecycle Diagram. (image by author)

restaurants, and food banks. Because food containers are a significant contributor to Seattle's landfilled waste (CCG, 2017, 2022), I also added a box to promote container repair and reuse to reduce the amount of container waste.

To narrow the focus and prioritize design interventions, I simplified the diagram into two primary cycles (see Figure 34). These two cycles are: (1) P-Patch gardens → food banks → community kitchens (new) → biodigesters (new) → P-Patch; and (2) roof gardens (new) → restaurants → customers → public compost cans (new) → biodigesters (new) → roof gardens (new). I chose three sites in the U District for the four new interventions to test their feasibility and effectiveness.

The three sites I propose in my design are "Be Boundless Kitchen" at 4144 University Way NE, "Biodigester Plaza" at 4227 University Way NE, and "Station South Roof Garden" at 1305 NE 43rd St (see Figure 35). The Be Boundless Kitchen is a community kitchen that also has a biodigester. It completes the first food lifecycle with University District P-Patch and UW Food Pantry (see Figure 36). The Biodigester Plaza and Station South Roof Garden are places to process food waste and use the fertilizer to grow food. They complete the second food lifecycle with two local restaurants (i.e., Chipotle and Pho Shizzle; see Figure 37). Each site has a primary theme (biodigester, roof garden, and community kitchen respectively) and each is supplemented by other elements (e.g., public compost cans, sinks, and seatings).

Figure 35. 3 Piloting Sites. (image by author)

Figure 36. First Proposed Food Lifecycle. (mapped by author)

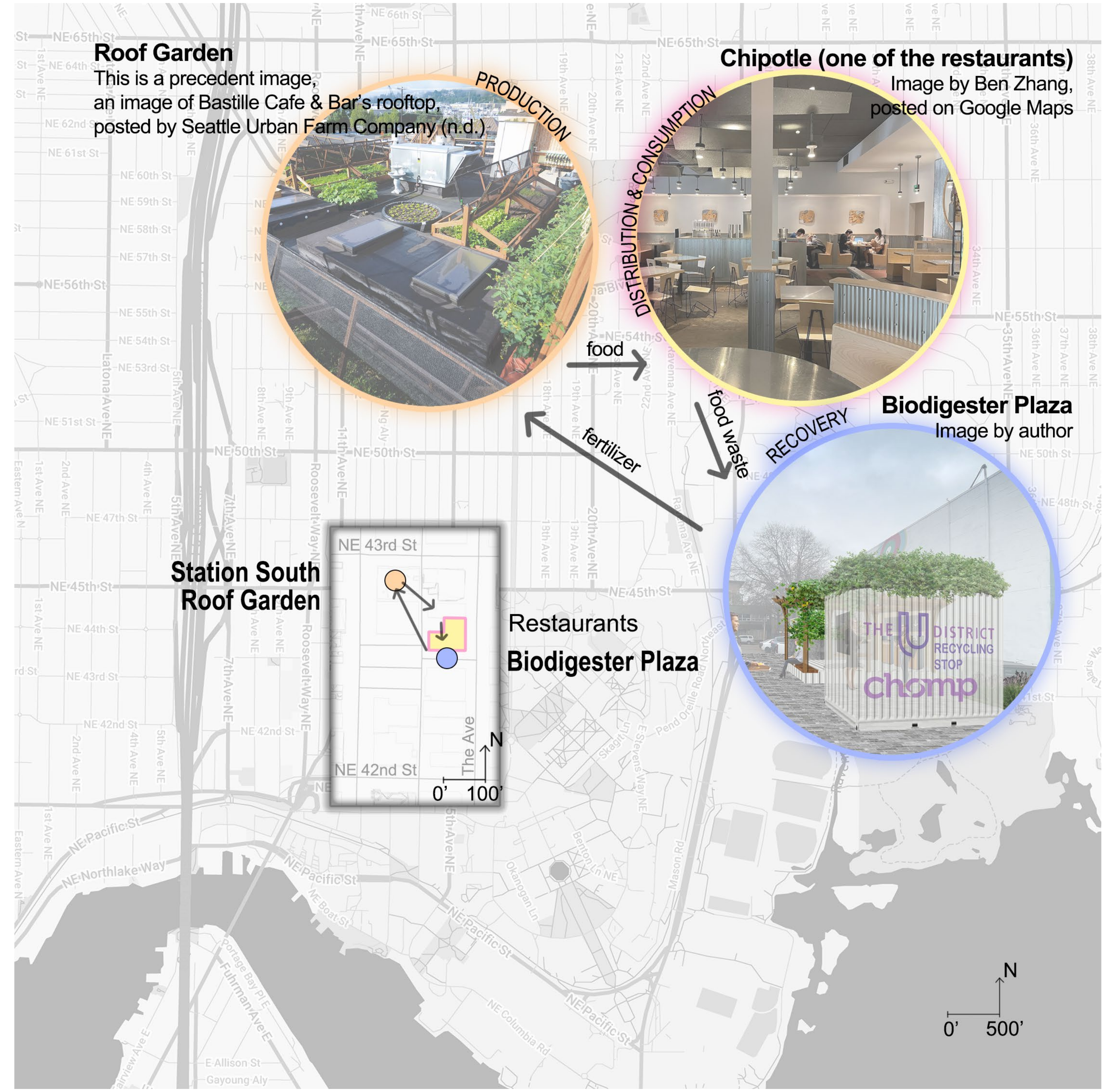

Figure 37. Second Proposed Food Lifecycle. (image by author)

5.2 Biodigester Plaza

5.2.1 Location

The “Biodigester Plaza” is proposed for what is now a parking lot at 4227 University Way NE. This midblock site would be a place to showcase how food waste can be turned into fertilizer. This site was selected because the biodigester needs constant food waste input, and the site is located in a mixed-use area between restaurants on University Way and apartments to the West (see Figure 38), whose workers and customers can feed the digester food waste. As an open public space close to the UW campus and Link light rail station (see Figure 39), this site would have many people use or pass through it. It could have supplemental programs like outdoor dining, public recycling cans, and sinks to increase awareness of the circular economy and zero waste.

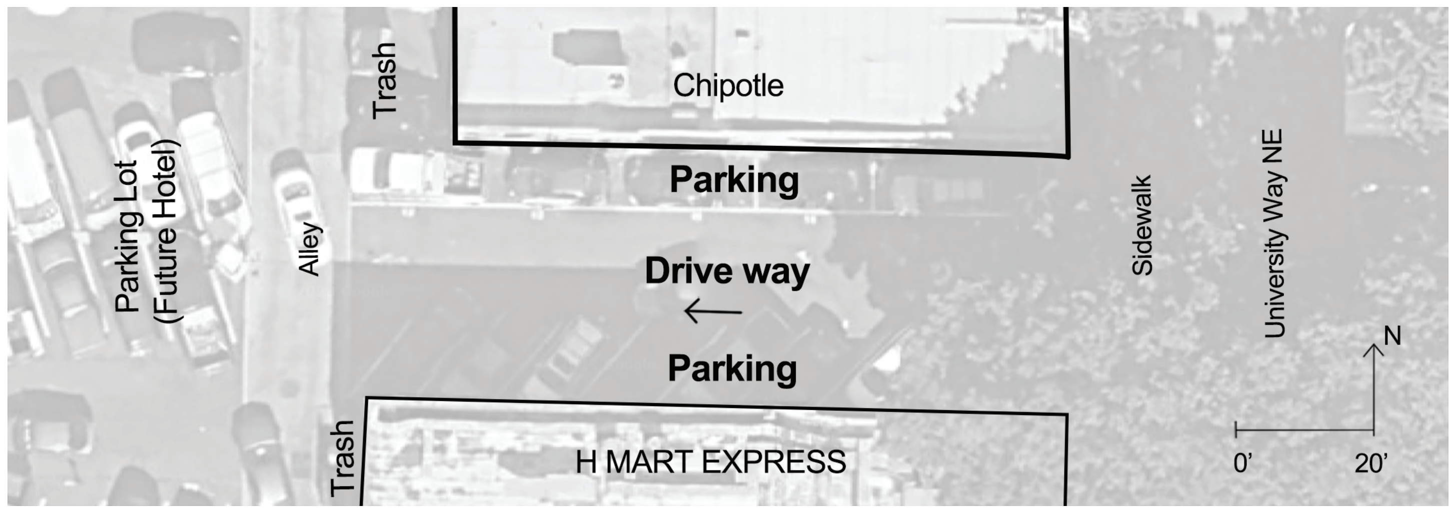

Figure 38. 4227 University Way NE Site Inventory. (image by author)

5.2.2 Layout & Primary Elements

The Biodigester Plaza would include covered tables and chairs at its center and a recycling area near the alley to buffer the socializing area and make garbage pick-up more convenient. Delivery parking is also next to the alley to reduce vehicular traffic on pedestrian-oriented University Way. The street side has a public restroom, providing a visual buffer to the seating area (see Figure 40).

The recycling area has a half-underground biodigester that connects to a compost can above. This site uses Chomp Energy’s biodigester Horse AD25 Model, which can take 960 pounds of food waste per week, a little more than five 96-gallon compost carts’ weight (see section 5.5.1 for calculation; Chomp Energy, personal communication, May 3, 2023; SPU, 2023a). The biodigesters can output 107 kWh of energy and 100 gallons of liquid plant food (fertilizer) per week (Chomp Energy, personal communication, May 3, 2023). That is enough power to charge one electric car (Marsh, 2022) or more than 100 electric bikes (assume the e-bike’s battery capacity is 1kWh). The amount of fertilizer it produces is enough to fertilize 2-3 acres of farmland (Chomp Energy, personal communication, May 3, 2023). Their biodigester can do this without using much space, given that the Horse Model is the size of a 20-foot shipping container (20’ by 8’) and can be placed in a parking spot.

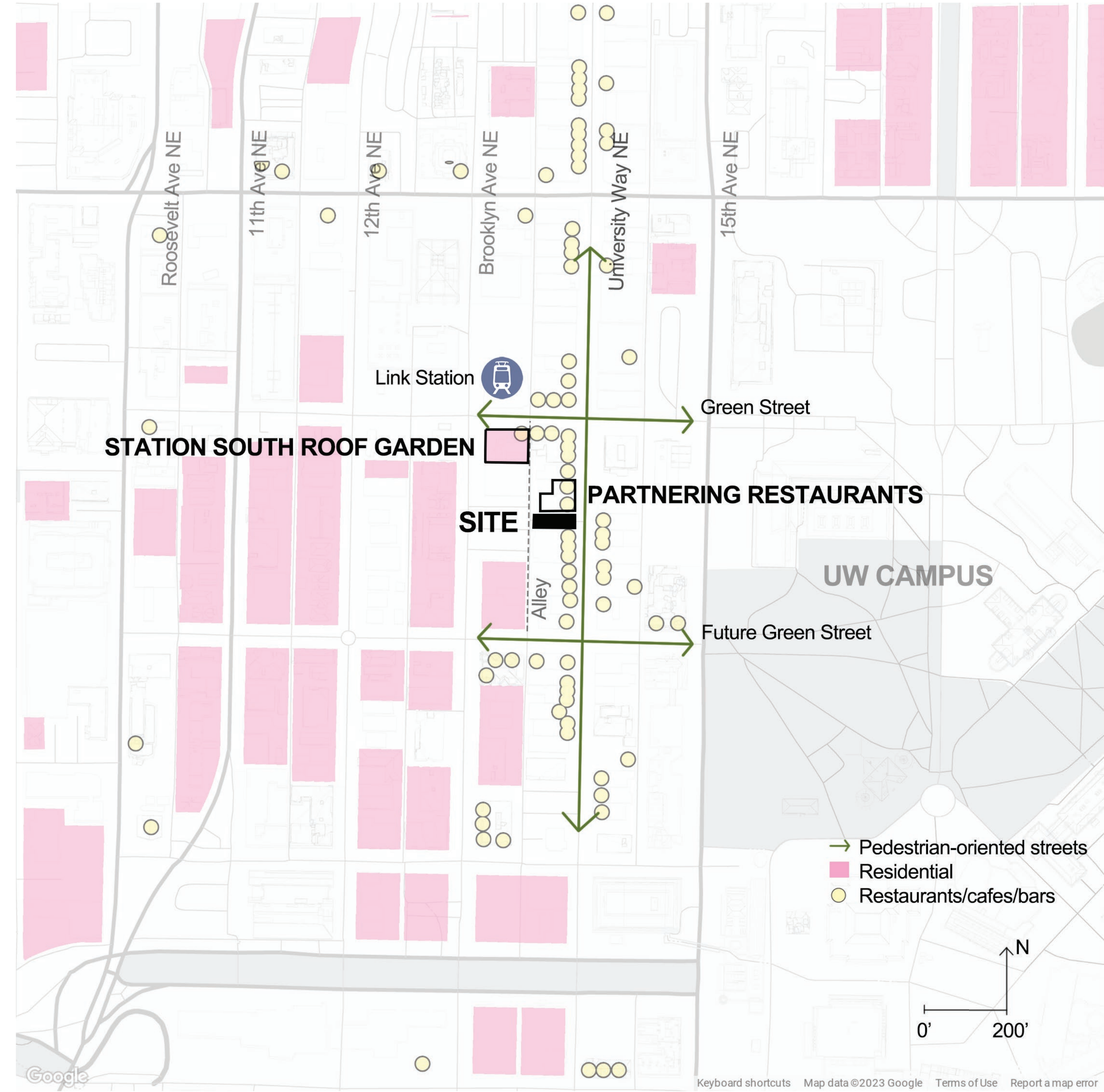

Figure 39. Biodigester Site Context Analysis. (image by author)

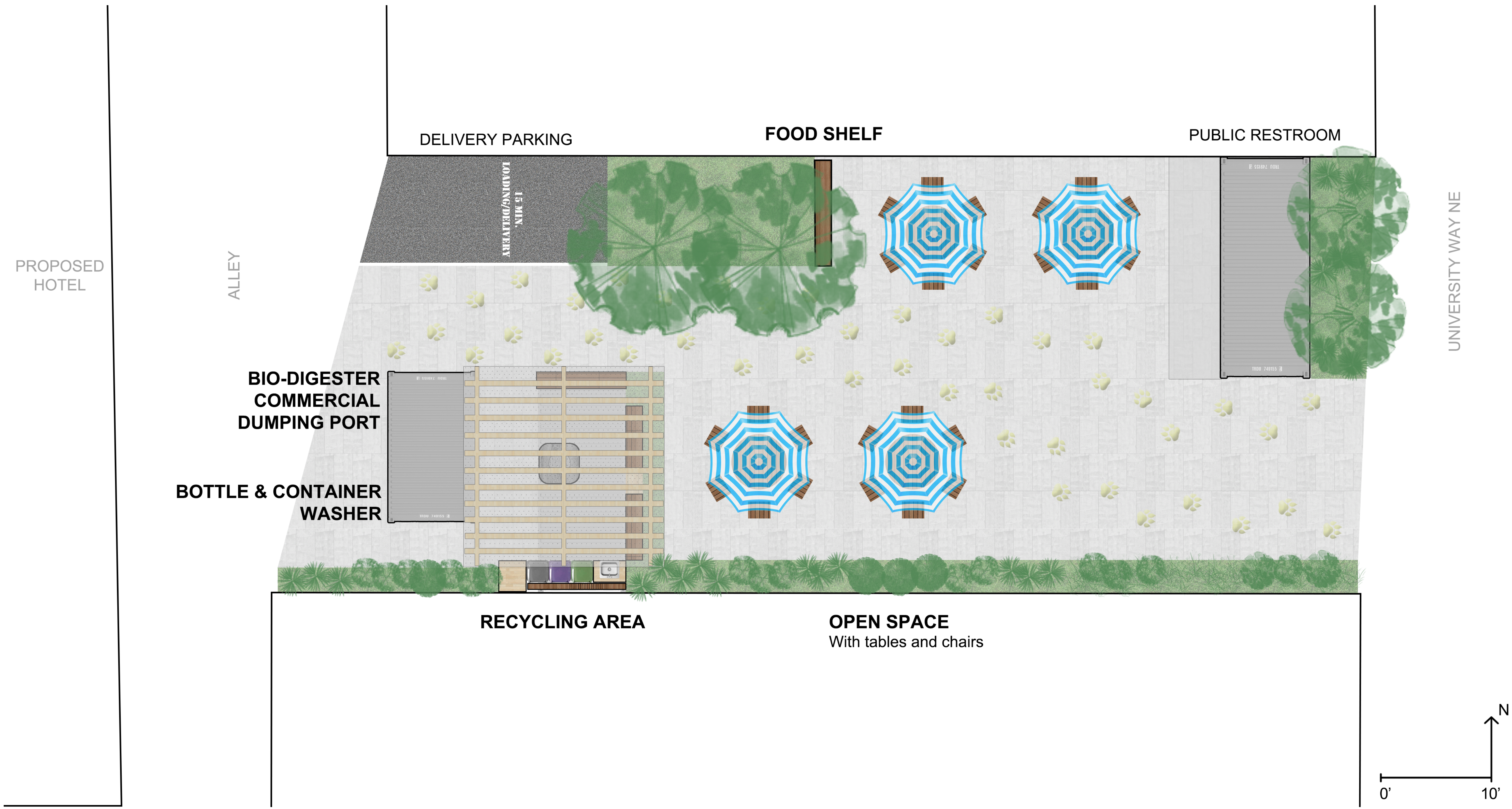

Figure 40. Biodigester Plaza Plan. (image by author)

The biodigester on this site processes food waste from the public and nearby restaurants. I used two restaurants, Chipotle and Pho Shizzle, as a basis for calculations around the amount of compost they produce. Both restaurants have a total of five 96-gallon compost carts, they can generate an estimated 900 lbs of food waste per week. The energy produced by the biodigester can charge plaza visitors' e-bikes and phones, and the fertilizer can be used in the Station South Roof Garden or sold to Seattle residents. Its revenue from energy and fertilizer can cover the cost of installing and maintaining the biodigester.

The biodigester enables the public to witness their food waste turned into fertilizer and energy, making visible the values of food waste and encouraging the public to dispose of food waste in the digesters instead of on the ground or in garbage cans. The biodigester is also a part of the food lifecycle network, which aims to send less waste to the centralized system and reduce the district's ecological footprint.

In addition to waste diversion, the biodigester at this site can add a scale and a screen to record and publicize the weight of the food waste thrown away to date and during the past week, challenging the public and restaurants to reduce their food waste generation.

5.2.3 Other Elements

A garbage can, a recycling can, and a sink accompany the compost can where the public can feed the digester. A pergola covers the area to protect people and waste from weather and animals. The sink allows people to wash hands and food containers so that soiled containers can be recycled or reused (see section 5.5.4 for details).

To prevent those who do not know Seattle's recycling and composting requirements from throwing garbage into the wrong cans, I designed an AI sorting platform to guide them. It uses laser and LiDAR detectors hidden in a Harry Potter sorting hat hanging from the pergola to identify the correct placement for people's garbage based on SPU's Where Does It Go Tool (SPU, 2023e). After the sorting hat identifies the type of waste, corresponding trash cans will have arrows light up (see Figure 41). This program can attract visitors to play, increase their knowledge about what goes where, and prevent recyclables and compostables from going to landfills.

A shipping container (see Figure 42) is placed west of the pergola for restaurants to dump food waste in large quantities. The shipping container also has an automated bottle and food container washer. Compared to the public sink, the washer saves time from washing by hand and can be used by UW's reusable container program. This machine can potentially generate revenue to maintain the machine and the plaza.

Figure 41. Recycling Pergola. (image by author)

Figure 42. Biodigester Plaza View From Alley. (image by author)

5.3 Station South Roof Garden

Edible roof gardens have great potential for the U District. Many buildings in the U District today have open and accessible rooftops. New housing developments also have roof gardens. Roof gardens produce food and yard waste (e.g., fruit peels and leaves) that can be handled on both the building and neighborhood scale. First, yard waste can be composted on the roof with a compost tank, and in time that compost can be used to fertilize the rooftop gardens. In addition, food waste generated by the rooftop gardens can be sent to the U District biodigesters.

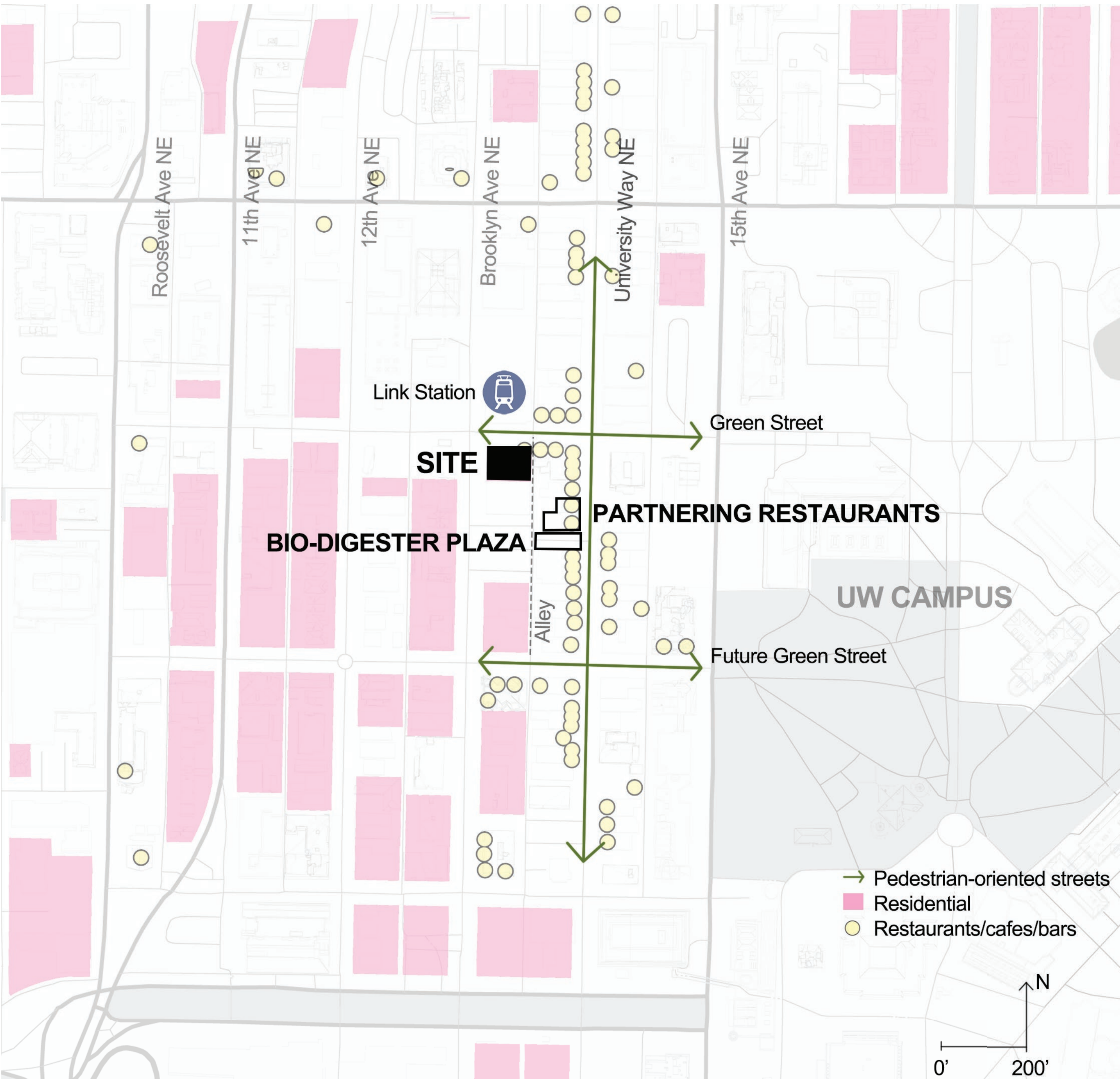

Figure 43. Station South Roof Garden Context Analysis. (image by author)

5.3.1 Location

For the Roof garden prototype, I have selected the site of University Manor, an eight-story apartment building with 80 residential units, on 1305 NE 43rd Street, to the south of Link Light Rail U District Station. This site is close to the Biodigester Plaza that will provide it with fertilizers, and to the partnering restaurants that take its produce (see Figure 43). Fertilizers coming to the garden and produce from the garden can be carried through the alleyway, where restaurants' waste pick-up and loading areas are. Considering more activated alleyways in the future and having the site in close proximity to the U District Light Rail Station the location can increase the program's exposure, raising awareness of this closed-loop partnership and encouraging other businesses and apartments to join the program. It is also a convenient place for tenants and their visitors to learn about zero-waste programs and enjoy the rooftop.

The roof has two existing entrances without any amenities (see Figure 44). The large vacant space could become an edible roof garden to complete a food lifecycle. However, there are many mechanicals on the rooftop. They need to be reorganized and grouped to transform the rooftop into a garden.

5.3.2 Layout

The proposed roof garden features planting beds and a fruit tree area on its south side for more sunlight, a seating area with dining tables on the north side, another seating area on the east side with coffee tables, and supporting areas like food storage, a tool shed, a compost tank, centralized rooftop

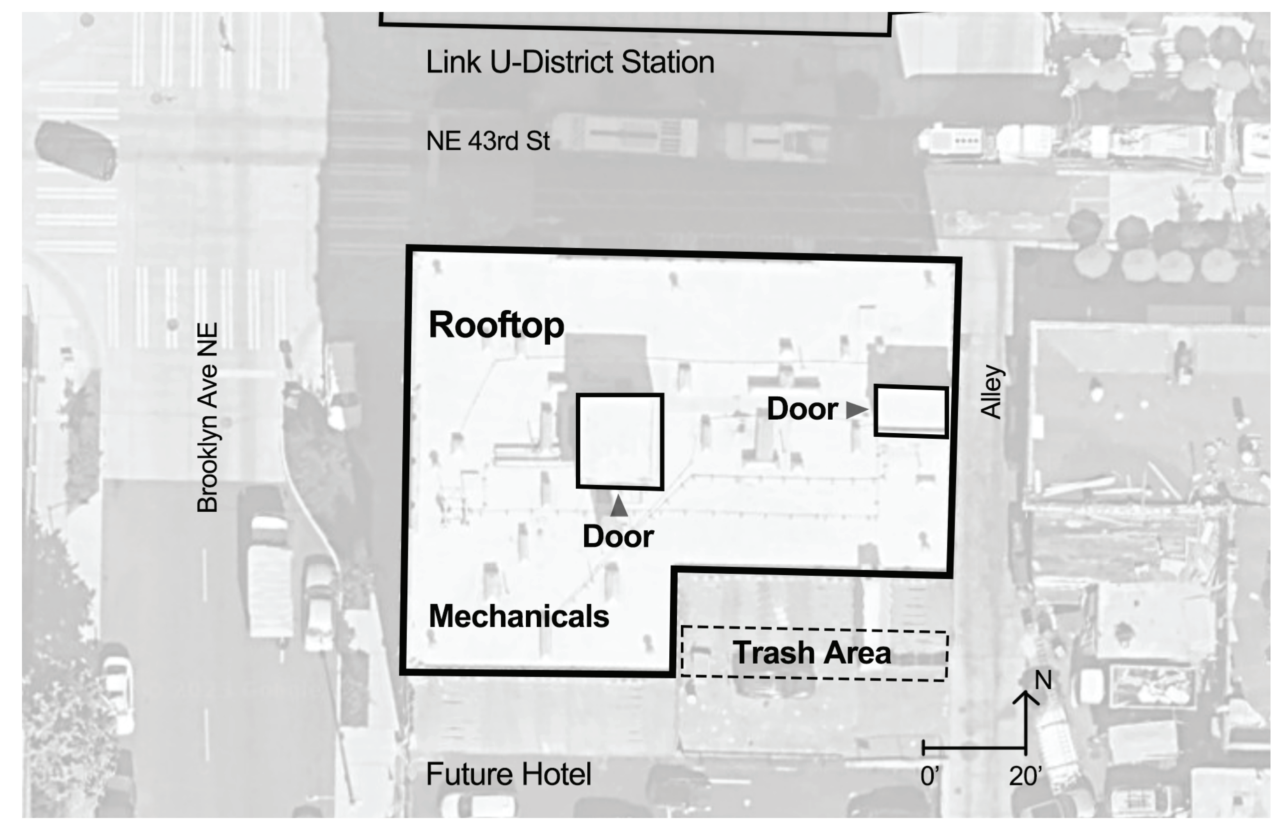

Figure 44. University Manor Rooftop Inventory. (image by author)

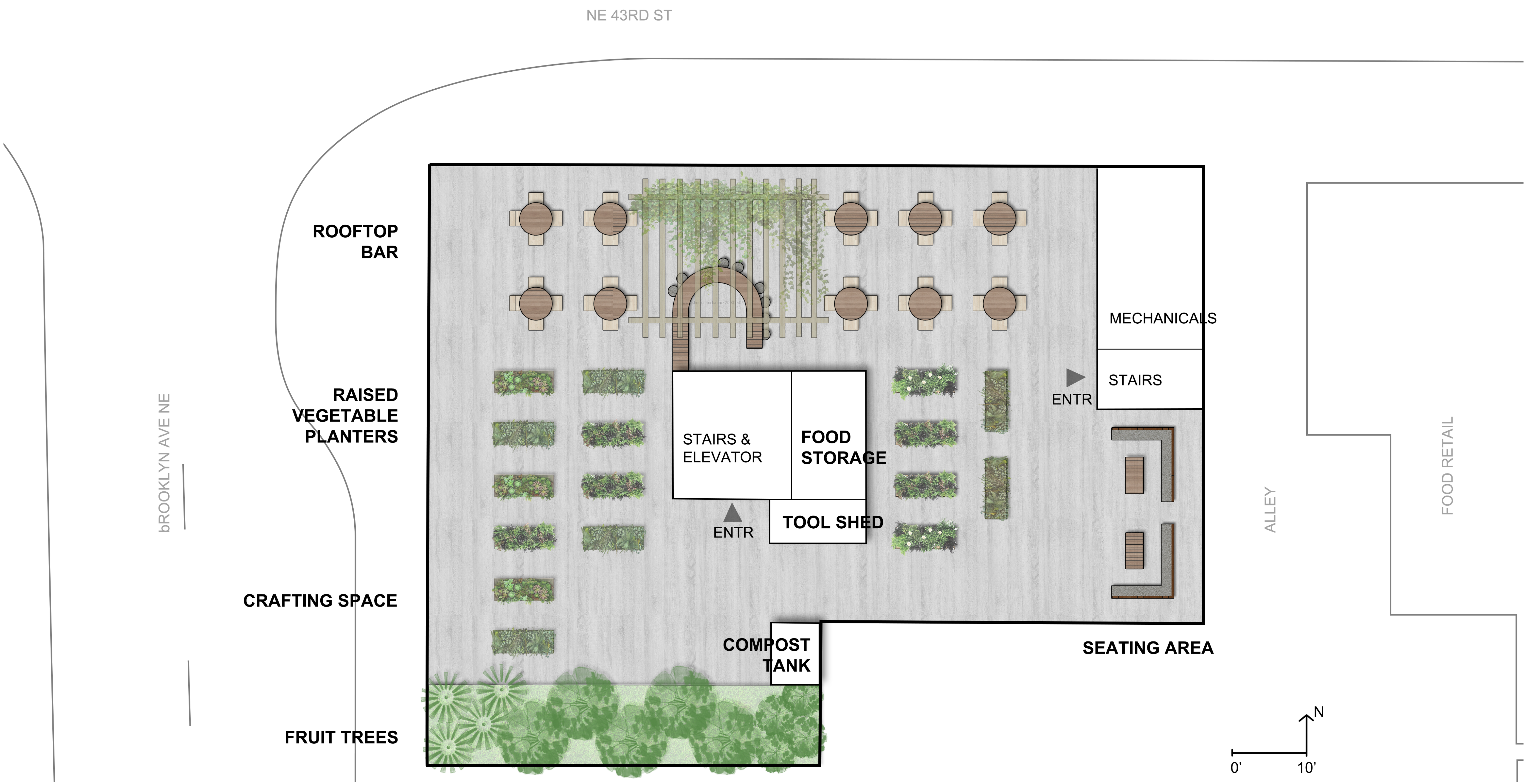

Figure 45. Station South Roof Garden Plan. (image by author)

mechanicals, and crafting space to process the plants (see Figure 45). The open spaces in front of the two entrances and along the roof's west edge are to offer panoramic views of Mount Olympic, Mount Rainier, and the Cascade Range. The open spaces can also accommodate gatherings for gardening, harvesting, and composting workshops.

Through these activities, residents can learn about sustainable food and yard waste management, valuing the waste, thus making their environment cleaner, generating less waste, and reducing the ecological footprint.

5.3.3 The Elements and Their Benefits

If they are accessible, residential rooftops are often used for studying, dining, and social activities. The Station South Roof Garden lets residents learn about gardening and engage in a more environmentally friendly approach to the food lifecycles by growing their food and fertilizing their vegetables with fertilizer from the district's biodigester. The food grown on roof gardens rewards residents for growing food locally. Gardening can also strengthen community bonds through classes and workshops. Together, these elements would support gardening, studying, dining, and socializing activities.

The roof garden can reduce food waste generated during harvest, transportation, and consumption. The views and workshops on the roof would attract residents and their guests, where they can learn about Seattle's edible roof gardens and experience a localized food lifecycle through gardening or tasting vegetables and fruits produced on the roof. By learning waste prevention techniques and seeing fertilizer made from food waste used to grow food, people can acknowledge the value of waste and contribute to a cleaner and more sustainable U District. These hands-on programs are more effective in diverting compostables than informational fliers placed by trash receptacles teaching about waste disposal because, according to Xun (ca. 313-233 B.C.E.), "doing is better than knowing, and knowing is better than seeing" (para. 23). Roof gardens reduce transportation distances compared to industrialized farms, thus reducing damage due to transportation. In addition, the amount of time residents spend gardening and harvesting increases the value of vegetables, thus decreasing the likelihood of residents wasting them.

5.4 Be Boundless Kitchen

5.4.1 What are Community Kitchens?

The community kitchens are shared cooking facilities with community events to turn raw ingredients into meals, improve food taste, and share food storage, cooking tips, and innovative techniques to minimize waste. A community kitchen would require moderate space to host cooking, dining, waste collection, socializing, and educational functions.

5.4.2 Location

The parking lot at the southeast corner of University Way NE and NE 42nd St was a two-story building with two restaurants and a store. The parcel (5,253 sf) is large enough to accommodate a kitchen, an open space, and 4-10 table sets. It is close to the UW campus and surrounded by cafes and restaurants (see Figure 46), which can bring many visitors to this site. I named this site "Be Boundless Kitchen" in response to UW's Be Boundless Campaign. I also hope this place can break the boundary between indoor and outdoor, break the barrier between the unhoused and housed, and bring the program to places beyond the U District.

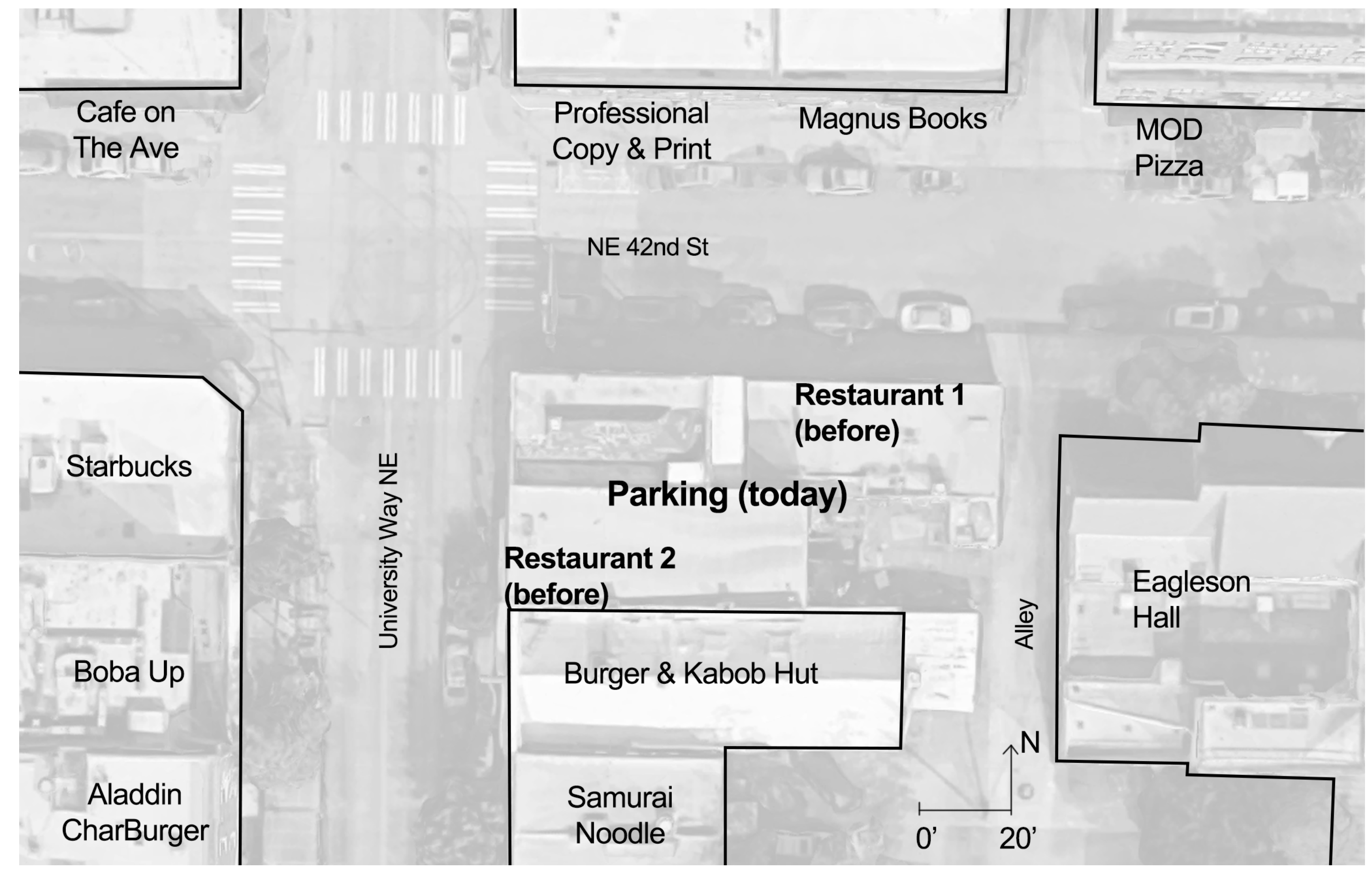

Figure 46. 4144 University Way NE Site Inventory. (image by author)

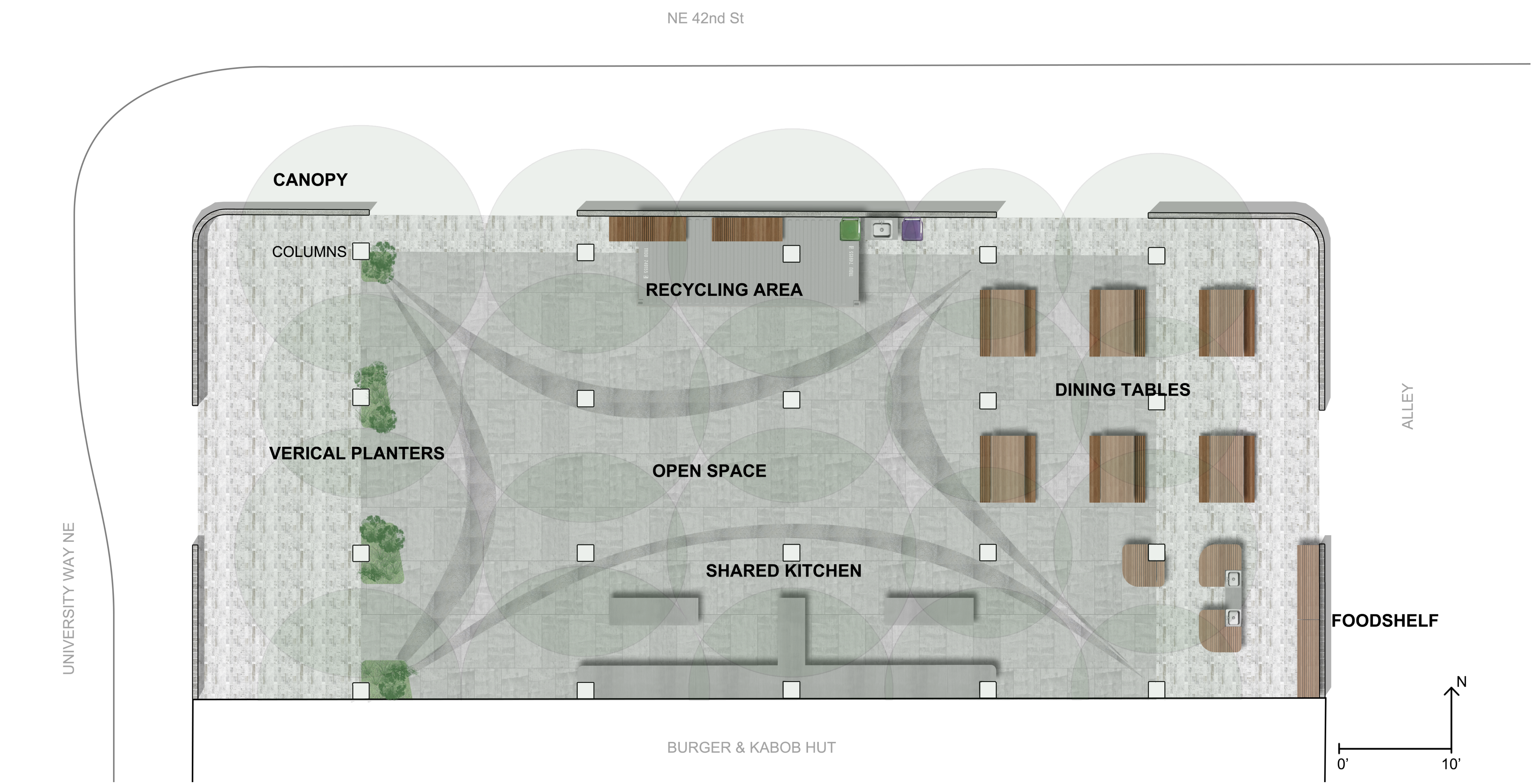

Figure 47. Be Boundless Kitchen Plan. (image by author)

The Be Boundless Kitchen will take food from the UW Food Pantry, process food waste through an on-site biodigester, power a fertilizer cart and the kitchen, and produce fertilizer for the University District P-Patch. The biodigester could also take food waste from nearby restaurants, including Samurai Noodle, Cafe Allegro, and MOD Pizza, to reach full capacity.

5.4.3 Layout & Elements

The Be Boundless Kitchen would have walls made from locally sourced bricks and use an array of recycled steel columns to support a recycled glass canopy to protect it from weather. There are four areas under the canopy. On its west side is a vegetable garden with vertical planters and shelves to grow and temporarily store food from the University District P-Patch and UW Food Pantry. On its south side is a cooking area featuring large counters, sinks, cooking appliances, cabinets, and refrigerators to store food. The kitchen area is separated into two sections with an island in the middle to accommodate two groups cooking simultaneously and to create opportunities for "cooking contests." Placing the kitchen to the south, in its south side building's shadow, can reduce its heat in summer. On the east side of the structure are table sets, sinks for washing, tables without seats, and food shelves for storage. On its north side is the recycling area. Like the midblock crossing, this area has garbage, recycling, and compost cans, a sink to wash containers, and an underground biodigester connected with the compost can. (See Figure 47)

5.4.4 Programs

The Boundless Kitchen can reduce food waste and food container waste through the following activities and programs: (1) the storage area could host food donation events and showcase professional ways to store food, which can help residents reduce food spoilage at home; (2) the culinary classes and competitions could be hosted by popular regional restaurants, and use diverse ingredients donated from the food pantry and the public to make tasty meals, which could inspire ways to cook leftovers at home; (3) the food shelf can securely store unserved leftovers, keeping crows and other animals out; (4) the sink allows people to wash their hands and containers, increasing food container recyclability and reusability; and (5) the Boundless Kitchen could sell its affordable reusable containers made from recycled materials, promoting reuse and reducing single-use items.

The three site designs above are initial sites to complete the food lifecycles in the U District in the short term. They are conceptual landscape designs and provide references for U District stakeholders and future researchers to implement the strategies. They can gather data on how much food waste is diverted and how much of U District's food lifecycle can be localized through those interventions.

5.5 Future Expansions

This section identifies potential sites for mid and long-term expansions of biodigesters, roof gardens, community kitchens, and public compost cans and sinks.

5.5.1 Biodigesters

Biodigesters are necessary to localize the food lifecycle. They turn food waste from restaurants, community kitchens, and homes into liquid plant food (fertilizer) and biogas (which can be used for heating or electricity). They reduce the distances from the food's consumption stage to the recovery stage and the food waste recovery stage to the food production stage (see Figure 48). This would reduce greenhouse gas (GHG) emissions and ecological footprint.

Potential Sites for Biodigesters in Future

The Biodigester Plaza is proposed as a short-term solution to reduce waste in the U District and catalyze a change in people's waste-related behaviors. I chose Chomp Energy's Horse AD25 biodigester because it is designed for urban areas, and the company has installed a biodigester on Vashon Island (a different model). For the U District, the Horse AD25 is suitable for places where pedestrians can learn and interact with it safely, presenting opportunities for education. Therefore, I chose 21 midblock crossings and vacant parcels close to restaurants and cafes as sites for 21 future biodigesters (see Figure 49; biodigesters in blue; restaurants in yellow) as a mid-term plan. Some locations have the potential for more than one or higher-capacity biodigesters. Considering future developments, Chomp Energy's biodigesters or other brands' at-home composters can be incorporated into residential buildings, backyards, and street-side parking spaces as the long-term plan.

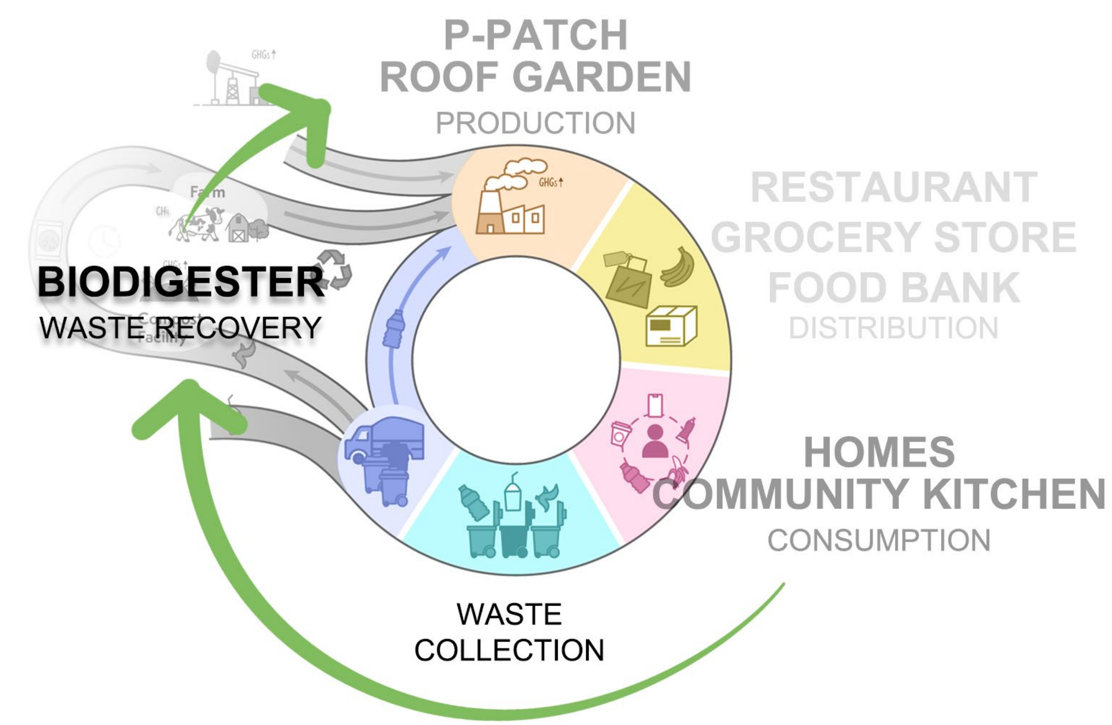

Figure 48. Biodigester's Role In Food Lifecycle. (image by author)

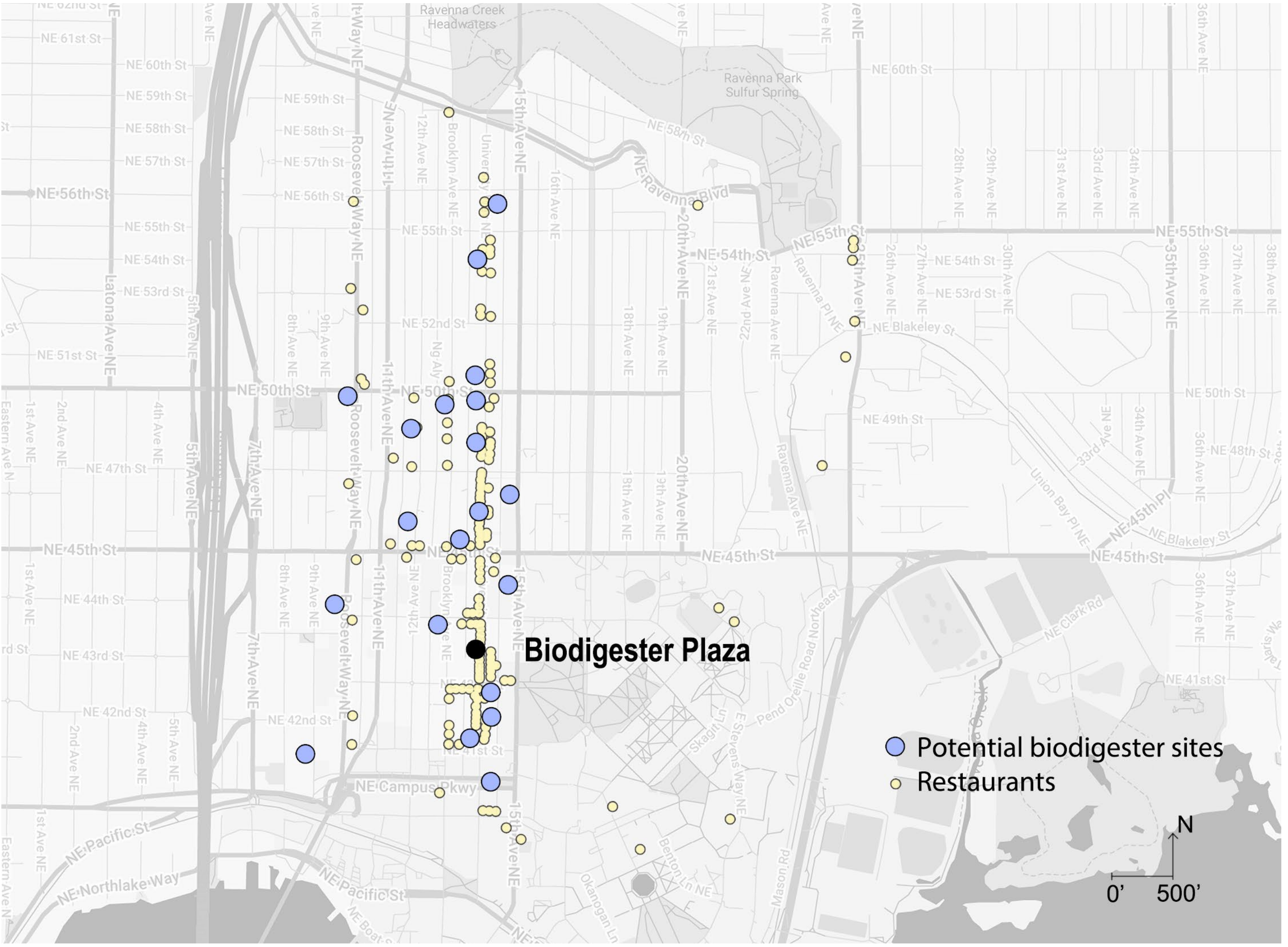

Figure 49. Potential Biodigester Locations in U District. (image by author)

Future biodigesters can be managed under co-ownerships to allow customizations in different places while forming a cohesive network. For example, some biodigesters are proposed in parking lots. They can be maintained by UDP and Chomp Energy and owned by UDP, University District Parking Association (UDPA), and participating businesses.

Biodigester Quantity

I interviewed seven restaurants and cafes on the Ave to understand how many restaurants are suitable for a biodigester to take food waste from. The restaurants were asked: (1) how many compost carts of food waste they dispose of each week; (2) how many orders they receive each week; (3) are their food containers reusable; and (4) are their food containers recyclable or compostable (personal communication, March 21, 2023, see Table 1).

Based on the results and observations of private compost carts at the back of restaurants and cafes on The Ave, I estimated these businesses generate a range of one to four compost carts (96-gallon

RESTAURANT NAME	COMPOST QUANTITY	# OF ORDERS	CONTAINER REUSABILITY	CONTAINER RECYCLABLE/ COMPOSTABLE?
Boba Lust	N/A	5000/week	No	PET w/ film
Aladdin Falafel	2-4 carts/wk	N/A	No	No
Master Bing	44 gallon/day, 3.2 carts/wk	700/wk	No	Partially
Supreme Pizza	24 gallon/day, 1.75 carts/wk	N/A	Maybe	Yes
Panda Noodle Bar	1 cart/wk	N/A	Maybe	Yes
BUGIS	2 carts/wk	N/A	No	Yes
Bulldogs News	N/A	N/A	Yes	PS lid, paper cup

Table 1. Restaurant Food Waste Generation among a Sample of U District Restaurants. (Table by author)

carts) of food waste per week. Each 96-gallon compost cart can hold up to 180 pounds of food waste based on SPU's weight limit (SPU, 2023a), which means each restaurant can generate 180 lbs to 720 lbs of food waste, depending on the size of the business, type of cuisine, and time of year (e.g., some restaurants have fewer orders from June to September; personal communication, March 21). Since a Horse AD25 biodigester can take up to 960 lbs of food waste per week, the biodigester's manager can partner with two to five restaurants for each biodigester.

Because a considerable number of students leave the U District in the summer, there will be less food waste sent to the biodigester from restaurants. But considering more outdoor dining in the summertime, the amount of food waste from the public compost cans and community kitchens may increase, balancing the fluctuation. The exact quantity would need to be tested through a pilot project (Biodigester Plaza & Be Boundless Kitchen).

In a localized cycle, how much fertilizer from the biodigester can be used within the district is essential. Based on examples in Vashon Island, a biodigester can fertilize 2-3 acres of land (Chomp Energy, personal communication, May 3, 2023), which can produce 43,560 to 65,340 pounds of food annually (Rabin et al., 2012). The 21 biodigesters proposed in the map above (see Figure 48) can fertilize 42-63 acres of land. However, the amount of fertilizer that can be used within the district also depends on the amount of arable land (see next section: roof gardens).

The implementation of biodigesters could have many challenges. It can be challenging to install in areas without enough budget and funds. The biodigesters used in this thesis (Horse AD25 by Chomp Energy) cost $133,000 to $383,000 for base systems. Potential cheaper alternatives with similar size and waste processing capacity to Chomp Energy's biodigester include AART1 by Living Arts Systems, Big Hana by Susteco AB, and EF-20 by Green Mountain Technologies (Vazifdar, 2020). AART 1 is the same size as Horse AD25 and costs only $75,000 each.

5.5.2 Roof Gardens

Roof gardens could utilize fertilizer produced from biodigesters to grow food for residents and businesses (see Figure 50). They are in urban areas, close to food retailers and consumers. Along with the help of food waste processors, food grown on roof gardens would have shorter mileage than food grown on regional farms. Because urban farms reduce transportation distances of food, they reduce food waste that could occur on the road and reduce the energy required for shipping. In other words, reduce the area's ecological footprint.

The Station South Roof Garden is a plan to showcase a circular food economy to U District residents and visitors. This section identifies the existing and proposed rooftops that can integrate edible gardens. It then estimates how many rooftops in the U District could become edible roof gardens in the long term with the help of building-codes change.

Potential Roof Garden Locations
The potential sites for roof gardens (see Figure 51) are selected using Google Map 3D and Seattle In Progress to identify rooftops that are: (1) large enough to accommodate the programs listed above; and (2) have existing access to their roofs or have potential to provide access to its roof. The boxes presented below are the buildings that have roof gardens, proposed to have roof gardens, or have the potential to have roof gardens. There will be more possible locations in future years.

Roof Garden Quantity
To estimate a reasonable portion of land that can be converted for agricultural use, I sampled 11 new and recent housing developments from Seattle In Progress (Phelps-Goodman, 2023; see Table 2). I traced the parcels and the planting areas in their proposed floor plans. Then I used Photoshop's

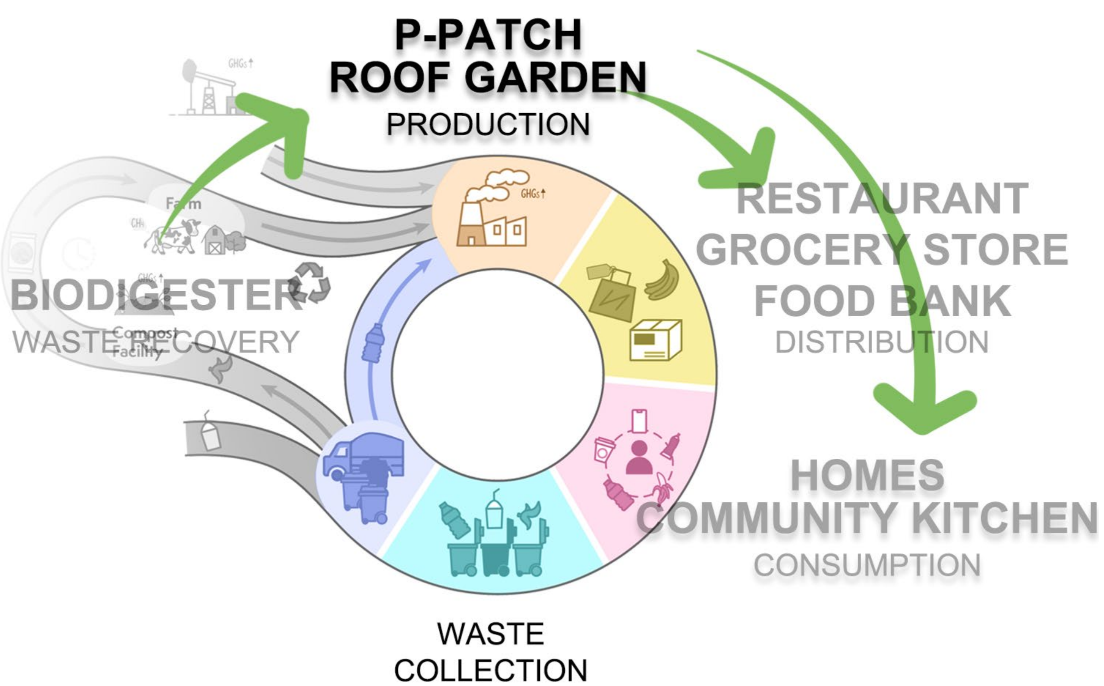

Figure 50. Roof Garden & P-Patch's Role In Food Lifecycle. (image by author)

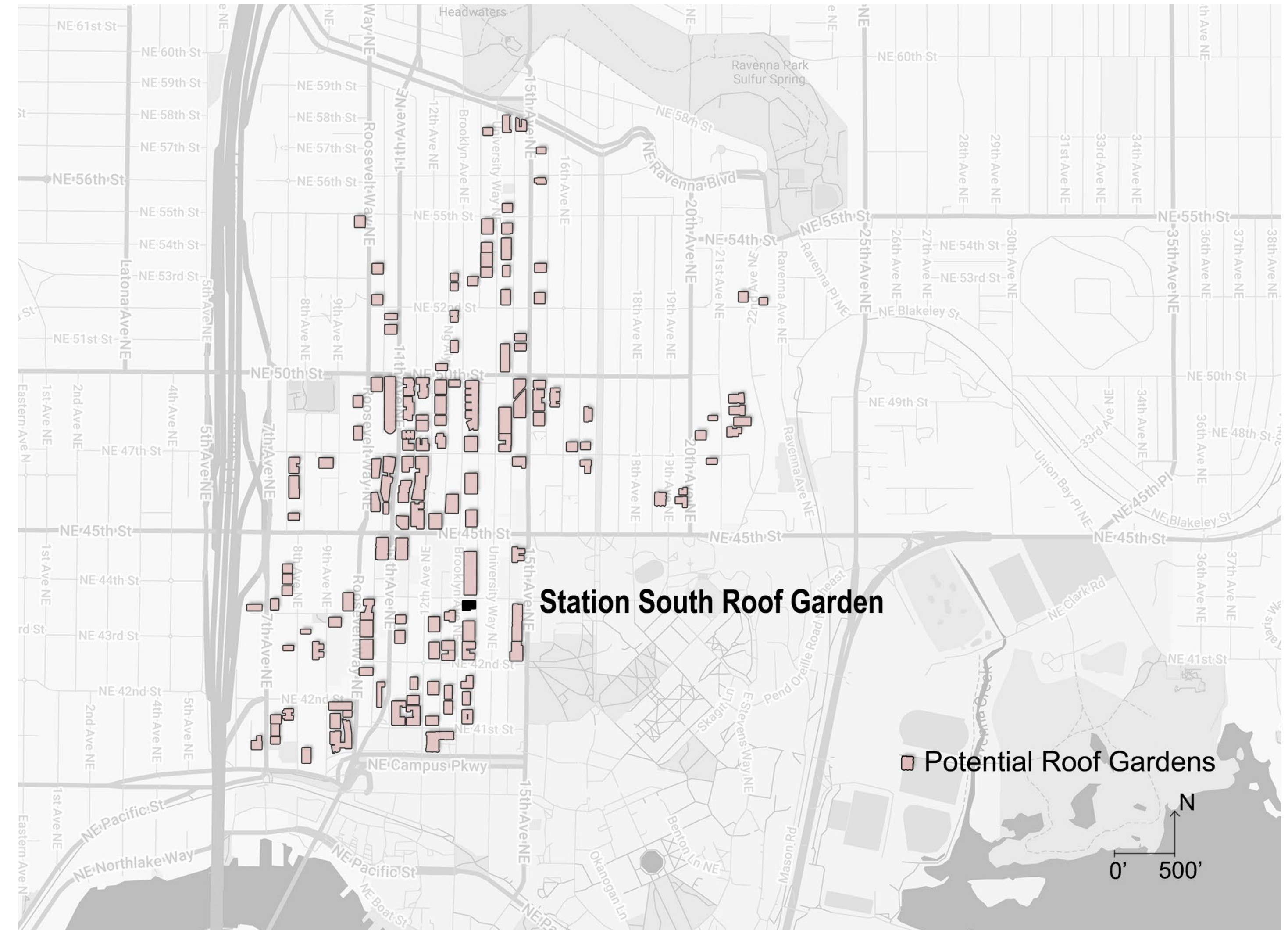

Figure 51. Potential Green Roof Locations in U District. (image by author)

ADDRESS	ROOF PLANTING / PARCEL	PURPOSES
1200 NE 45th St	14.80%	apartments, retail
1300 NE 45th St	10.57%	apartments, retail
1202 NE 50th St	25.08%	apartments, retail
4306 8th Ave NE	8.46%	apartments
4522 Roosevelt Way NE	10.58%	apartments, retail
4220 12th Ave NE	7.11%	apartments, retail
4236 Brooklyn Ave NE	8.96%	hotel
4525 Brooklyn Ave NE	34.89%	apartments, retail
5500 University Way NE	13.89%	apartments, retail
4726 15th Ave NE	28.80%	apartments, retail
5228 15th Ave NE	25.13%	apartments
Total	17.12%	

Table 2. U District Development Roof Planting Percentage of Total Parcel. (Table by author)

histogram to count the pixels of the traced areas. For each parcel's arable land, I divided the number of pixels in the planting areas by the number of pixels in the parcel. The results represent what percentage of a parcel is available for edible gardens. The mean of the samples is 17.12%, a reasonable range considering setbacks, step-backs, mechanicals, and other programs.

The following calculation applies the average percentage a parcel could farm to commercial/mixed-use and multi-family land uses (the two types sampled) in the whole district because the arable portion of a rooftop can vary greatly based on land use. This long-term plan needs the community and the city's support to require developers to integrate edible landscapes in their parcels.

There are 9,193,406 square feet (sf) (211 acres) of commercial/mixed-use and multi-family parcels in the U District (Seattle GeoData Private Member, 2022). If 17.12% of these are designated to edible gardens, the U District can have 1,573,911 sf (36 acres) of gardens, enough to take fertilizers from 12-18 biodigesters and produce 786,955.6 lbs (393.5 tons) of food annually.

The U District has many roof types, and I only sampled eleven roofs with planting spaces. Therefore, the calculations for potential rooftop planting areas can have a large margin of error. As of May 2023, many single-family and multi-family houses in the U District have slanted roofs, and residents do not have access to their roofs, so the available land for community gardens can be less than this thesis' calculation. However, because of the advantages of rooftop gardens to humans and the environment (e.g., affordable and healthy food, less waste, reducing CO2), the City of Seattle and U District stakeholders can require new developments to have a certain percentage of their parcel dedicated to community gardens, and implement a "cap and trade" program to incentivize new developments to designate more areas for edible gardens.

To further encourage developers to have roof gardens, designers can integrate different programs with the gardens, such as placing foldable solar panels on top of aisles between rows of planters to shield gardeners from rain. To save water costs, designers can place stormwater tanks in the buildings, which may also serve as tuned mass dampers (TMD) for high rises.

Considering the drastic differences between U District's food production and consumption and more than a quarter of Washington State residents experiencing very low food security (Otten et al., 2023), future roof garden expansions could consider vertical farming and other means to increase productivity.

5.5.3 Community Kitchen

The community kitchens are intended to turn raw ingredients into meals, become public spaces for the U District community to witness how food waste can be reduced or turned into resources, and have the visitors carry those sustainable practices home. The community kitchens could take food from community gardens, food banks, and public donations. The food waste from community kitchens could use biodigesters to turn into fertilizer and energy, which can fertilize community gardens and power the community kitchens (see Figure 52).

Management

A variety of groups can manage the community kitchens. First, they can be managed by the UDP, which also manages the biodigesters. Second, they can be managed by food banks as an extension of their functions. Teen Feed and the University District Youth Center are two organizations that serve cooked meals to teens and youth. Therefore, there is an opportunity for those two food banks to have a communal kitchen as an extension of their own kitchen. There is also a potential for other food banks to use community kitchens to prepare meals for those in need, building an inclusive community. Third, churches and other charities can manage the community kitchens because religious organizations and charities are good at hosting activities with food and fostering a peaceful community.

Potential Sites for Community Kitchens

Because community kitchens require a moderate amount of space and need to be close to food banks, P-Patch gardens, and residential areas, three vacant lots were selected as potential sites (see Figure

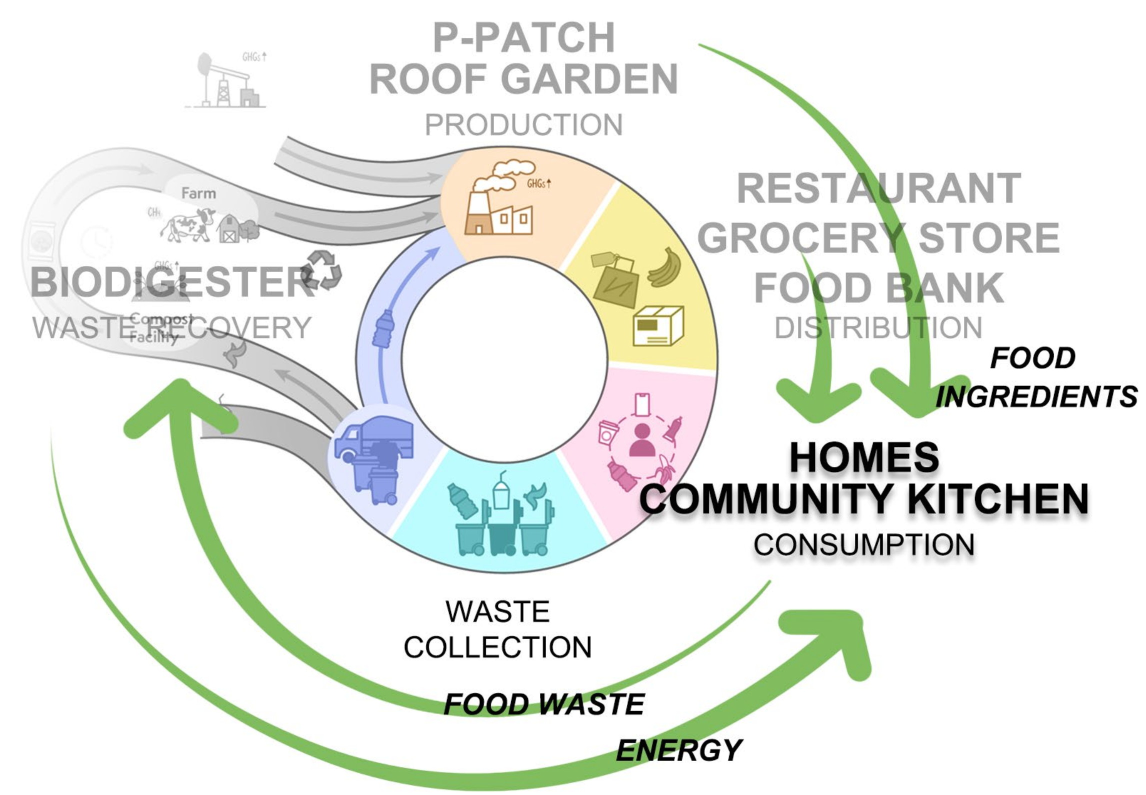

Figure 52. Community Kitchen's Role in Food Lifecycle. (image by author)

53) to complete the food lifecycle with three other P-Patch gardens and four food banks in U District (see Figure 54). Because there are no data on how much food it could receive, the piloting site can be used as a lab to test the quantities and the effectiveness of designs and programs for more community kitchens in and out of the district.

Figure 53. Potential Community Kitchen Locations in U District. (image by author)

Figure 54. Community Kitchen, Food Bank, P-Patch Networks. (image by author)

5.5.4 Public Compost Cans & Sinks

Functions & Locations

The proposed street composting program collects food waste from the public to be processed at biodigesters. To increase public participation, the public compost cans should be close to outdoor seating, where food waste could be generated, and the biodigesters, where food waste would be processed. Though there are many restaurants on The Ave, there are only six outdoor dining areas. Some are on the street (e.g., Boba Up, NE 43rd St), and some are in alleys (e.g., Cafe Allegro, Shultzy's Bar & Grill; see Figure 55).

The public sinks are intended for people dining outdoors to wash their hands and food containers and reduce food container waste. A clean plastic food tray is recyclable but cannot be recycled if soiled. Therefore, one can recycle a plastic container after composting leftovers and washing the grease off. In addition, the sinks allow people dining outdoors to wash their personal reusable containers so they do not have to carry soiled containers on the streets. Though the sinks increase the "time cost" of reusing, they decrease the "social cost" of carrying dirty containers on the street. The future public sinks and compost cans are proposed together near restaurants (see Figure 56).

Figure 55. Outdoor Dining Tables in U District (Winter 2023 Locations; image by author)

Because some businesses do not accept personal reusable containers due to liability/legislation issues, the sinks' effectiveness in promoting reusable containers can be limited. The compost cans and sinks at two piloting sites can test the strategy and hopefully invite local businesses to accept personal reusable containers.

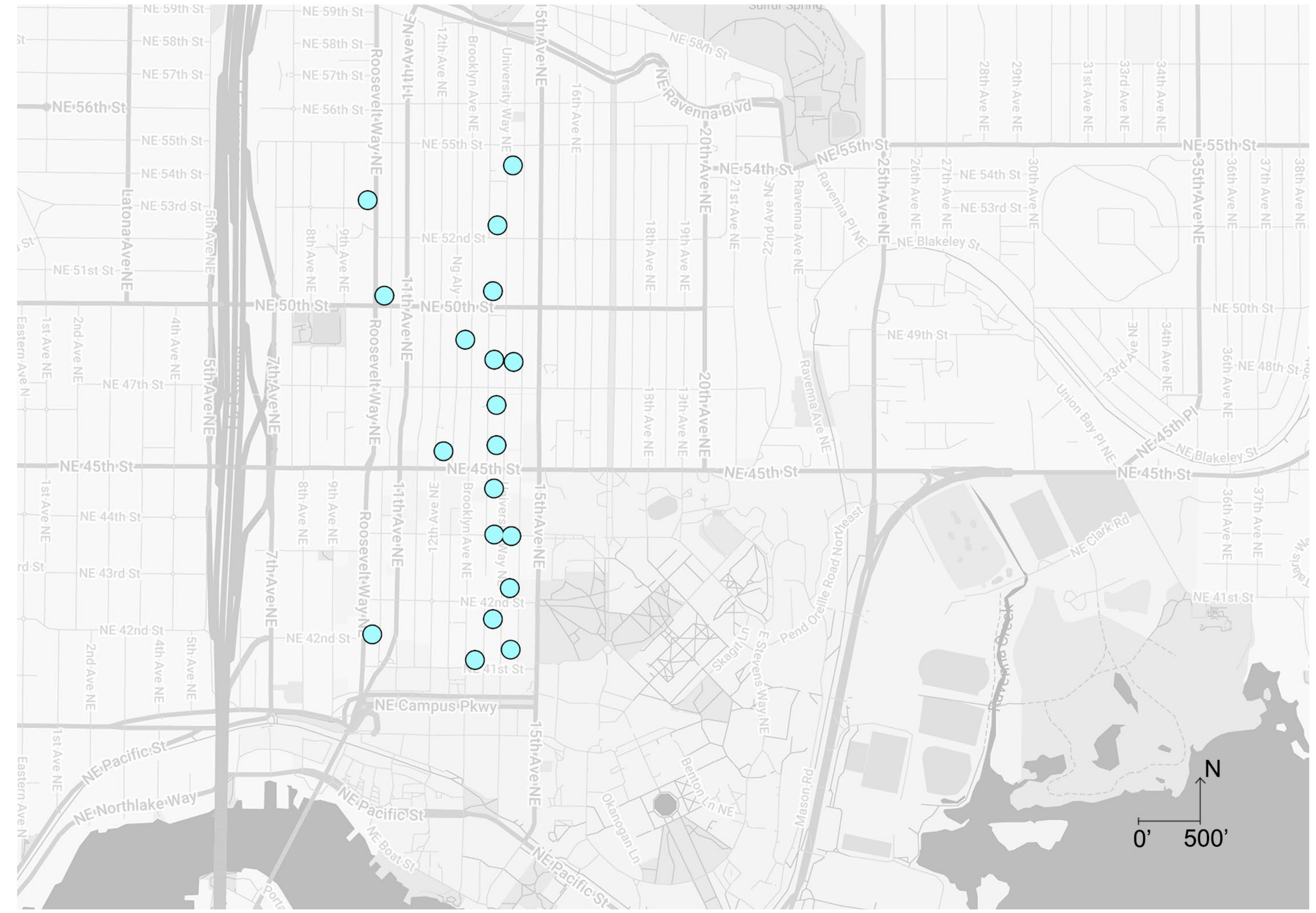

Figure 56. Potential Sink & Compost Can Locations in U District. (image by author)

Management & Opportunities

Additional compost cans throughout the U District could be managed by staff from the University District Partnership (UDP) which provides “daily professional cleaning within the neighborhood BIA boundaries” (UDP, n.d.). Their staff would periodically empty compost cans into biodigesters instead of using Seattle Public Utilities’ service. This way, the food waste is diverted from the centralized system, reducing the ecological footprint and diverted from garbage cans on streets, reducing littering by crows and rodents.

The street sink program can partner with Seattle Street Sink by Clean Hands Collective, a program that started during COVID so people could wash their hands and improve their hygiene. Today, the sinks are primarily placed near homeless shelters. They are pre-made or homemade using off-the-shelf materials (see Figure 57). They receive water from public or private properties and discharge wastewater into a rain garden (The Collective Team, n.d.). When placed near outdoor dining areas to wash hands, utensils, and food containers, they would need special drains and pipes to accommodate grease from food containers. As they are close to outdoor dining areas, they would also need more frequent maintenance to keep up with the frequent usage. The proposed public sinks may improve public health, increase container recyclability and reusability, and reduce the number of food containers going to landfills. Though the sinks’ usage may require frequent maintenance, their environmental and social benefits can increase businesses’ attractiveness.

In addition to encouraging reusable containers through street sinks, the U District can also expand UW’s Ozzi reusable container program to reduce waste. The program provides students with a reusable container that they only need to rinse and return after use to replace with a clean one (Wood, 2022). Participants deposit $5 to join the program and receive a token that can be redeemed for containers (2022). When participants return the reusable containers to the two collection points (in Local Point and Center Table), they can receive a new token (2022). However, according to Ozzi’s video (Wright & AGreen Ozzi, 2019) and conversations with Local Point employees (a UW dining hall), there are three limitations: the boxes can only be used up to 300 times, the program lacks marketing and therefore users, and employees have little knowledge on how to return the deposit (personal communication, May 15, 2023). Expanding the Ozzi program to off-campus locations can expand its users and reduce single-use containers. Shared reusable containers provide people without personal reusable containers and restaurants with an affordable, convenient, and reliable solution to reduce container waste regardless of its current disadvantages (e.g., convenience, container life after usage, and affordability).

5.6 Summary

This chapter proposes biodigesters, roof gardens, community kitchens, and public compost cans & sinks in the U District to make it cleaner, generate less waste, and reduce its ecological footprint. The four types of interventions help the U District with localizing the food lifecycle and help the public to reduce food waste and reuse food containers. In doing so,they have addressed the three zero-waste strategies (i.e., localization, closing the loop, and reuse/repair).

This chapter selected three piloting sites in U District Core with high pedestrian traffic to test the proposed strategies and programs’ effectiveness and maximize their educational value. Their designs illustrate what zero-waste landscape interventions would look like or how landscape architects could help a city achieve zero waste.

This chapter also discussed the potential expansion sites for the four types of interventions. These could assist the city in diverting compostables (food scraps and food containers) away from the alleys, landfills, and centralized composting facilities. Though the quantity is far from localizing 100% of the food lifecycle and eliminating all waste going to landfills, the landscape elements and their designed activities would raise the values, decrease the costs of reducing, reusing, and recycling, and pave the path for programs and interventions from other industries.

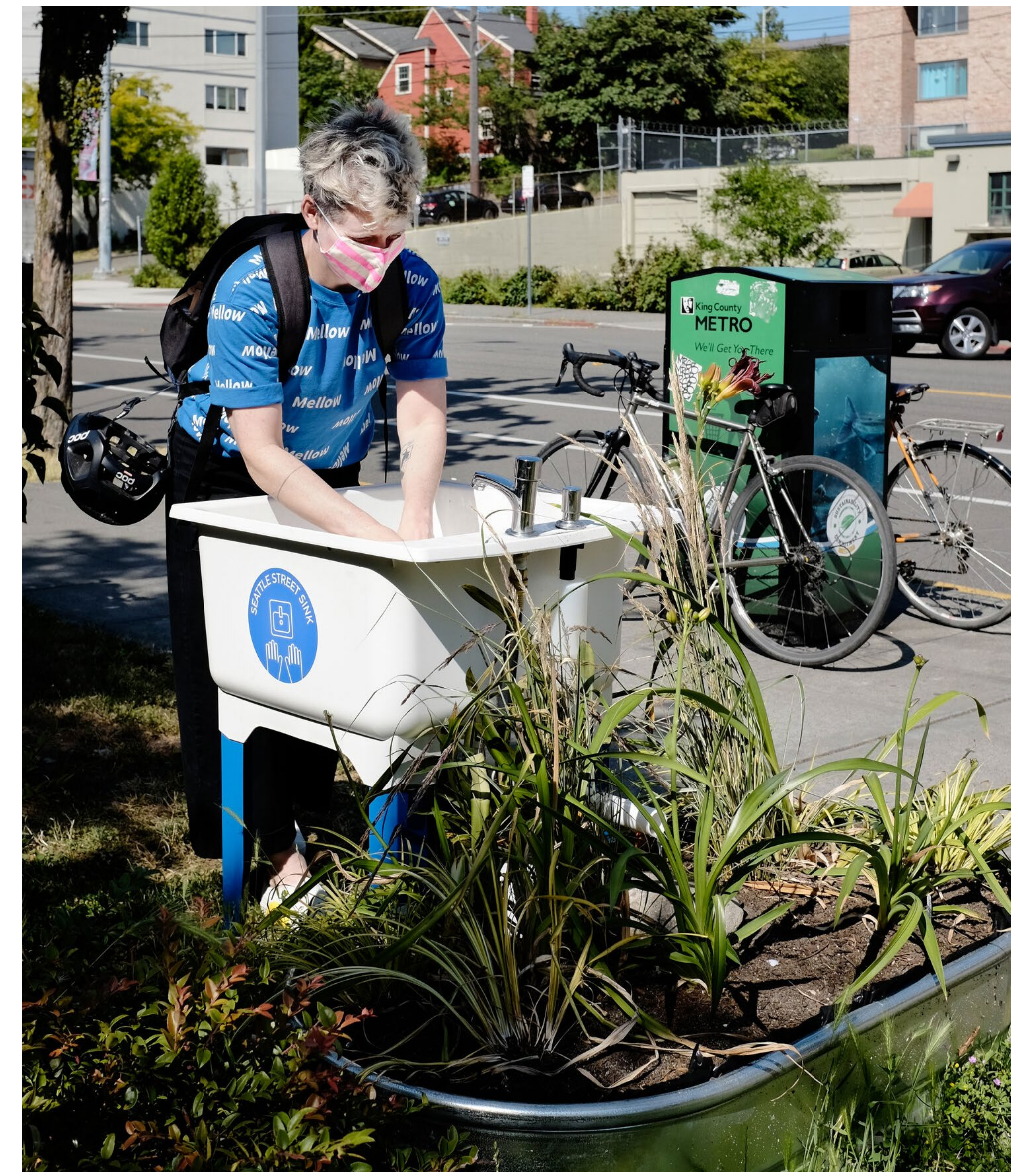

Figure 57. University Heights Center Street Sink. (The Collective Team, n.d.)

CHAPTER 6 REFLECTION

This chapter reflects upon the advantages and disadvantages of the design approach I took in this thesis project, identifies future opportunities for the U District and researchers, and lastly, summarizes what landscape architects can do to help a city become zero waste.

6.1 The Design Approach

This thesis' design approach has three steps: first, prioritize material lifecycle(s) to address and understand its current state and problems, second, identify strategies from municipalities and case studies, and third, find suitable places for zero-waste interventions.

I used Seattle Public Utilities' website for this thesis to understand the historical and current waste management system. This information answers the first two research questions: What are Seattle's solid waste management (SWM) practices today? And what waste management practices has Seattle tried thus far, and how well did they work? Seattle has been looking for sustainable and financially feasible waste management solutions. Its recycling and composting programs effectively improved Seattle's recovery rate, but due to insufficient enforcement and public awareness, Seattle still has recoverable items going into landfills.

To answer the third research question: What design and waste management precedents can help Seattle or U District achieve zero waste, I first looked at Seattle's 2022 Solid Waste Plan Update, which indicated three circular-economy strategies: localization of material lifecycles, prevention of waste going to landfills, and promoting reuse and repair to reduce waste generation. I then looked at the Zero Waste Index, waste behavior model, and case studies from Seattle, Japan, and ASLA websites for precedents.

I focused on the food lifecycle because of time constraints and the abundance of compostables in Seattle's garbage stream. I developed landscape designs and programs to help Seattle reduce food waste generation, localize the food lifecycle, divert food and containers from landfills, and establish a circular food economy.

The proposed landscape designs and programs also considered the three thesis goals: to make the U District cleaner, to generate less waste, and to reduce its ecological footprint. The interventions include biodigesters, roof gardens, community kitchens, and public compost cans to collect food waste. They are incorporated into unused urban landscapes, including midblock crossings, vacant lots, sidewalks, and roofs. Those public and private spaces create opportunities for the apartment managers, U District Partnership (UDP), and other stakeholders to participate in building a circular economy and host activities to showcase waste-less lifestyles.

This design practice helped me understand the roles of landscape architecture in a zero-waste movement. While working on the landscape designs, I realized that landscape architects have limited ability to help a city achieve zero waste on their own. Reaching a zero-waste target and a circular

economy requires multiple sectors' participation and collaboration. Nonetheless, landscape designs are essential to achieve zero waste because research shows that accessibility to waste receptacles, social values, and environmental values have significant impacts on people's waste-related behaviors. Besides, public open spaces could attract visitors from different disciplines and foster multidisciplinary zero-waste collaborations more than indoor private places. Public and semi-public landscapes like streets, alleys, midblock crossings, and rooftops are all places that can be utilized. Public spaces present great potential to implement waste collection and processing amenities, host waste reduction activities, and raise public awareness of the circular economy's benefits.

6.2 Effectiveness of Designs & Future Opportunities

The effectiveness of my designs relies on the model evolved from the literature review, which discussed environmental and psychological factors impacting people's waste-related behaviors. This design approach could have a visible impact on food waste reduction.

However, the designs may not significantly impact container waste reduction because the designs aim to complete the food lifecycle and are not designed to complete the food container lifecycles. In addition, food containers and other products involve a diverse range of materials, making their cycles challenging to complete. In my earlier designs, some of the proposed interventions tried to upcycle plastic bottles, but the concept was abandoned due to a lack of available technologies, precedents, and effectiveness in completing material lifecycles. Future landscape projects in Seattle could seek partnerships with other disciplines and companies to reduce other types of waste, such as animal by-products, including animal carcasses not resulting from food storage or preparation, animal wastes, and kitty litter (9.2% of residential garbage stream, 2.1% of commercial stream), plastic films (5.3% of residential garbage stream, 6.5% of commercial stream), and textiles (3.7% of residential garbage stream, 2.2% of commercial stream; CCG, 2017, 2022).

Though the three sites focus on food lifecycles, they can host programs to reduce other types of waste. For example, the biodigester plaza could have sculptures or murals illustrating a circular economy or exhibiting garbage art. It could also host flea markets, yard sales, and furniture sales at the beginning and the end of school quarters. The Station South Roof Garden could use edible plants for other uses, such as medicines and plant-woven baskets, thus reducing the consumption of petrochemicals. The Be Boundless Kitchen could expand its boundary and sell locally grown salads in locally grown baskets to the U District community, promoting localized material lifecycles. It could also provide studying and resting places or offer item-repair workshops to encourage reuse and repair in off-peak hours.

Furthermore, to reward manufacturers, businesses, customers, and recyclers in zero-waste behaviors, such as producing, selling, purchasing with, and cleaning/repairing/repurposing compostable and reusable bags, landscape architects and financial professionals can collaborate with the U District Partnership, local businesses, and apartment managers to establish the UD Coin. This economic system would flow in the reverse direction of material lifecycles to make participants from all stages of a material lifecycle aware of the circular economy.

The strategies used for U District can be applied in other neighborhoods, such as placing waste collection furniture (e.g., street compost cans & sinks) close to the source of generation (e.g., outdoor dining areas), using playful and interactive structures (e.g., AI garbage sorting guide) to guide locals and visitors to sort correctly, and utilizing public spaces (e.g., midblock crossings) and activities (e.g., cooking classes) to raise awareness on circular economy and support public engagement.

Seattle already has some interventions, such as the UpGarden at 300 Mercer St and indoor community kitchens. Some kitchens have staff cooking for those in need (e.g., Musang Community Kitchen; That Brown Girl Cooks), while others allow the community to cook for themselves (e.g., SPU Community Kitchen, Feed The People). Those programs could provide opportunities and data for U District's and other places' interventions.

In summary, landscape architects play a crucial role in helping a city achieve zero food waste by implementing various strategies and interventions throughout the everyday landscape. They can design and integrate food waste processing systems and management infrastructure into public spaces. They can create edible landscapes and community gardens that promote local food production, reducing reliance on external sources and minimizing food waste during transportation. Landscape architects can also design educational spaces and interpretive signage to raise awareness about sustainable food practices and engage the community in waste reduction efforts. Additionally, they can collaborate with stakeholders to develop policies and guidelines that support establishing a circular food economy, encouraging food recovery and redistribution initiatives, promoting composting and recycling programs, and fostering sustainable urban agriculture practices.

It is my sincere hope that this research will inspire landscape architects, urban planners, policymakers, and community stakeholders to embrace innovative approaches that promote sustainable food systems, reduce waste, and contribute to a healthier and more environmentally conscious U District.

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