Energy Commons:
A Hypothetical Replacement for Urban Gas Stations in Seattle

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Abstract

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While surviving as a monument to the power of car culture in the 20th century, today the gas station has become increasing obsolete in the face of growing cities and increasing environmental awareness. Alternative energy sources and different modes of transit such as walking, biking, car sharing, and public transit have grown in popularity. As a result, the number of gas stations nationally has decreased since the 1970s, especially in urban contexts. While the redevelopment of gas station sites aims to increase density by filling the voids in the fabric once dedicated to the car, they typically fail to address the history of the site as an urban node in the circulation of people, vehicles, and energy. With their prime urban locations and past associations, the sites of former gas stations have the potential to become new nodes of distribution and communication in the city.

This thesis argues that the obsolesce of the urban gas station offers the potential for a new building type that will better serve today's changing needs for transportation and distribution of energy. The proposal consists of the design for a small-scale urban amenity node, or "Energy Commons" in Seattle. The "Energy Commons" will combine utilitarian functions with a contextual neighborhood-based program through personal vehicle recharging, neighborhood co-working offices, cyclist and pedestrian amenities, and solar energy and water harvesting and storage. The goal is to transform the former car-centered and consumptive structure into a new public urban asset that is human focused and production-minded.

ENERGY COMMONS

a hypothetical replacement for
urban gas stations in Seattle

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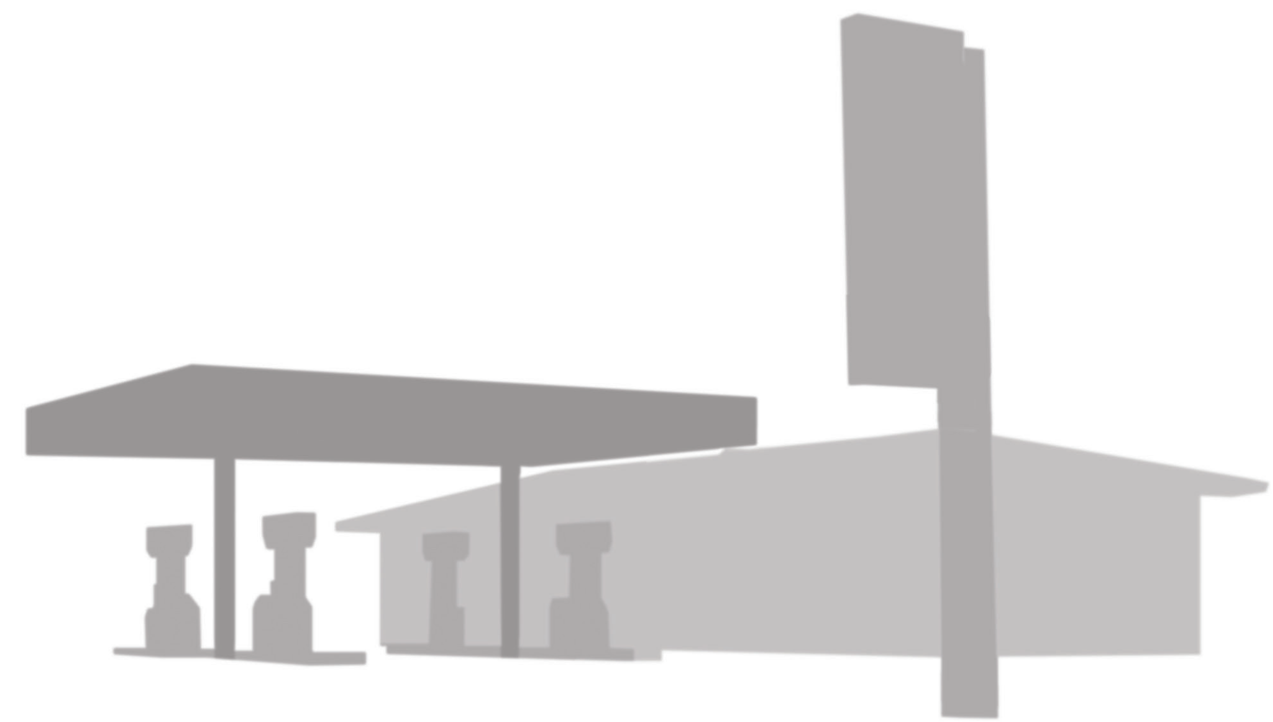

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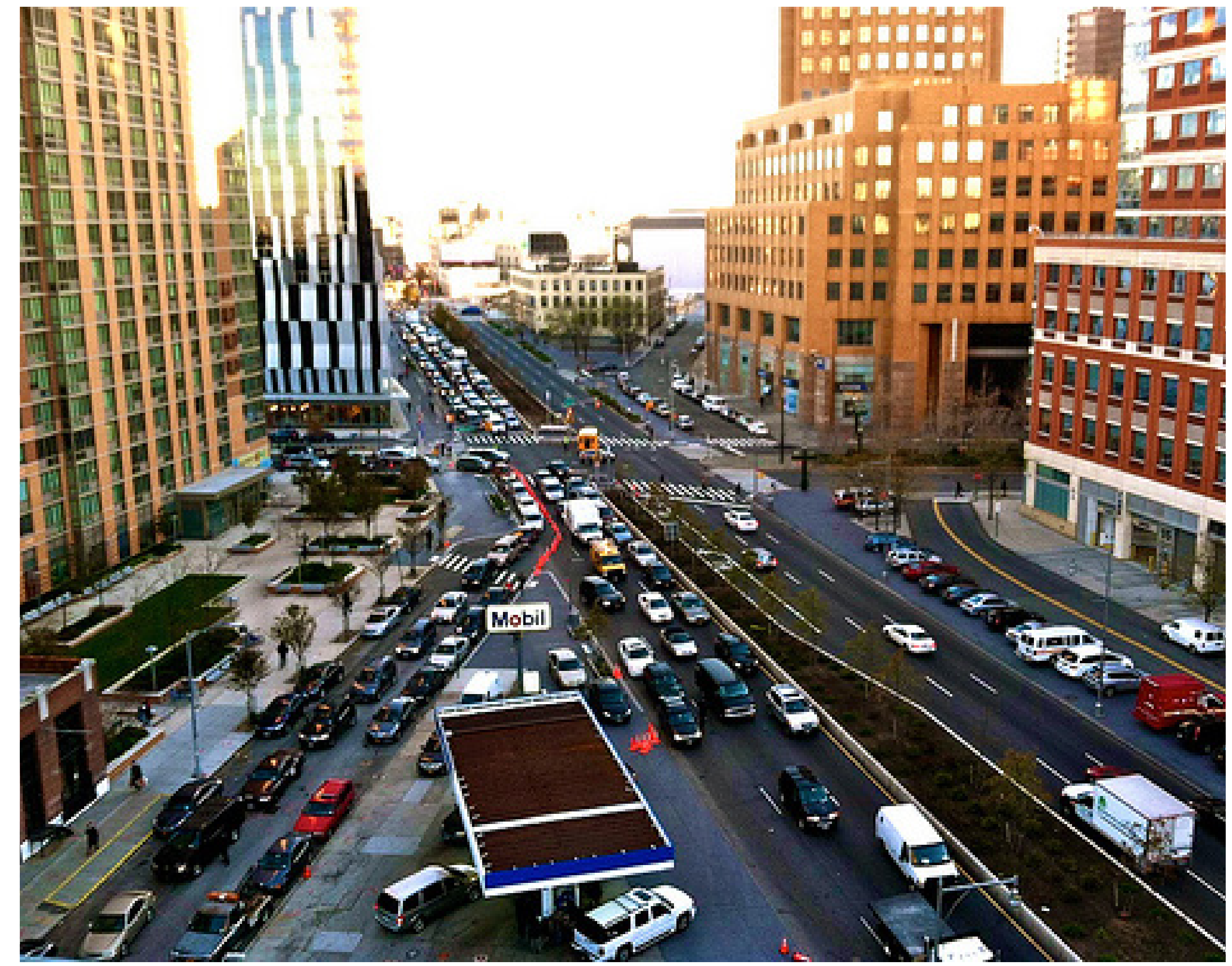

fig. 1 gas station at the intersection of Flatbush Avenue and Gold Street in Brooklyn, NY, USA

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ONE

introduction

The gas station is a twentieth century building type that offers utility and amenity by facilitating the flow of automobiles and drivers. Since the early twentieth century, these utilitarian structures have become familiar sights on the major arterials and highways in the United States. The discrete and familiar architectural components of the gas station are the retail box, canopy, gas pumps and storage and vehicle lot. The primary formal expression of these elements is utilitarian, designed to be practical rather than attractive. Each element is designed for economy – taking on the most basic form to achieve maximum function. In addition to its primary function of providing fueling services to automobiles, over the last century the gas station has taken on additional functions for both cars and people. With the addition of planned accessory uses and informally accrued amenities, the gas station has continued to fulfill the needs of American drivers for the consumption of fossil fuel and for consumer goods and service.

While surviving as a monument to the power of car culture in the 20th century, today this building type has become increasingly obsolete in the face of growing cities and increasing environmental awareness. The gas station continues to be fondly regarded in American pop culture as a sentimental artifact of a bygone time that was dominated by automotive transportation. But today, gas stations reflect the hugely negative impact of fossil fuels on people and the environment in terms of airborne emissions and soil contamination. The prime locations these urban gas stations occupy and the amount of area they cover have made them popular sites for redevelopment. While these projects typically aim to increase density by filling in the voids in the urban fabric, they fail to address the history of the site as an urban node in the circulation of people, vehicles, and energy.

Alternative energy sources and modes of transportation are gaining prominence as electric powered vehicle use has increased. In large cities alternate modes of transit such as biking, car sharing, and public transportation have grown in popularity. Additionally, economic issues, government regulation, and consolidation of gas stations at big box stores has reduced the number of gas stations nationally

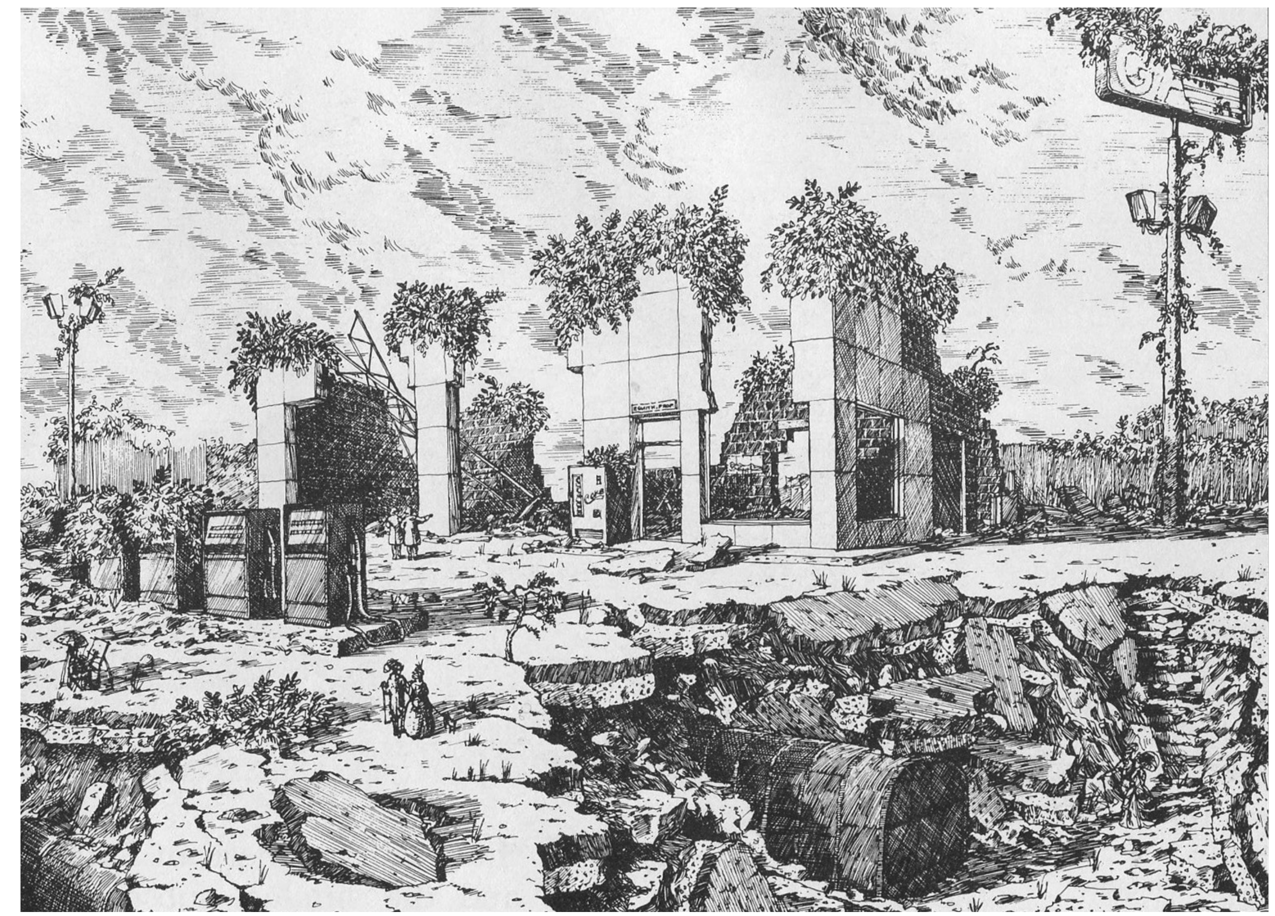


fig. 2 illustration of nature overtaking an unnamed gas station since the 1970s, especially in urban contexts. Specifically in Seattle, one of the fastest growing cities in the country, the number of gas stations has decreased by half over the last 40 years.[1] While the need for affordable housing has been a concern of city officials and developers, the importance of urban amenities to support residents has typically been overlooked.

In cities, gas stations are typically located on corners of major arterials. This placement within the urban fabric allows for a higher probability of usage by automobile drivers. The corner site makes it possible for two edges to be used for vehicle access, facilitating movement of cars in and through the station. The flow of vehicles and people through the site is divided depending on user. Clearly segregated, the proportion and placement of this circulation on the site reveals the automobile as the primary user of the current gas station. These urban building types served as essential points of convergence for people and vehicles in the city.

With their prime locations and past associations, the sites of former gas stations have the potential to become new nodes of distribution and communication in the city. This reinvented building type can support urban growth through the harvesting of renewable energy and production of human capital rather than perpetuating a waning culture dominated by the car. This thesis argues that the obsolescence of the urban gas station offers the potential for a new building type that will better serve today's changing needs for transportation and distribution of energy. The proposal consists of a design for small-scale urban amenity nodes, or "Energy Commons" in Seattle. The goal is to transform the former car-centered and consumptive structure into a new public urban asset that is human focused and production-minded. The proposed "Energy Commons" will provide the spaces for clearer circulation of vehicles and people and serve as a hub of sustainable energy powered by natural and human forces.

The design proposal is to utilize a former gas station lot in Seattle for a small-scale urban amenity node, or "Energy Commons". The goal is to transform the former car-centered and consumptive structure into a new public urban asset that is human focused and production-minded. The proposed "Energy Commons" will serve as a new amenity in the city that will advance the adoption of cleaner vehicles while offering a primary and stable node for the flow of pedestrians and bicycles. In the aim of selecting a site that is centrally located and neighborhood based, the program of the proposed "Energy Commons" responds to contemporary shifts in energy distribution and urban mobility, serving a range of personal transportation modes and renewable resource distribution needs in the city. Cyclist and pedestrian amenities will be provided to create a human-centered program rather than the car dominated focus of the past gas station. The "Energy Commons" will not only power operations on site with its own energy harvesting but also will supply electric vehicle charging stations and vehicle share parking. The final component of the program will be flexible, determined by the given need in the neighborhood where the "Energy Commons" is located. By providing the local community with an adaptable space, the prototypical "Energy Commons" will ground itself within its immediate context. In its function and form, the "Energy Commons" will act as a literal "battery" that will power and empower human mobility in the city.

The theoretical framework of this thesis begins with an investigation into the history of the function and form of the current gas station type. The current decline of this building type in cities today will be studied in relation to the growing density of urban centers and increased environmental awareness. The program of the "Energy Commons" will then be defined as a response to contemporary shifts in energy distribution and urban mobility. The methodology for site selection will then be described through the study of the current state of gas station infrastructure in Seattle. The thesis proposes a new network of energy nodes that will be investigated through the design of one test site in the University District. This new "Energy Commons" at the intersection of NE 47th Street and Brooklyn Avenue NE will demonstrate how architecture can facilitate the fueling of future personal transportation and the distribution of energy required in the flow of vehicles and people. To this end, the proposed project, the Energy Commons, attempts to power and empower urban and human mobility through the integration of architectural form and a progressive program. The goal is to transform the former car-centered and consumptive structure into a new public urban asset that is human focused and production-minded.

TWO

form follows function: gas station as utility and amenity

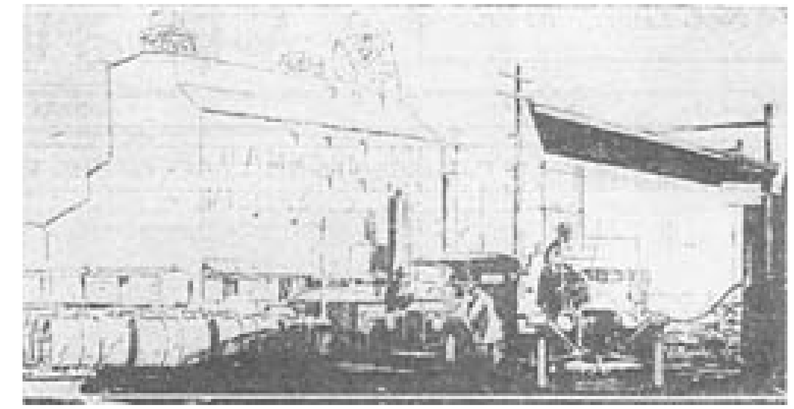
2.1 Background: Definition and History

For the purposes of this thesis, the gas station is defined as a commercial building type that has distinct physical characteristics and serves unique functional needs. The primary function of gas stations is to sell fuel such as gasoline, diesel, and biofuel to consumers for automobiles and trucks. (fig. 3) They may also provide other automobile services including repair and maintenance of vehicles, providing air pumps, and washing facilities. Many gas stations today also contain a convenience store that sells everyday small-serving food and personal items. (fig. 4) Largely dependent on a clientele of drivers, gas stations are thus oriented toward the automobile in their siting and layout. The location of entrances and exits and treatment of site edges are designed for efficient traffic flow and expedient refueling. They are often located on the corners of major or highly trafficked arterials, whether in cities or on highways. Typically, consideration of pedestrians and bicycles are absent from the design of this building type. Architecturally, the essential elements of the gas station are the gas pump, canopy, retail box, and vehicle lot.

fig. 3   gas station in Seattle's Georgetown neighborhood
fig. 4   convenience store and Citgo gas station in Philadelphia, PA, USA

The gas station type has existed in the United States in various forms and functional permutations since the early 20th century.[2] The architectural form of the gas station has evolved to incorporate new uses such as automobile repair and sales of other goods. However, the main function of storing and dispensing fossil fuels has remained constant. Popular accounts trace the first "station" back to Seattle in 1907 when Standard Oil of California sold gas directly to consumers from a roadside pump connected to their main storage tank. (fig. 5) According to authors John Jakle and Keith Sculle, these first gas stations were curbside pumps usually found at the intersection of major roads in towns in front of grocery and hardware stores.[3] The pump was large enough to be recognized from the road but small enough to be manually refilled by station owners. (fig. 6) As seen in a photograph of a "shed" station in Kansas, some curbside pumps were also accompanied by sheds as storage buildings. (fig. 7) In 1910 the first building specifically designed to distribute gasoline was built in Michigan.[4] This structure consisted of a post-supported canopy that spanned two driveways and covered a single pump. In the following decade, similar informal buildings for the sale of gas sprouted up around the country. (fig. 8)

Beginning in 1913, architect-designed stations appeared as gasoline companies began developing standardized, homogeneous stations in response to industry competition.[5] This trend for branded stations continued through the 20th century as the number of gasoline stations exploded with the increasing popularity of the automobile.[6] By 1920, city ordinances for fire safety forced many of these urban curbside stations to close, shifting attention to service stations in neighborhoods.[7] Continuing to seek access from two sides, gas stations were established at the corner of major residential streets.[8] John Jakle and Keith Sculle observe that these new gas stations needed to blend into residential neighborhoods. (fig. 9)[9] Therefore, gas stations were often designed in a contextual manner to look like a small house with hip and gable roofs. Unlike the residential buildings they were modeled after many of these neighborhood gas stations were constructed of prefabricated steel cladding faced with brick, stucco, or galvanized steel. (fig. 10)



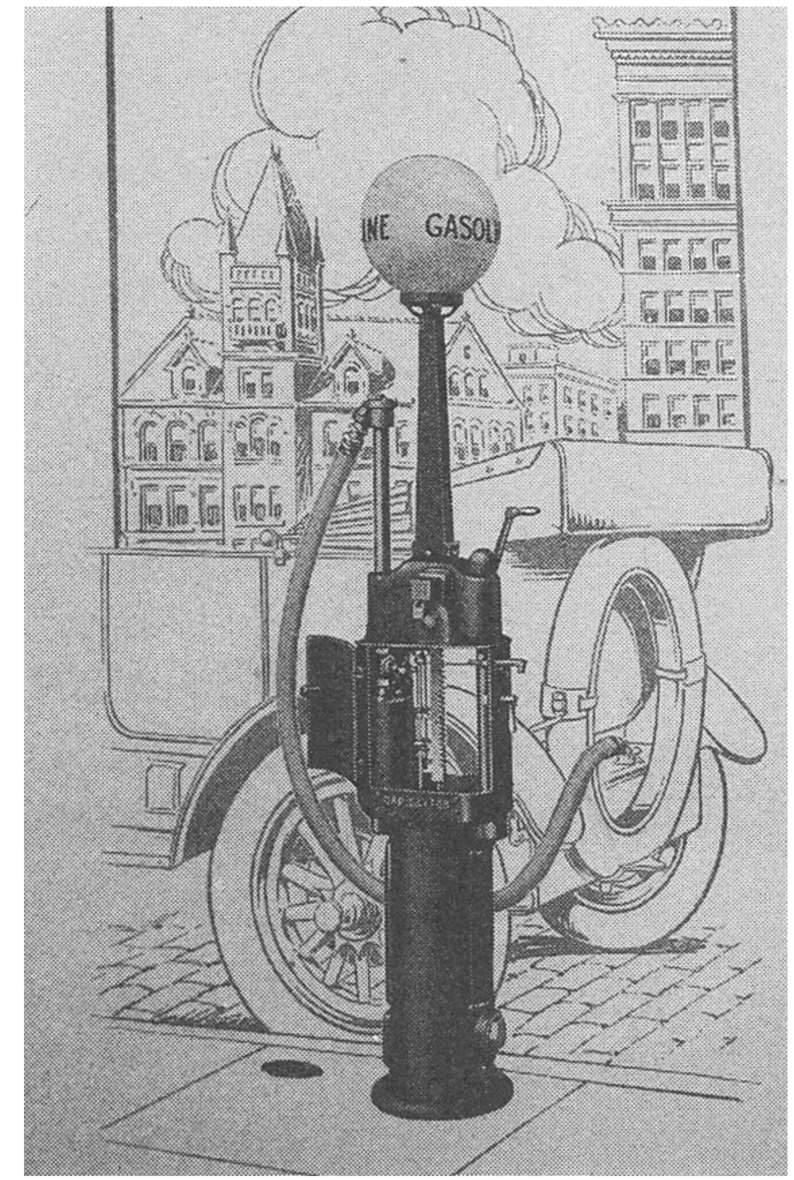
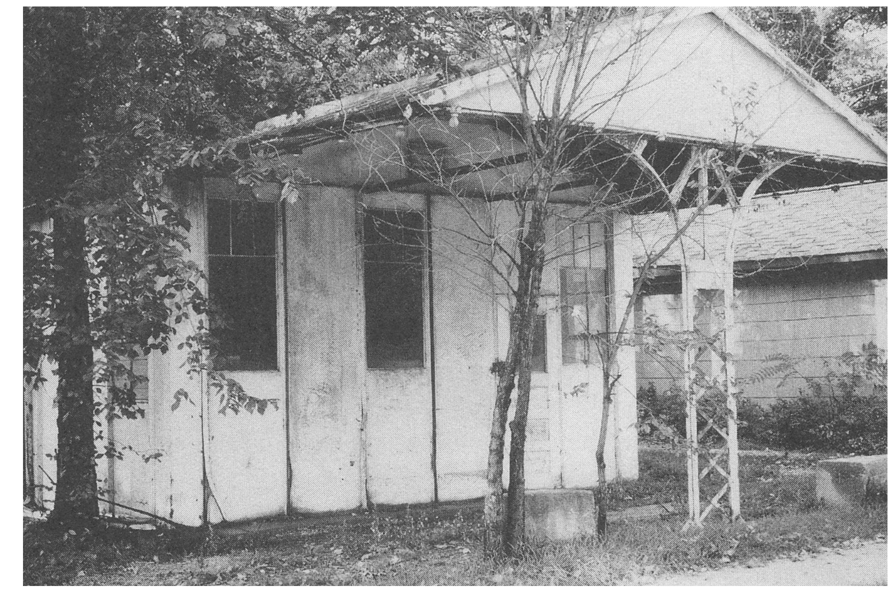


fig. 5 first gasoline pump in United States of America in 1907 in Seattle, WA, USA
fig. 6 drawing of early curbside gas pump



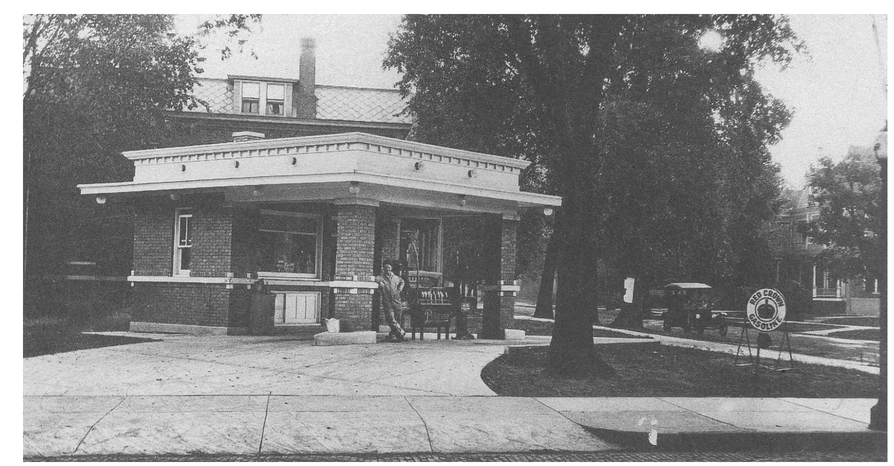


fig. 7 "shed" station in Pittsburg, KS, USA
fig. 8 first gas station in Columbus, OH, USA, crica 1910

fig. 9 gas station in Macomb, IL, USA that had been inserted into a previously all-residential neighborhood
fig. 10 prefabricated "house with canopy" station on old U.S. 66 at Wilmington, IL, USA

The 1930s brought further changes to gasoline station design due to increasing competition and the economic depression. Oil companies began offering the sales of automobile related goods like tires, and batteries and sought to emphasize vehicle repair to supplement declining gasoline sales.[10] As Jakle and Sculle observe, these added services and goods required larger driveways, bigger enclosed rooms and storage spaces, and added service bays. As gas stations moved away from residential areas due to fire marshal restrictions, the hip and gable roofs designed for the neighborhood context were replaced with flat roofs. This "oblong box" style in glass and steel began to dominate, reflecting the new 'International' style architecture championed by the Bauhaus.[11] This streamlined exterior enabled oil companies to advertise their products. (fig. 11) In the period following the Great Depression this modern form became increasingly "thoroughly functional and thoroughly bland in its functionality", according to Jakle and Sculle.[12] This increasingly standardized, white box communicated ideas of progress and speed associated with the automobile but also allowed oil companies to advertise their company brands. (fig. 12) Service stations and repair garages began to take on an added social function around this time as automobile repair become a shared pastime.[13]

The rise of the suburbs in the 1950s brought about the rise of more gas stations in business districts due to work-home commutes. Canopies over pumps began appearing in the 1960s, initially providing the practical function of protection from sun and rain. (fig. 13) But these structures also defined a designated covered area and served as visible advertising markers for oil companies.[14] The canopy was the tallest structure present on site and its location was between the road and the enclosed retail space. In contrast to the retail box which was at the back of the site and was now hidden from view, the spatial prominence of the canopy made it easily visible to drivers and allowed it to serve as a sign for individual companies. The 1980s saw the rise of the integrated convenience store located in the box portion of the gas station. (fig. 14) These commercial spaces easily fit into the rectangular and single-story volumes, typically constructed of masonry and/or metal.[15] The front facades were often composed of large display windows that displayed goods and signs and served as a backdrop for the outdoor pumps.

fig. 11 streamlined exterior enabled oil companies to advertise their products
fig. 12 gas station advertisement from 1932

fig. 13   canopy at 1968 Texaco station in El Reno, Oklahoma
fig. 14   integrated convenience store, "On the Run"

fig. 15   Gas. Edward Hopper. 1940.
fig. 16   Service Station. Ed Ruscha. 1966.

This overall massing of the gas station type and its related functions have remained relatively unchanged since the 1980s. As a result, the distinctive form continues to be readily found and is easily recognizable throughout the U.S.. (fig. 15, 16) Throughout history, the gas station type has evolved in response to changes in the economy and in the urban fabric. The integration of automobile repair and accessory sales have expanded its function beyond refueling and increased the size of the "box" building. But the canopy continues to define the boundaries of the gas station and protect drivers and cars from the elements. Through its physical evolution, the gas station has stood apart from its surrounding context, whether it is of the urban or suburban landscape. (fig. 17)

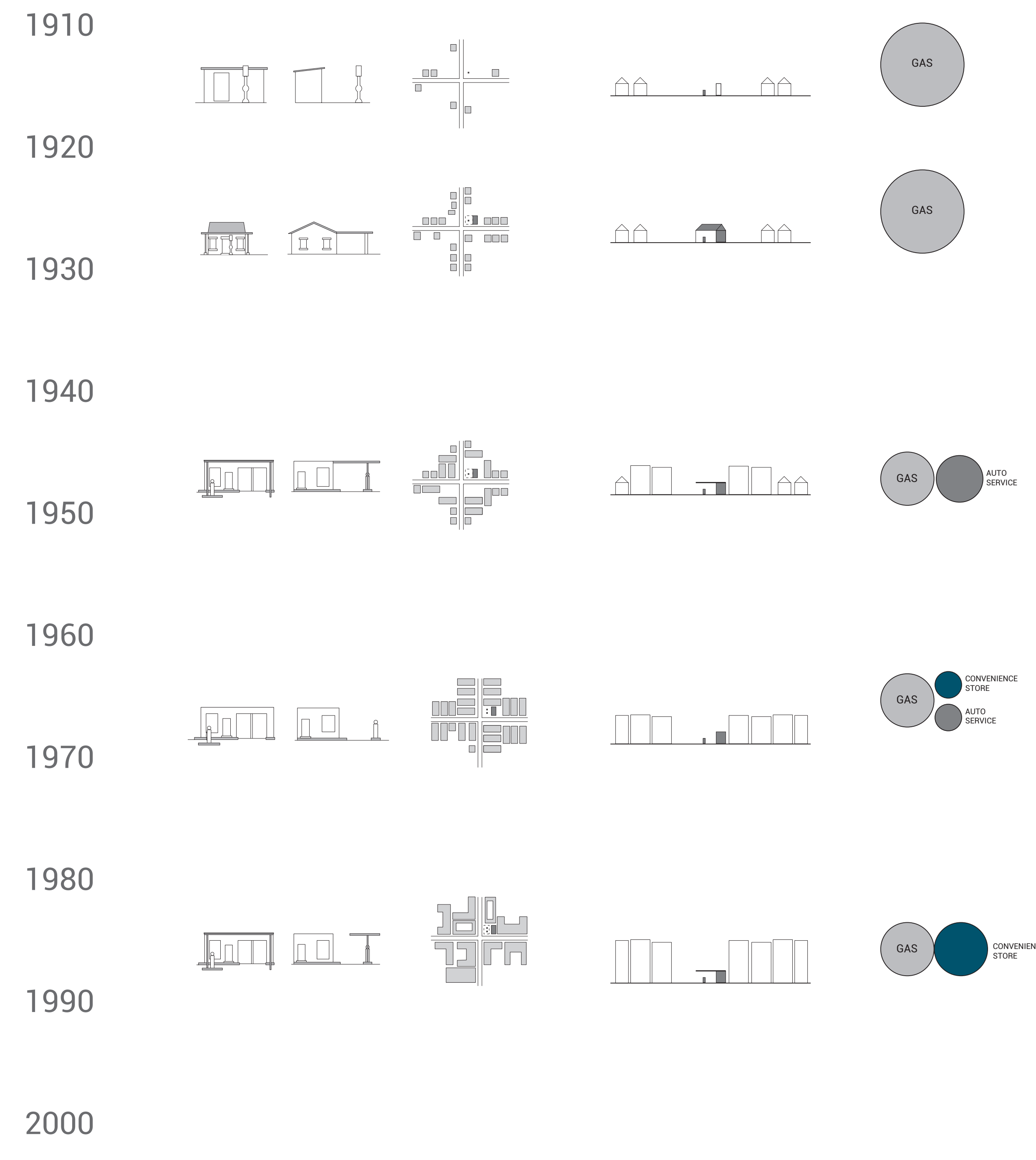


fig. 17   form, place in urban fabric, scale, and use of American gas stations in the 20th century

2.2 Utility: Machine-Driven Form

The basic architectural components of the gas station are the gas pump with its tank storage below, canopy, retail box, and vehicle lot. (fig. 18) The primary formal expression of these elements is utilitarian, designed for its functional efficiency rather than its appearance. Each element is designed for economy – taking on the most basic form to achieve maximum function.

The gas pump and tank are used for the storage and dispensing of vehicle fuel. Cylindrical tanks are located underground to minimize the risk of fire and explosion hazard. A typical underground storage tank is 12 feet in diameter and 30 feet long, with a storage capacity of 20,000 gallons. The pump apparatus is designed to facilitate the controlled transfer of fuel from tank to car. The numerical display is placed at the eye level of the standing driver and the pump holster at a hand height that corresponds to the vehicle gas tank. Pumps are typically located under the canopy to be easily accessible to incoming vehicles yet a safe distance from the building. (fig. 19)

The canopy is designed to protect the users of the pumps from sun and rain. The height of the canopy of current gas stations is determined by the standard height of commercial motor homes (13 feet) ensuring clearance for most vehicles. To facilitate free movement of cars underneath the canopy, the structure is clear span with minimal column support. In order to resist lateral and wind loads, large underground foundations and column footings are required. Although the primary purpose of the canopy is for the comfort of the human users, the scale and form is driven by the car. (fig. 20)

The most enclosed element of the gas station has evolved from its origins as a storage shed into a commercial building. This box is typically a single-story, rectilinear building constructed of masonry or steel and glass with minimal distinguishable formal architectural elements. This neutral exterior enables oil companies to have the building front to be composed of large windows that make visible retail functions. (fig. 21) The building can house a convenience store, bathroom, space for an attendant, and storage. The rectilinear form allows these uses to be housed in efficient spatial arrangements to allow customers to get in and out quickly.

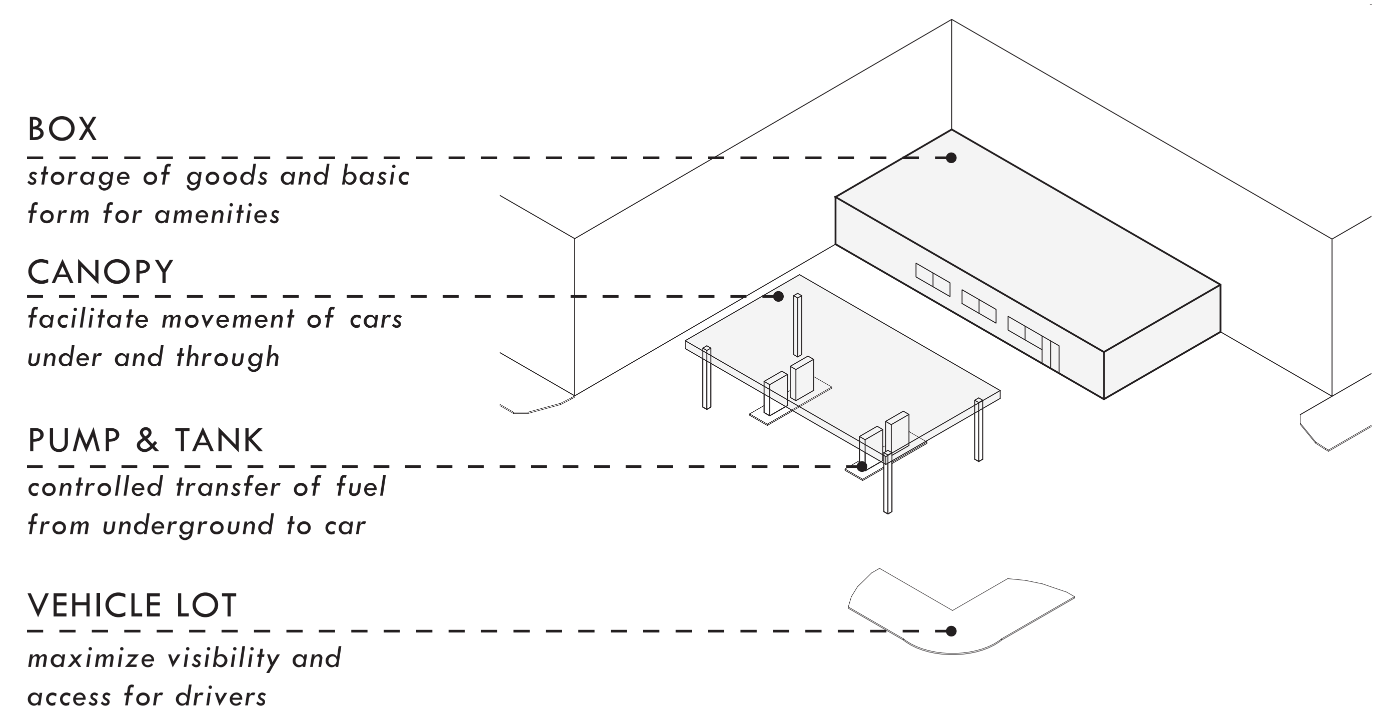


fig. 18 utilitarian architectural components of the existing gas station

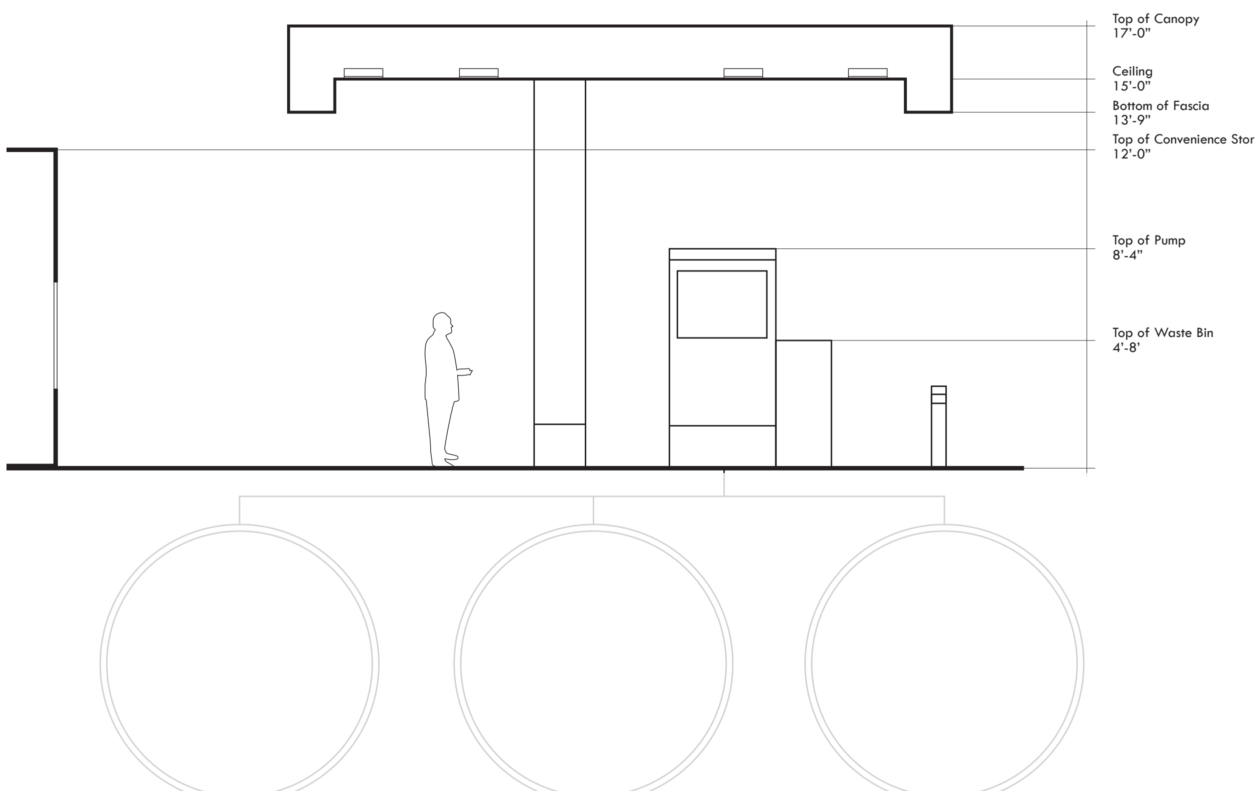


fig. 19   relationship of the human to the architectural components of the existing gas station

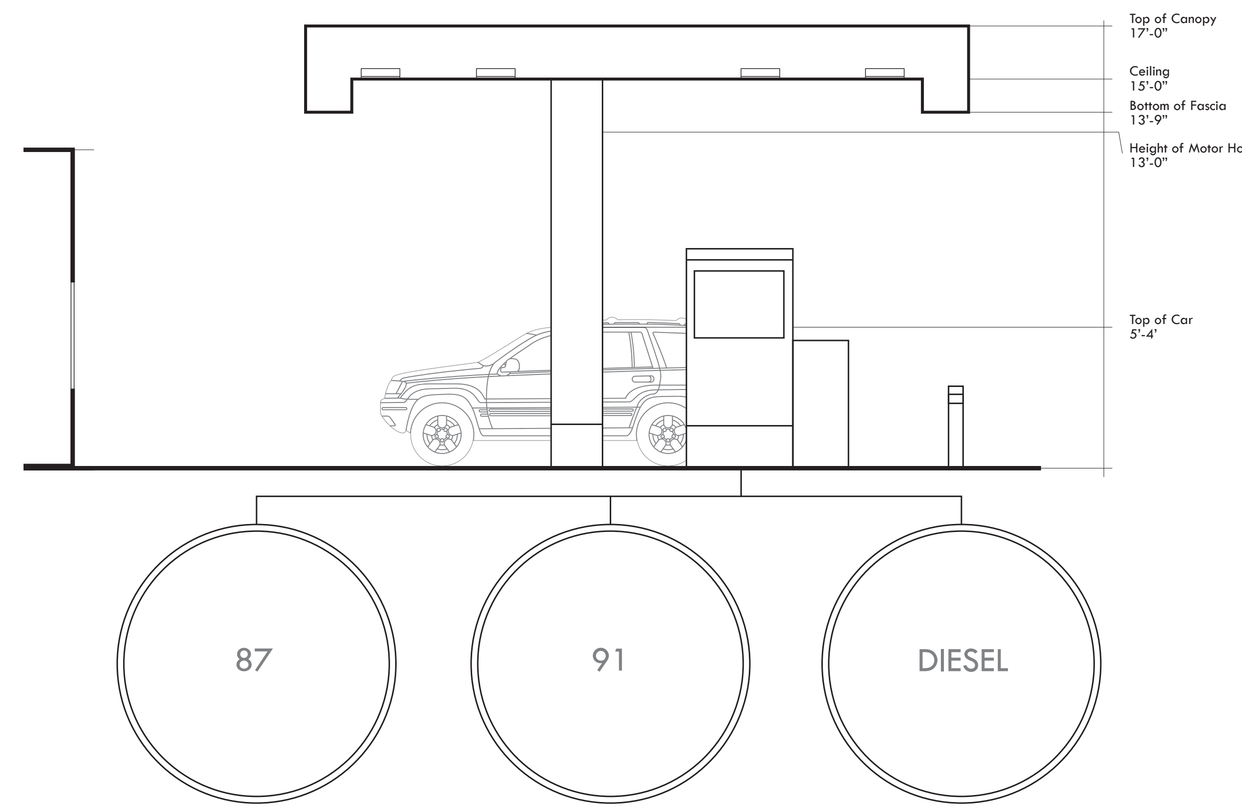


fig. 20   relationship of vehicle to the architectural components of the existing gas station

2.3 Amenity: Accommodating the Human

In addition to its primary function of providing fueling services to automobiles, the gas station has also taken on additional functions for both cars and people over the last century. (fig. 22) The size and form of these ancillary services varies depending on the company and the location. However these additional amenities have typically remained contained within or attached to the "box" form of the gas station. Accessory services can include mechanical car wash, full-service car repair, and self-service tire inflation. These functions are typically located in direct proximity to the retail box either in a separate structure or physically attached. The full-service repair function was more common until the mid 20th century when the convenience store began taking precedence.

Since the 1930s, public bathrooms have been provided as an amenity in the typical gas station. Because of the transitory nature of gas station consumers, the security and cleanliness of these bathrooms continues to be a major concern of station owners. The gas station bathroom is often regarded as more public, available for use by car owner, pedestrian, consumer, and/or passer-by. The bathroom is often located to the back or side of the convenience store as an accessory space.

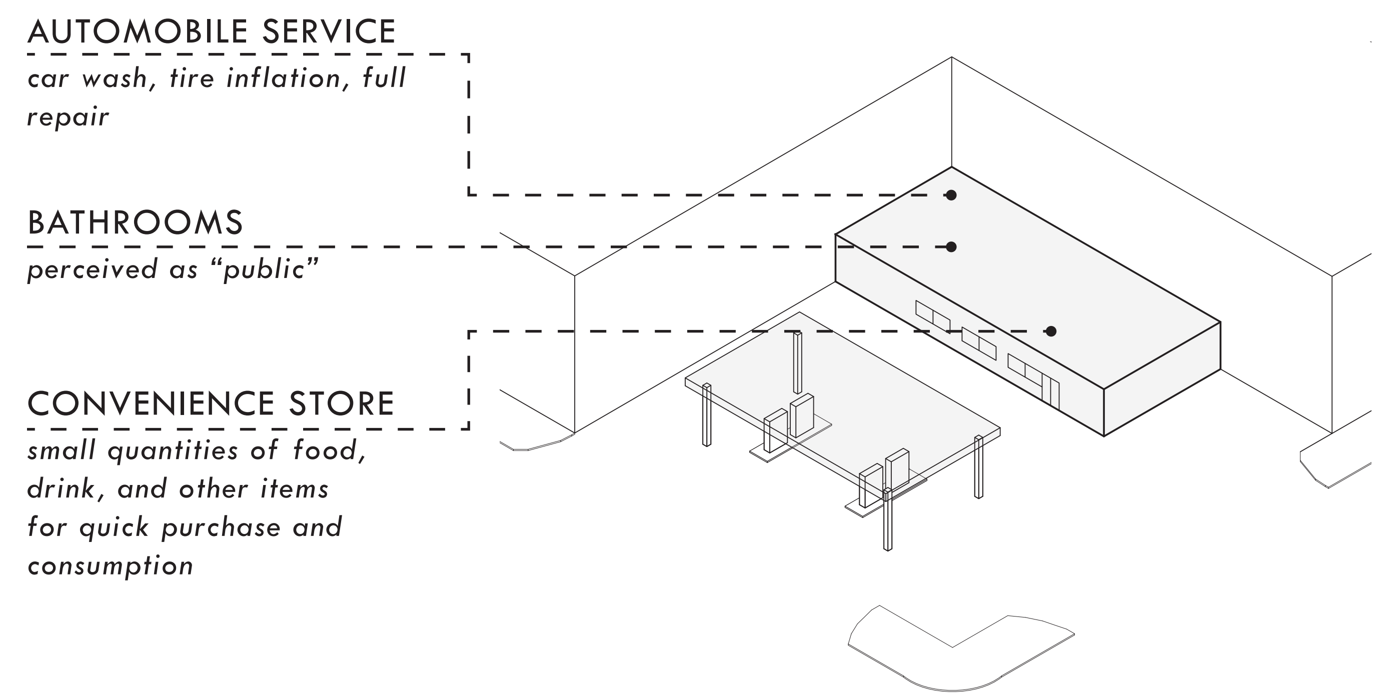
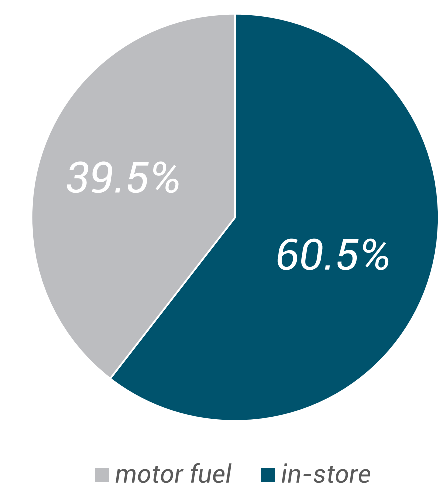


fig. 22 amenities offered by the existing gas station

Today the convenience store dominates the area of the building portion of the gas station. According to the Association for Convenience and Fuel Retailing in 2015 in-store sales accounted for 60.5% of profit dollars for U.S. gas stations while motor fuel sales accounted for 39.5%. (fig. 23)[16] This retail amenity offers a wide assortment of small convenience food items and drinks, along with home and/or auto goods. Food and other dry goods are located on lower height shelves in the center of the store. (fig. 24) The height of the shelves grants visual access for the consumer to the whole interior and thus to most of the items available for purchase. Taller refrigerated cases line the edges of the room, maximizing the use of the space. The consumer items offered are skewed towards quick consumption and long shelf life. The cashier is often near the door as a control point for customers. The simple layout of the store allows for quick spatial navigation so that customers can quickly enter the store, find items for purchase, pay, and quickly return to their car. The short length of time intended for the user when shopping reinforces the convenience nature of the goods offered.

In expediting the movement of automobiles and drivers, the gas station is an utilitarian typology that also offers amenities. These buildings have become common fixtures on major roadways and highways throughout the United States since the beginning of the twentieth century. The house-form of the gas station dominated until the integration of tire, battery, and accessory sales and automobile repair. The larger oblong box prevailed until high gasoline prices reduced the area required for automobile service bays and vehicle accessory sales.[17] Now as a signifier of gas refueling and quick sales of goods, the canopy is a dominant form. The current discrete architectural components are the retail box, canopy, gas pumps and storage, and vehicle lot. These elements took on an economic form – basic utilitarian trappings to accomplish maximum function. The gas station has added functions for both automobiles and people over the last century in addition to its principal function of providing fuel for cars. These additional amenities and uses casually accumulated onto the utilitarian structures. In doing so, gas stations have evolved to better satisfy the needs of the American driver in both the consumption of fossil fuel and for consumer goods and service.



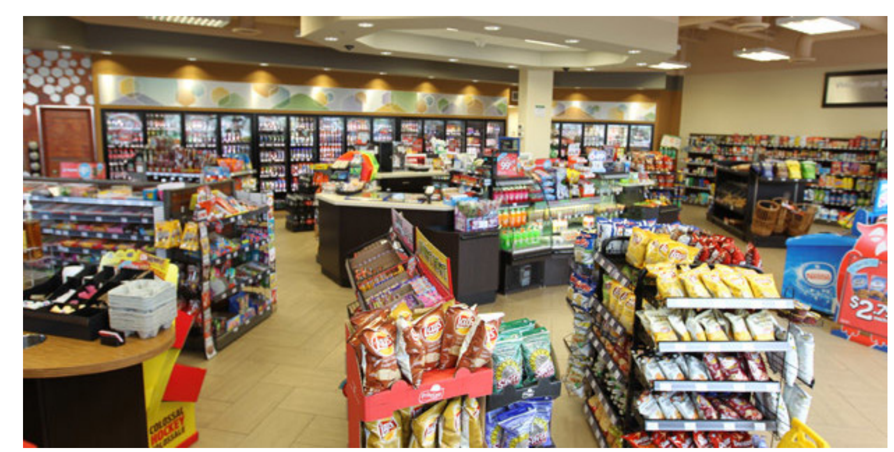


fig. 21 exterior physical elements of the box contain advertisements of the interior retail function
fig. 23 gas station sales in 2015
fig. 24 mid height shelves within the convenience store

THREE

gas station as node/connector: a study in Seattle

3.1 Location: Circulation and Flows

Urban gas stations are typically located on corner sites at the intersections of vehicular arterials so two street boundaries can be used for vehicle access. (fig. 25) This edge perimeter permits eight different ways in which cars can enter and exit the gas station lot on both sides, maximizing movement and flow. These multiple access points allow for maximum usage by an automobile driver who might otherwise bypass the station in these highly trafficked areas. Upon entering the site, the driver navigates his or her car to the pump for refueling. After filling the vehicle with fuel, the driver maneuvers the car back onto one of the streets. The corner lots that enable this quick and efficient transaction have today become even more valuable prime real estate because they provide maximum visibility for car users and pedestrians.

Pedestrians and cyclists also use the gas station either for the convenience store and/or to use the restrooms. They typically enter the gas station site on sidewalks that are not continuous around the site due to curb cuts. Field observation has suggested that pedestrians tend to stay towards the edges of the site to avoid car traffic and find the most direct route to the convenience store. Typically, the convenience store box has a single entrance and exit that faces the pumps. Once inside, people walk up and down the aisles browsing goods or head to the restrooms located at the back. Before exiting, customers pass the station attendant near the door where they can purchase goods.

The circulation of cars and people creates distinct areas for specific users of the gas station. The movement of vehicles most often consumes the majority of the gas station site, located on the front edges facing the street. Pedestrian circulation is often located on the back of the site, concentrated around the rectilinear form of the convenience store. The spatial hierarchy that emerges from the circulation patterns places the car as the primary user with pedestrians as secondary users.

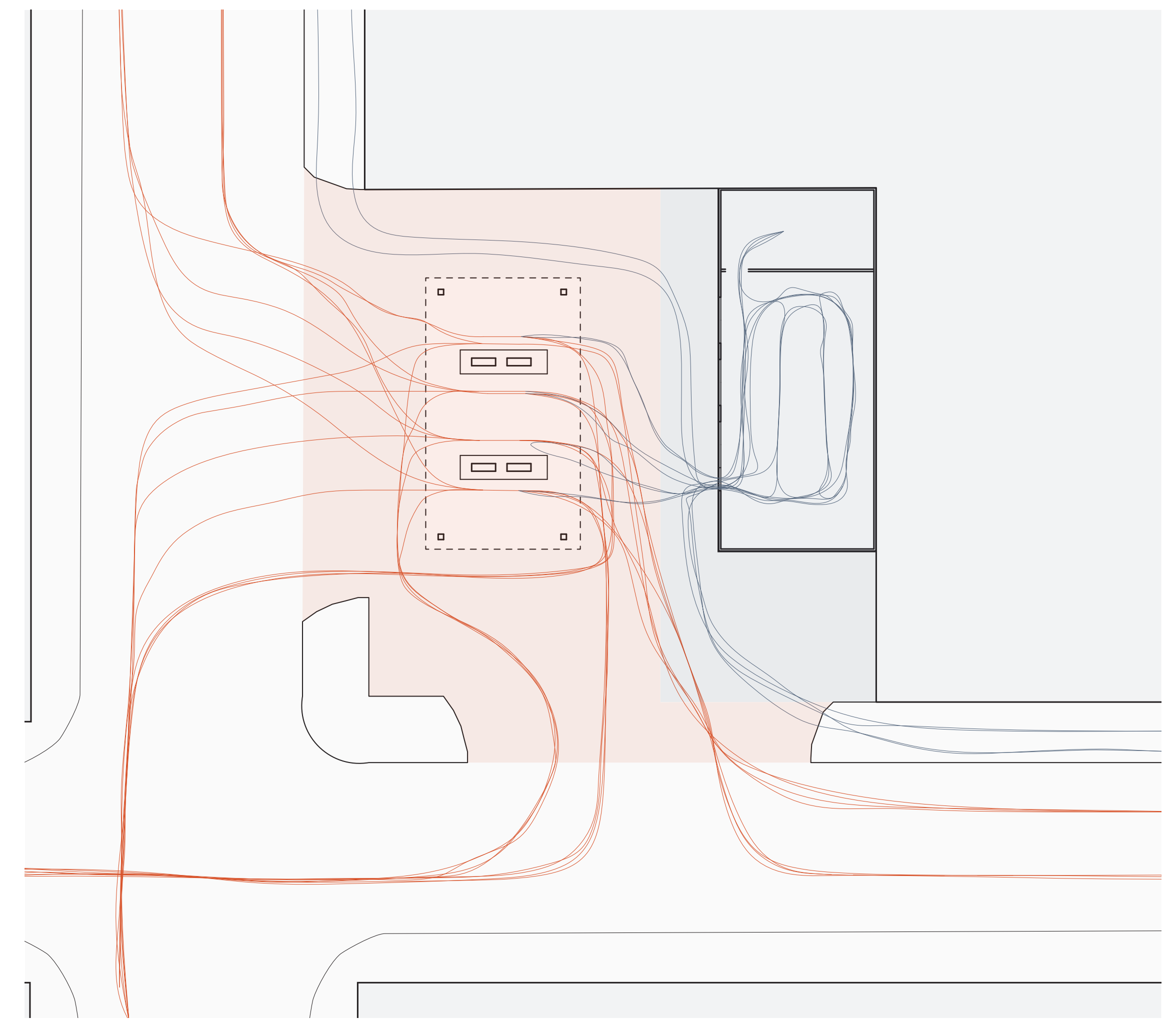


fig. 25 circulation of the existing gas station with cars in red and pedestrians in blue

3.2 Obsolescence: Changing Needs

While surviving as a monument to the power of car culture in the 20th century, the gas station today has become increasingly obsolete in the face of growing cities and increasing environmental awareness. (fig. 26) This building type is still often regarded fondly as a sentimental artifact of a bygone time that was dominated by automotive transportation. But, increasingly, gas stations reflect the hugely negative impact of fossil fuels on people and the environment in terms of airborne emissions and soil contamination. (fig. 27, 28)[18] Alternative energy sources and modes of transportation are gaining prominence as the electric powered vehicle use has increased. In large cities, alternate modes of transit such as biking, car sharing, and public transportation have all grown in popularity. (fig. 29, 30, 31)[19]

Until the increase in the cost of oil in the 1970s, the number of gasoline stations increased every year. With the rise of self-service pumps and convenience store tie-ins, the number of stations decreased starting in the 1980s and 1990s.[20] This reduction was accelerated by big-box store consolidation and government regulations. (fig. 32) According to the US Census in 2014, there were 111,583 gas stations in the country, which is slightly down from 1990, evidence of declining growth. (fig. 33)[21] Gas stations will continue to exist as long as Americans are dependent on vehicles for work and travel. But while automobile ownership continues to increase, the number of gas stations is in the decline, especially in urban areas. This is especially evident in Seattle, where the number of gas stations has decreased by over half from 340 in 1973 to 137 in 2016. (fig. 34)[22, 23]

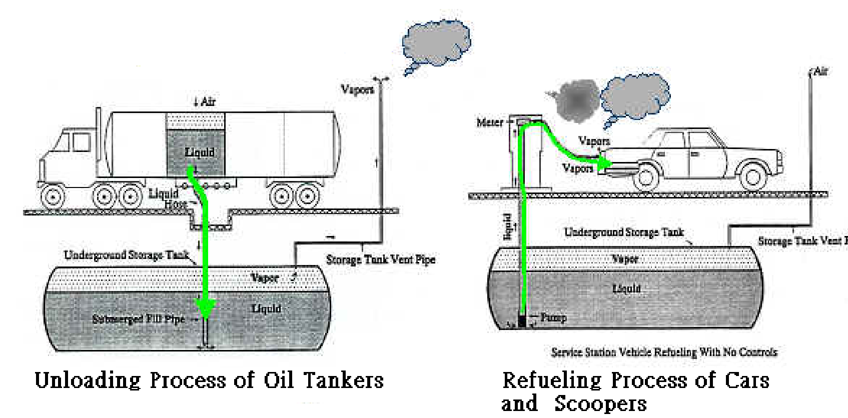
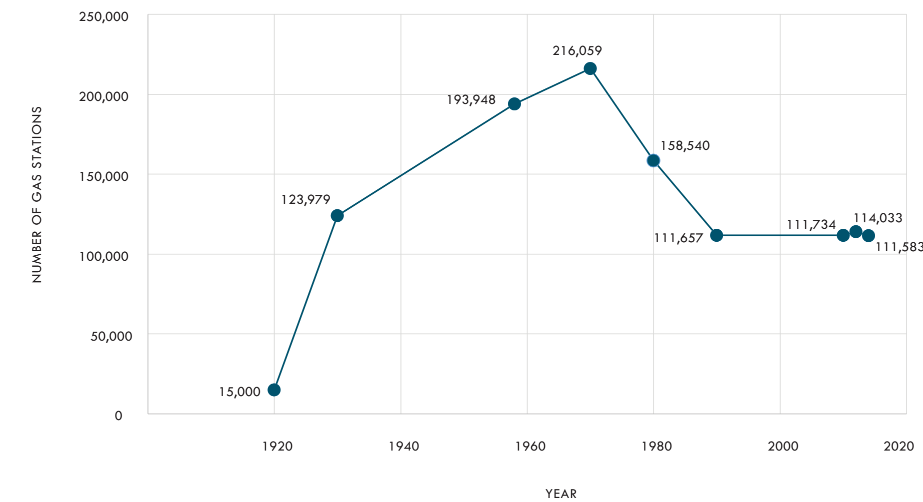


fig. 26 many gas stations in America are becoming obsolete and are closing
fig. 27 negative human health effects of existing gas station practices
fig. 28 negative environmental health effects of existing gas station practices

fig, 29   photovoltaic arrays harvest solar energy
fig. 30   commuting by bicycle and public transit is rising in American cities
fig. 31   electric vehicle use and charging infrastructure is rising
fig. 32   gas station consolidation at Wal-Mart and Sam's Club



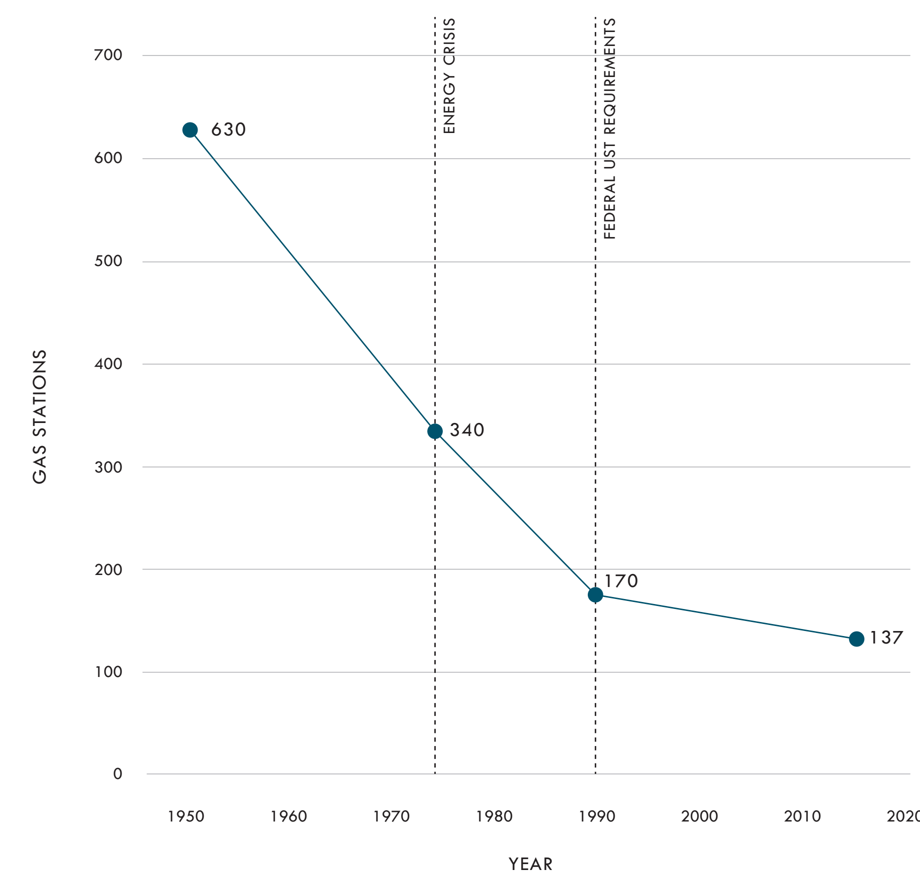
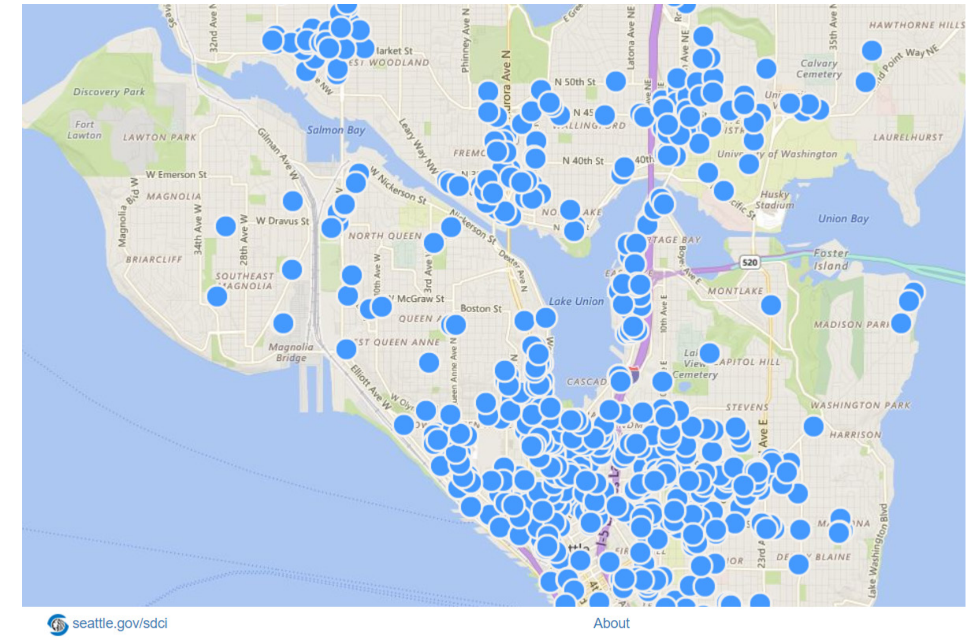


fig. 33   number of gas stations in U.S. has decreased over the last 40 years
fig. 34   number of gas stations in Seattle by year

Seattle is one of the fastest growing cities in the country, increasing in population and building density. (fig. 35) While the need for affordable housing has been a concern of city officials and developers, the importance of urban amenities to support the growing population has typically been overlooked. The prime locations the gas stations occupy and the amount of area they cover has made them popular sites for redevelopment. (fig. 36) While these projects aim to increase density by filling the voids in the urban fabric once dedicated to the car, they typically fail to address the history of the site as an urban node in the circulation of people, vehicles, and energy.



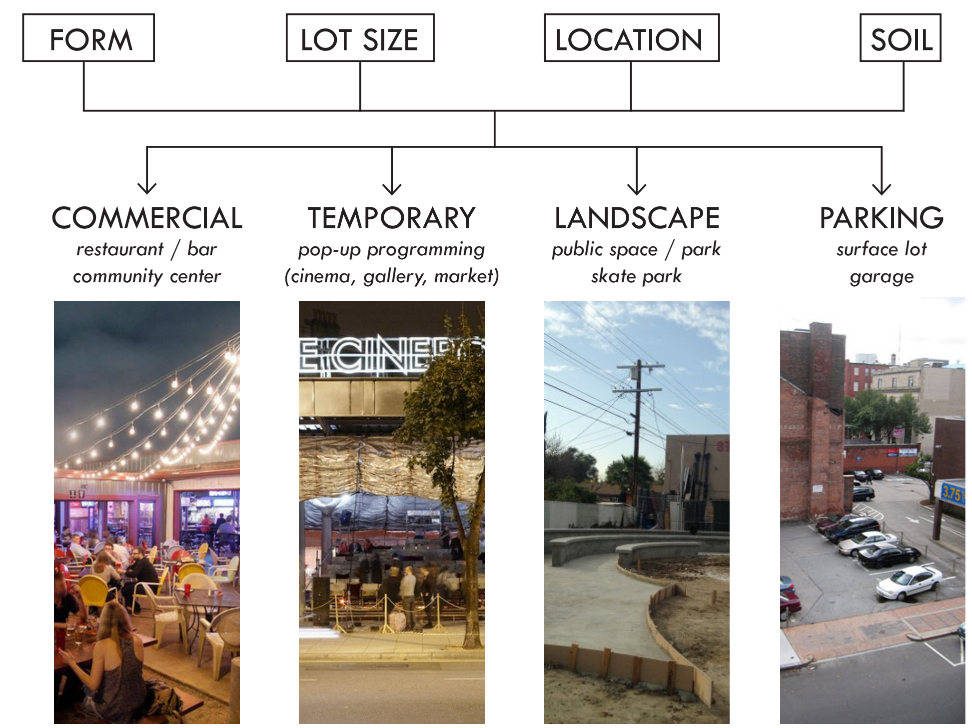


fig. 35 map of buildings in permit or review as of October 12, 2016
fig. 36 typical reasons and results of the redevelopment of gas station sites

3.3 Program Development

The program for the proposed urban amenity node, called the Energy Commons, is divided into four primary components identified by their primary user: 1) human, 2) bicycle, 3) electric vehicle, and 4) contextual/flex. (fig. 37) Compared to the program of the existing gas station, this new building type takes on more functions and thus engages a wider variety of people. The car is no longer the primary user and the hierarchy of architecture to user is more reflective of the intended emphasis on the human and bicycle than the automobile.

The program of the “Energy Commons” is defined as a response to contemporary shifts in energy distribution and urban mobility. (fig. 38) This reimagined building type will be a spatial means to serve a range of personal transportation modes and address renewable resource distribution deficiencies in growing cities. Cyclist and pedestrian amenities will be provided to create a human-centered program rather than one dominated by the car as in the past. The “Energy Commons” will not only power operations on site with its own energy harvesting but also will supply electric vehicle charging stations and house vehicle share on the site. The final program component will respond directly to the immediate need in the given neighborhood where the building is located. In better serving the neighborhood through a flexible use, this contextual program will allow the prototypical project to ground itself within its unique and immediate surrounding. In its function and form, the “Energy Commons” building will act as a literal “battery” that will power and empower human mobility in the city.

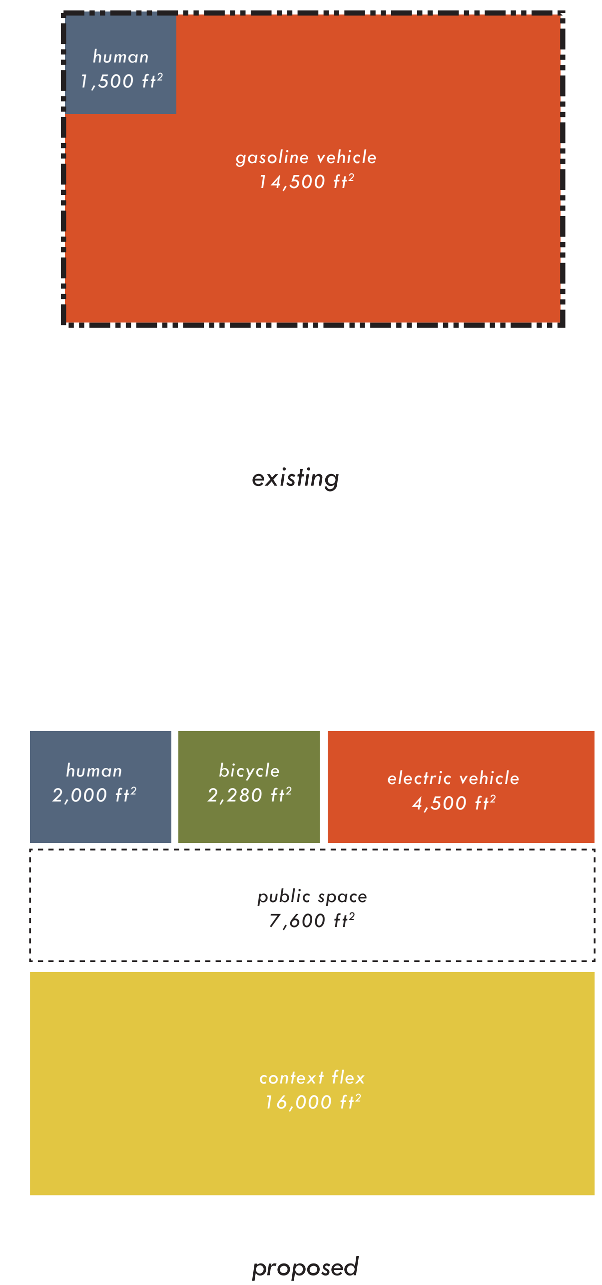


fig. 37 program components of the proposed “energy commons” compared to the existing gas station

The program of the Energy Commons advances the program of the existing gas station to better serve changing needs of growing cities. The base is from the current gas station – convenience store, restrooms, and vehicle refueling, in this case electric vehicle recharging. In the interest of promoting cleaner transportation, bicycle amenities for bike storage, rental, and repair are provided. The context component of the program can range from coworking, daycare, tool library, food truck park, bike playground, restaurant/bar, laundromat, gym, grocery pickup, Amazon Go, cinema, health clinic, etc. The goal is to have a program or combination of uses that is specific to the neighborhood in which the Energy Commons is sited while also providing a variety of functions to encourage diversity in the type of user, usage time and public/private functions. The contemporary urban condition in which the project is generally sited is characterized by societal flux and demographic changes. Adopting a similar approach as that offered by architect Rem Koolhas, this new program and building type will maintain current functional use and accommodates "future programming while keeping the illusion of architecture intact in the external shape."[24] Cities with increasing density are currently dealing with how to address mixing of utility and amenity in programming as public and commercial space encroaches on necessary utilities. Through proposed "programmatic alchemy", the thesis is attempting to use the "liberating capacity of architecture" to mark the Energy Commons as a "social condenser" that responds to future changing needs on a neighborhood and city scale.[25]

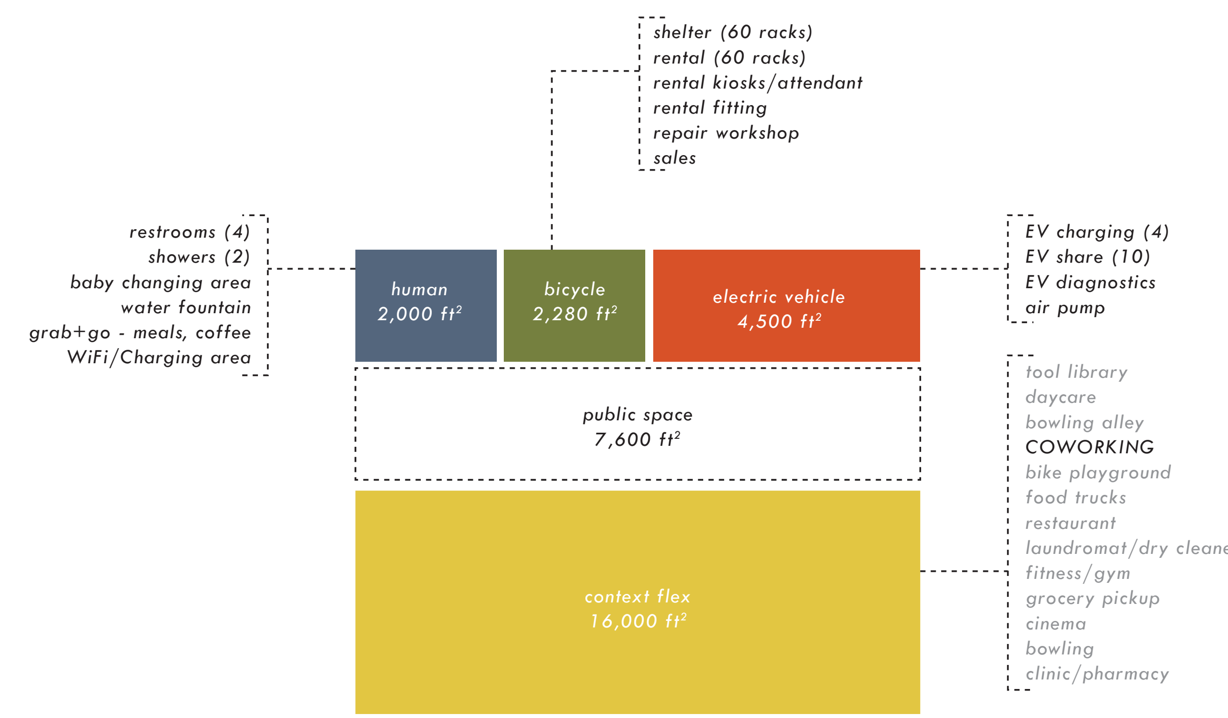


fig. 38   specific program elements of the proposed project

3.4 Site Selection

This thesis proposes the design for new urban amenity nodes, or "Energy Commons" based on the existing typology of the urban gas station in Seattle. Each node is small-scale but operates in a larger urban network within Seattle. (fig. 39) Operating at a neighborhood scale, the "Energy Commons" will serve as a local hub in accommodating basic utility and contextual amenity for humans, bikes and electric vehicles. A major component of this thesis is combating the obsolescence of the current gas station. By repurposing a current gas station into the new building type, the proposal capitalizes on the history of the gas station as a necessary junction for people and vehicles in the city. The selection of this building type also harnesses the American perception as a landmark to support urban growth instead of continuing gasoline automobile dependence. Thus, the first task is to catalog and map the existing infrastructure of personal automobile refueling in Seattle to determine a possible site(s) for the proposed intervention. A series of parameters are defined to assist in site selection. For the specificity of this thesis, the primary goal in this process is to identify one existing gas station for one possible examination as an architectural response. However, after each guideline is applied, a network could be developed from the remaining sites at a larger urban scale for the nodal network portion of this proposal.

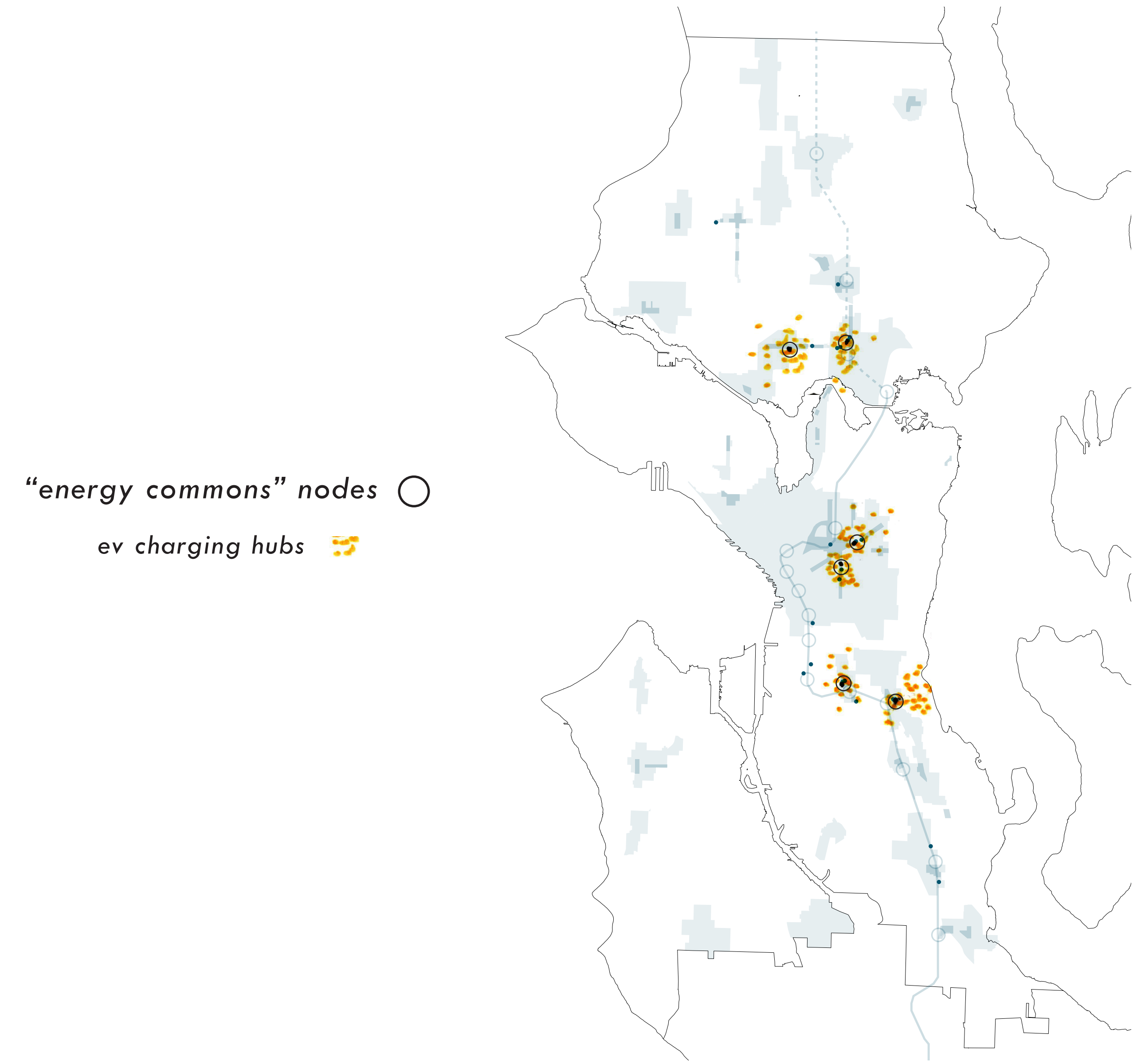


fig. 39 conceptual proposal of nodal network of energy commons in Seattle

In order to determine an existing gas station site to redevelop for the project from the 137 that are currently operating in Seattle, five criteria were established – 1) Within ¼ mile of another gas station, 2) Presence within an Urban Village, 3) Presence in a Pedestrian Oriented Zone, 4) Within a 10-minute walk to a Link light rail station, 5) Located on a collector arterial or lower trafficked street. (fig. 40)[26] Because a quarter of a mile is equivalent to a 30 second drive at a 30 miles per hour, this distance between stations is chosen as a cutoff point to identify gas stations that are too close to each other. This distance was coincidentally found to be the median distance between gas stations in Seattle. (fig. 41)[27] In selecting a gas station with adjacency to other similar underutilized sites, the hypothetical Energy Commons is placed at a gas station site that is over serving its surrounding neighborhood. Just under half (64) of the stations are located within a 1/4 mile of another station. (fig. 42) Second, the City of Seattle has designated certain areas of the city as urban villages, where focused and planned growth of housing and jobs will be directed in the immediate future.[28] To best serve the growing city, the proposed Energy Commons will be located within one of these high growth areas, which results in 59 existing sites. (fig. 43) Third, the City of Seattle has zoned urban areas as pedestrian oriented zones that encourage a mix of street-level, pedestrian-oriented businesses and destinations accessible by foot, bike, and transit.[29] With similar goals, the proposed project will be located in one of these areas, resulting in 22 remaining sites. (fig. 44) To promote multi-modal transportation options, being within a 10 min walk of current or planned light rail station (as of July 2016) is also important to the project. (fig. 45)[30] 16 sites meet these criteria. Finally, in order, to identify a site in a neighborhood, existing gas stations away from highly trafficked arterials were identified, leaving two sites. (fig. 46)[31] The combination of these criteria yielded the location of a site in the University District at 4700 Brooklyn Ave NE, about a mile north of the University of Washington. (fig. 47)

1. Within 1/4 mile of another gas station.
2. Presence with Urban Village
3. Presence in Pedestrian Oriented Zone
4. Within a 10-minute walk to a Link light rail station
5. Located on a collector or lower trafficked street

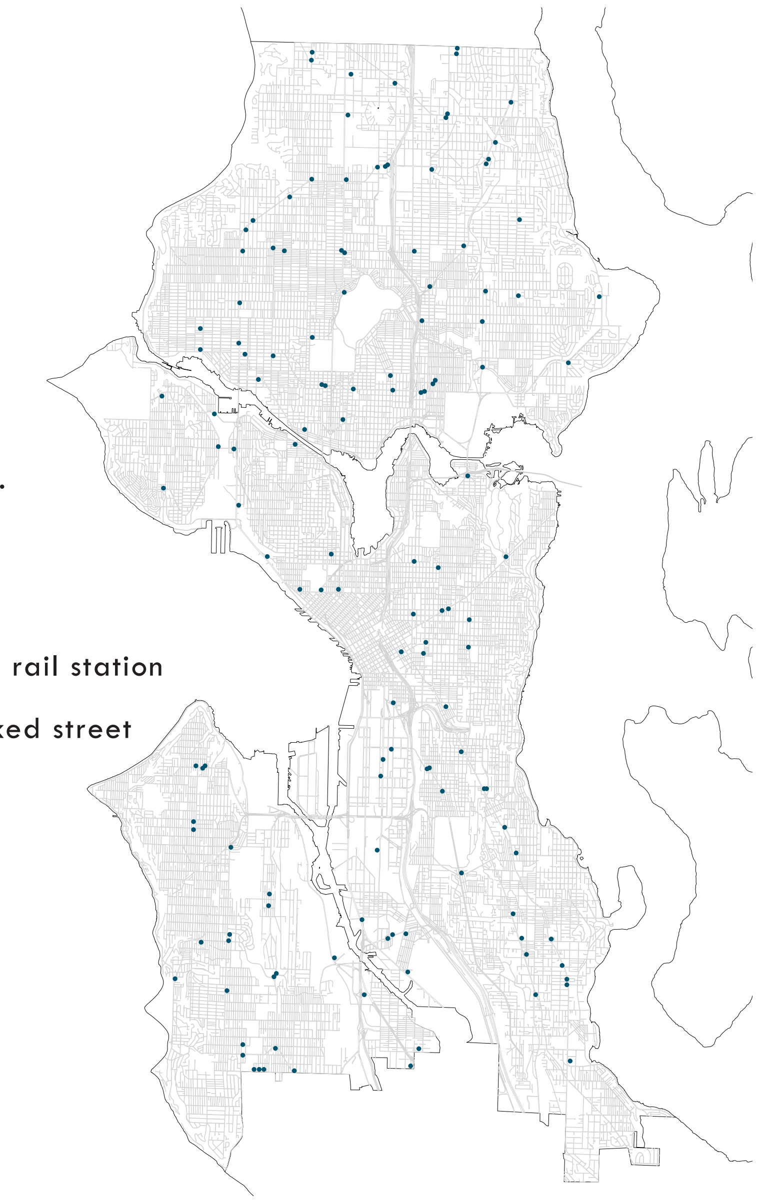
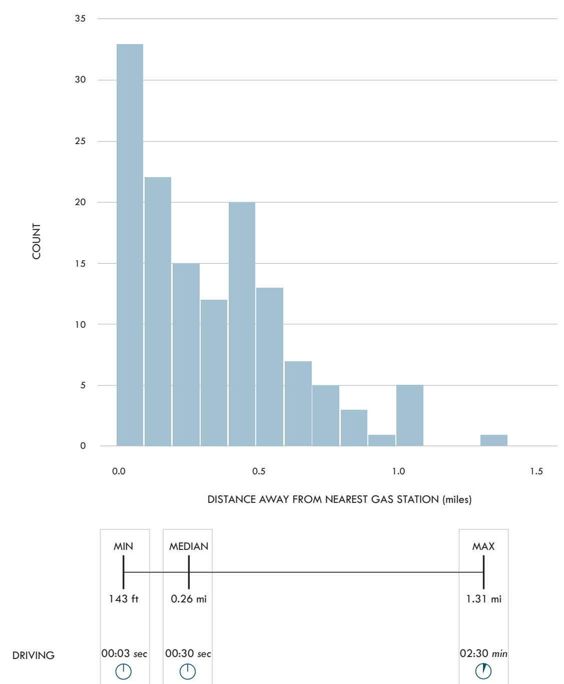


fig. 40   map of existing gas stations in Seattle and site selection criteria



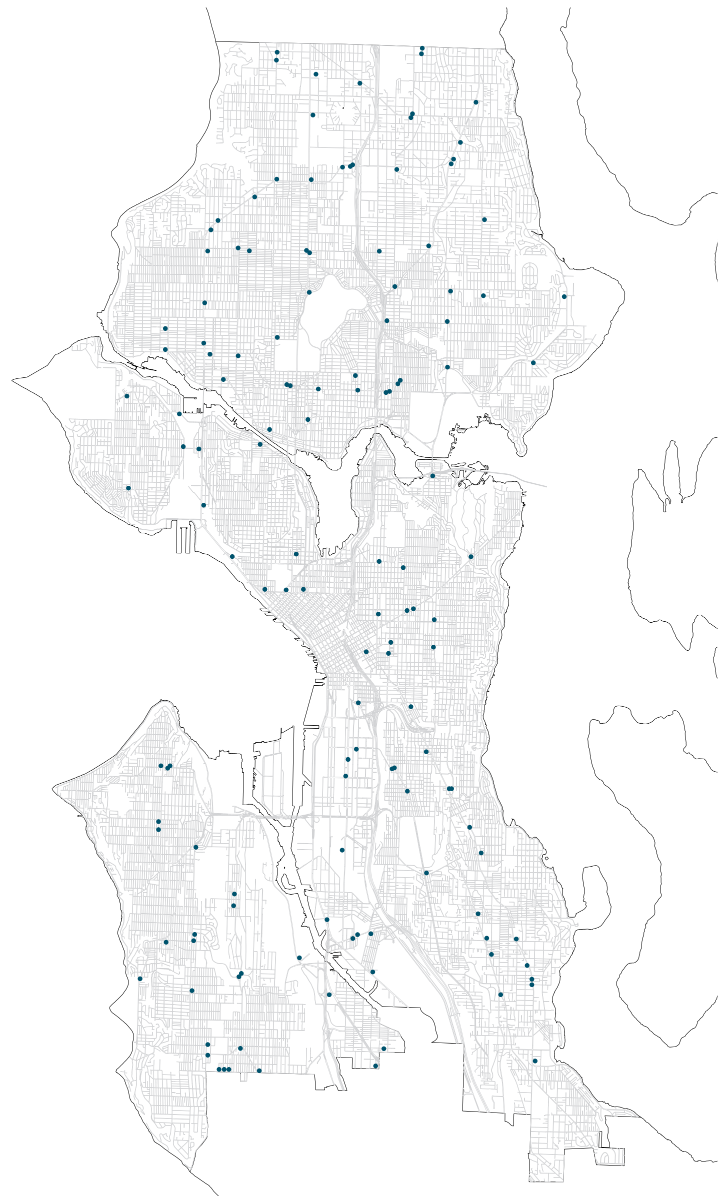
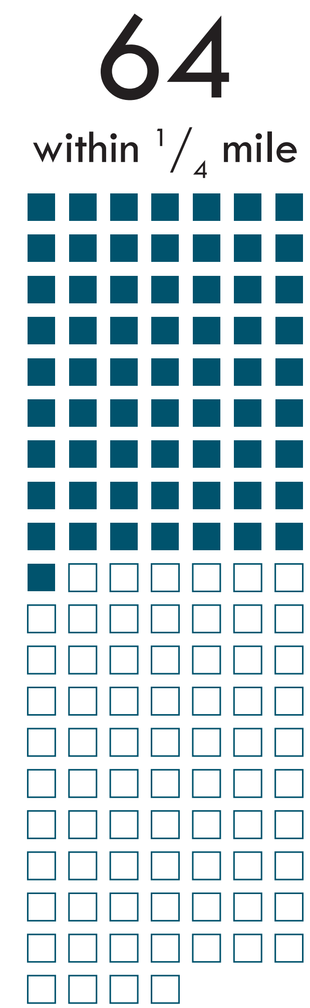


fig. 41   histogram of distance between nearest gas stations in Seattle



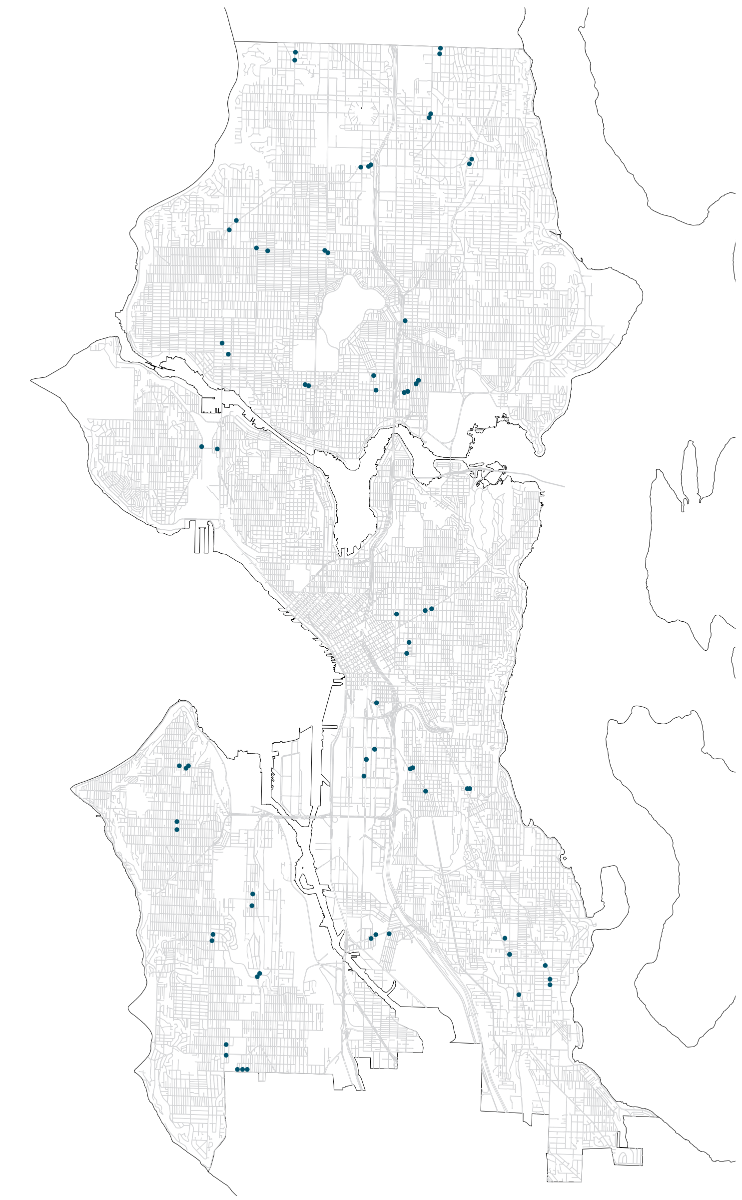


fig. 42   map of existing gas stations in Seattle within a quarter of a mile of another gas station

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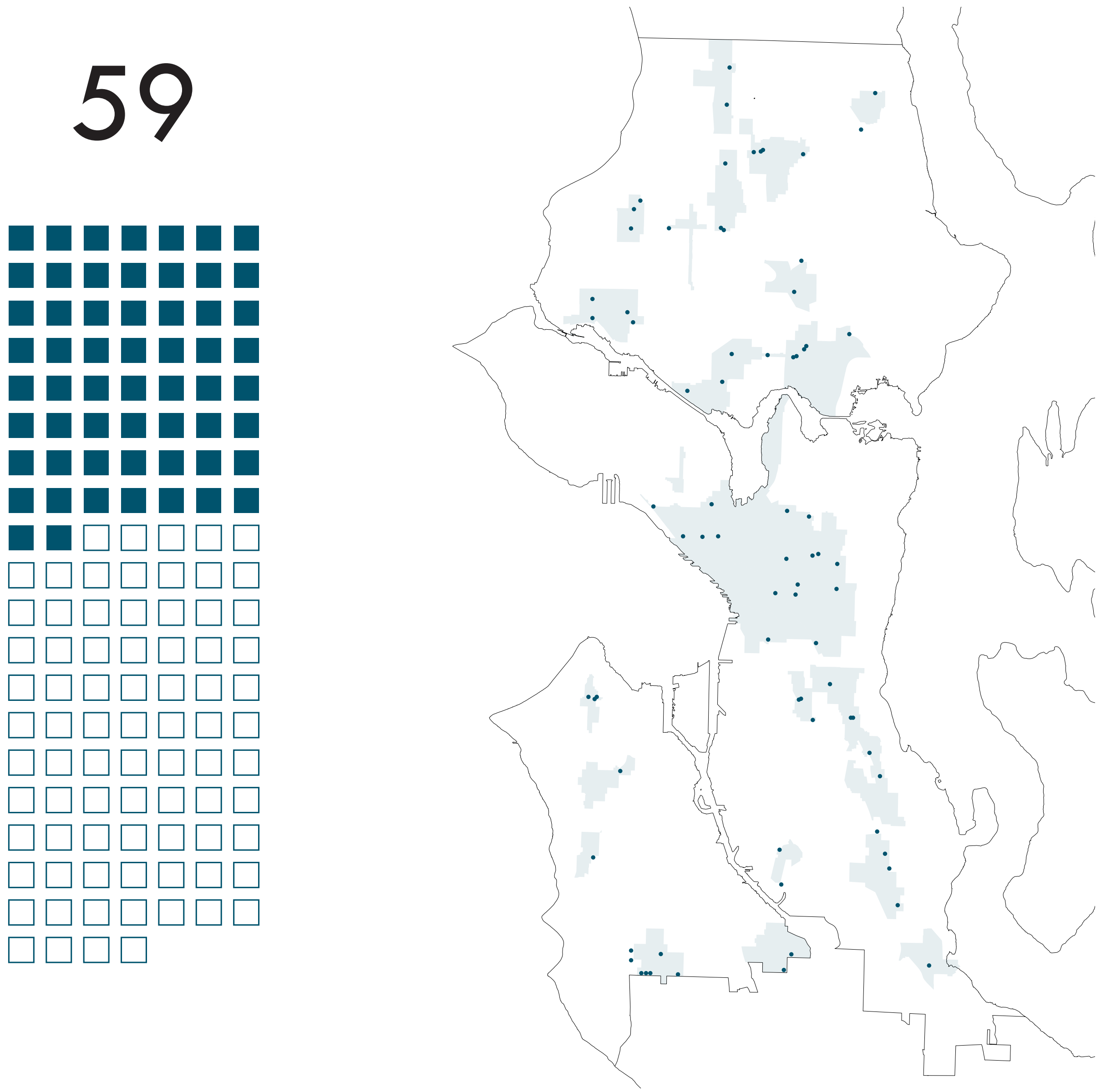

fig. 43   map of existing gas stations in Seattle within an Urban Village

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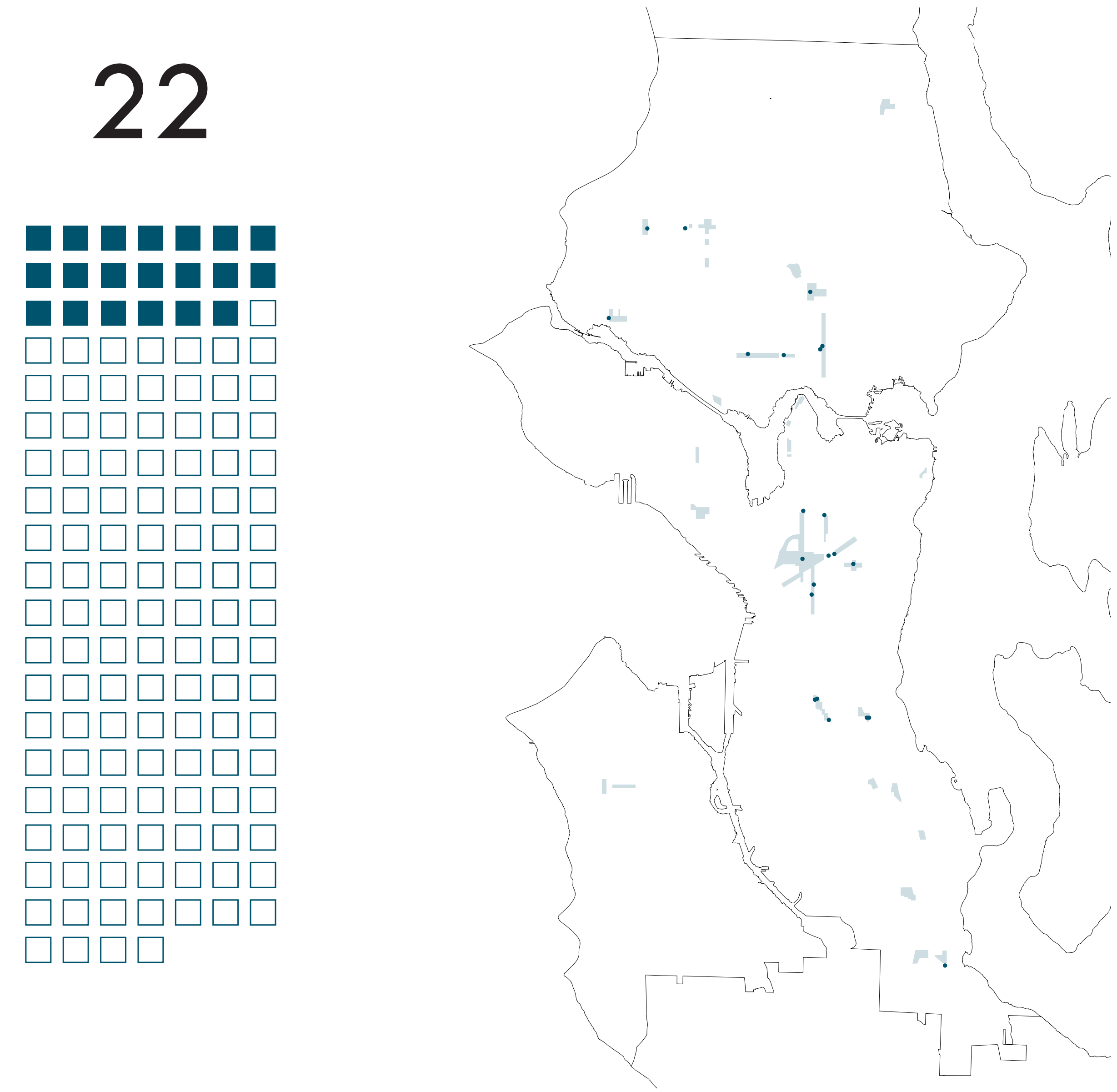

fig. 44   map of existing gas stations in Seattle within a Pedestrian Oriented Zone

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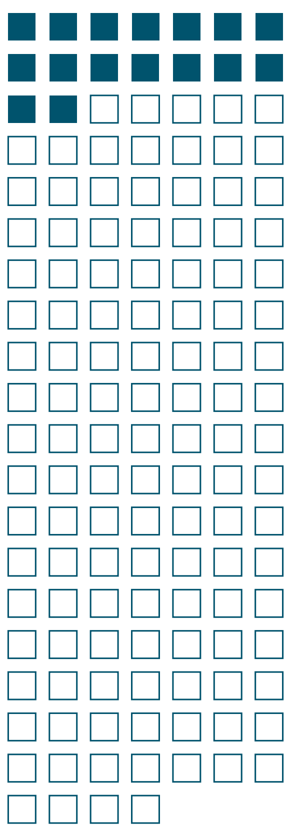


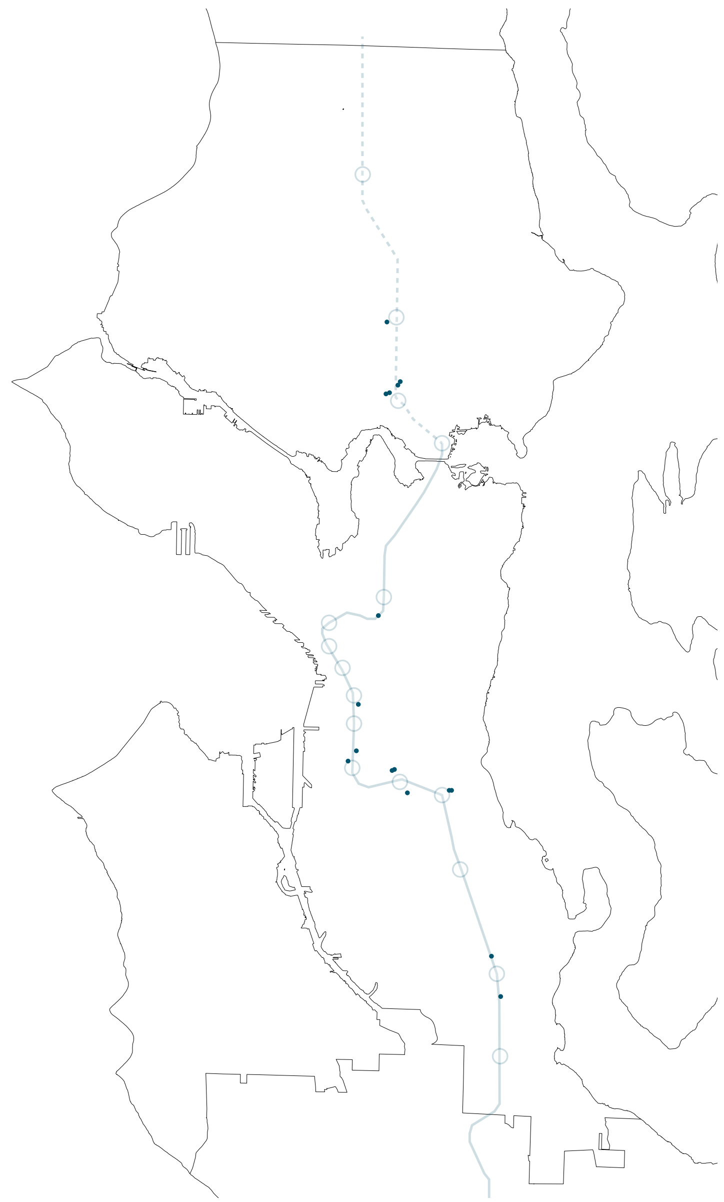
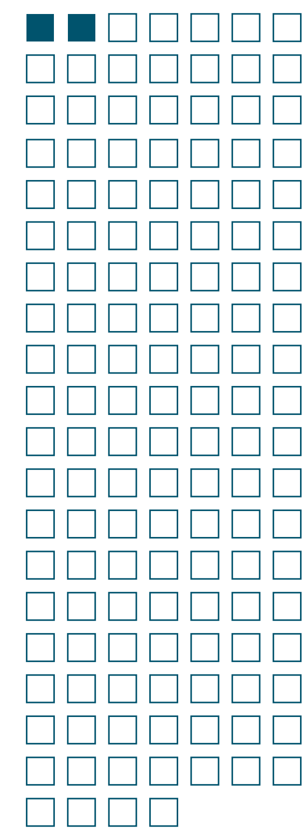


fig. 45   map of existing gas stations in Seattle within a 10-minute walk of an existing or planned Link light rail station

2



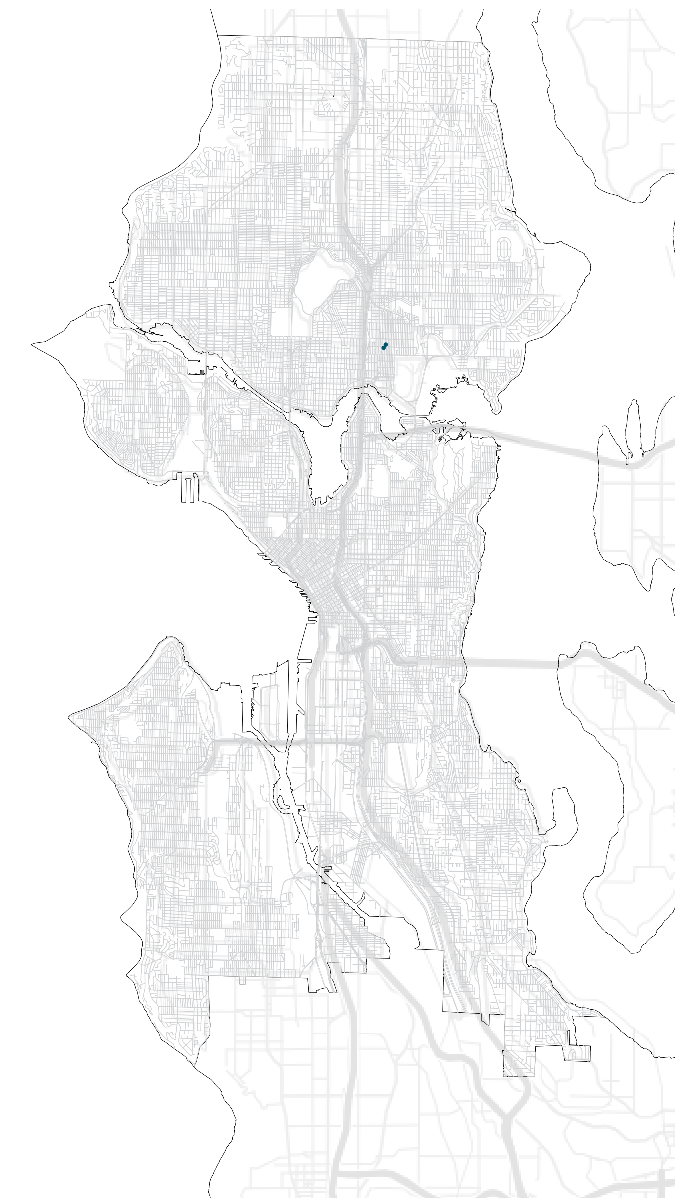


fig. 46   map of existing gas stations in Seattle on a collector arterial or lower trafficked street

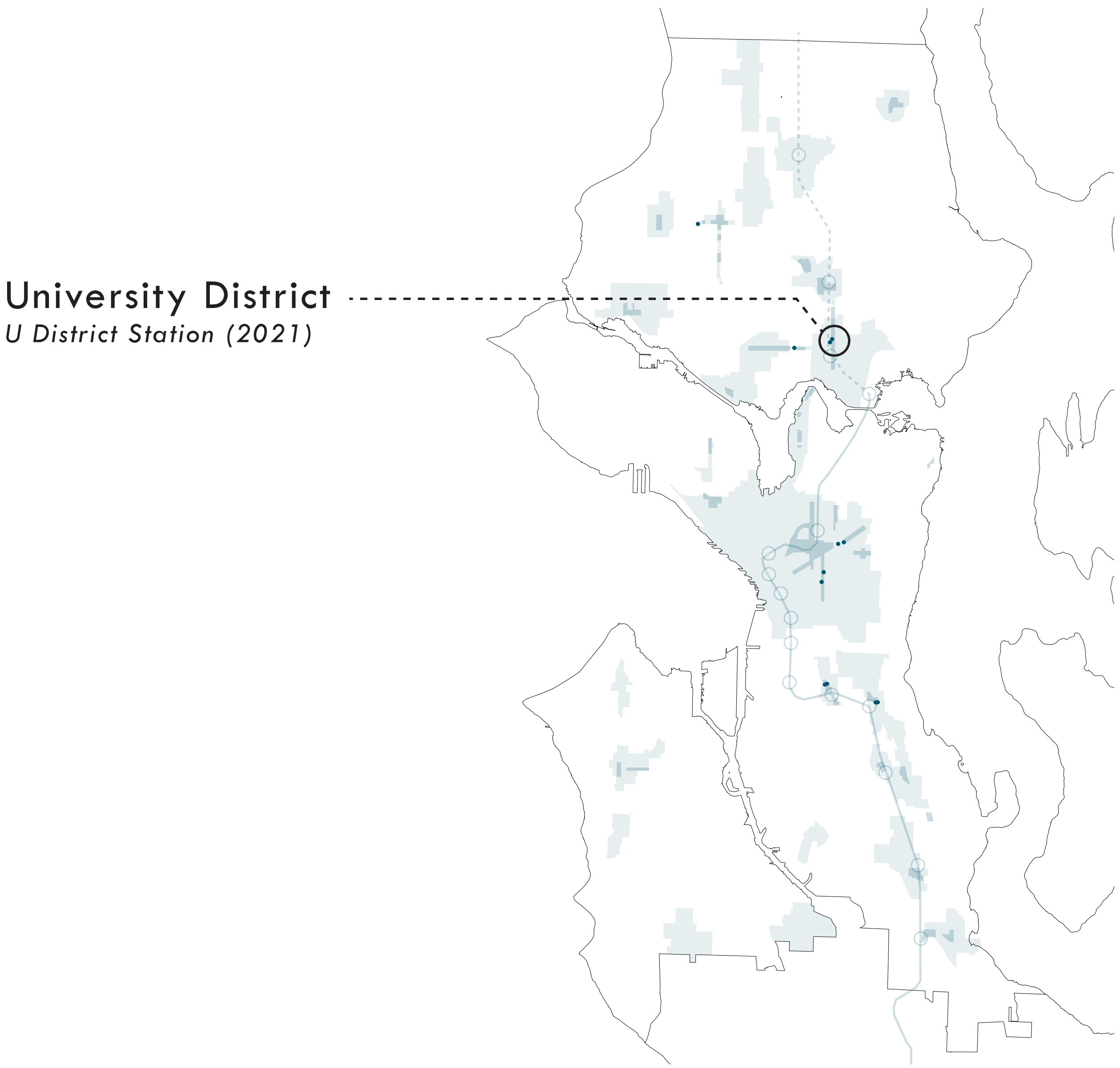


fig. 47 remaining site after the site selection process

University District

33,763.5 inh/mi²

urban center

SM-U 75-240

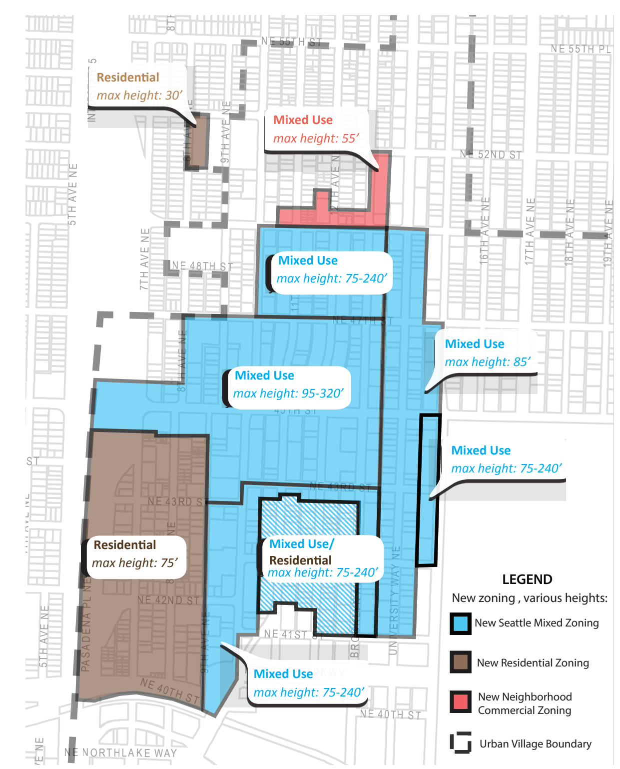
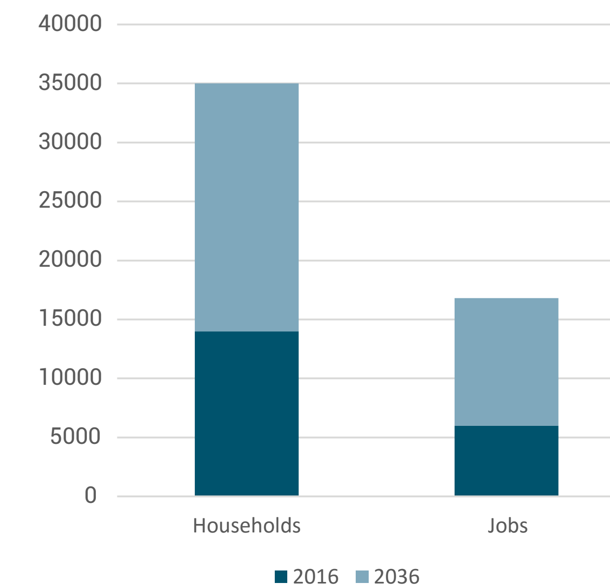


fig. 48 snapshot and vicinity map of chosen site
fig. 49 proposed zoning map of the University District

The neighborhood of the University District has a higher density (33,763.5 inhabitants per square mile) than the city as a whole (7,962). (fig. 48)[32,33] In serving a higher density area, the project presents opportunities to service a more diverse population in a variety of programs. Additionally the city has designated the area as one of six urban centers, which are defined as “the densest neighborhoods in the city and both regional centers and neighborhoods that provide a diverse mix of uses, housing, and employment opportunities.”[34] By placing the project in one of these areas, the new building type will have greater efficacy as a pilot project. The City of Seattle has proposed an upzoning to the University District that would allow minimum building heights of 75 feet and maximum of 320 feet.[35]. (fig. 49) This zoning change will dramatically increase the current building density of the neighborhood as existing building stock is a maximum height of 65 feet. In locating the project in an area of tall buildings, the thesis has the opportunity to add more density than the existing gas station but remain midrise to distinguish the project as a new building type. Given the proximity to the University of Washington, the neighborhood skews younger and more racially diverse than Seattle as a whole. (fig. 50)[36] These trends are expected to continue in the future. Furthermore, in this neighborhood, growth in housing and jobs is skewing toward tech and remote workers and is in line with city trends. Given the high density, neighborhood growth designation as an urban center, and upzoning, an existing gas station in the University district was chosen to redevelop into a test case of the proposed Energy Commons.



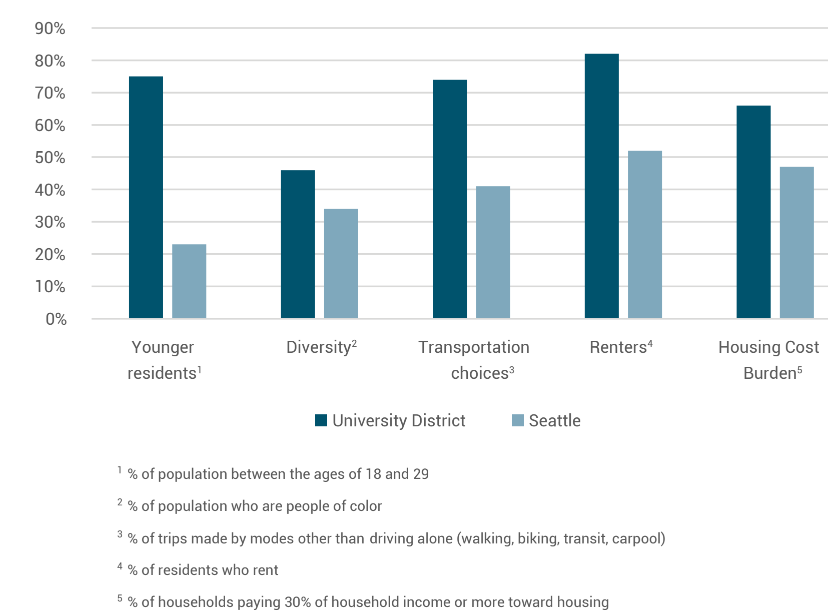


fig. 50 demographics of the University District

The site is currently a Chevron station located at the northeast corner of NE 47th St and Brooklyn Ave NE. (fig. 51, 52, 53) The owners of the property recently completed the permit and design review process for a 6-story mixed-use multifamily apartment building. The four block radius of the site has seen significant new construction since 2012. (fig. 54) Since then, eighteen buildings have been built or are in permit accounting for an addition of 773 housing units. Numerous parking lots are present in the area, and this thesis presumes that similar new development will continue on these open sites. The neighborhood is fairly well served by community amenities and the commercial strip along University Way, one block to the east. (fig. 55) A YMCA and community center are located on separate blocks to the north of the site along NE 50th St. Most other buildings surrounding the site are mixed use housing or housing. Based on demographic trends, existing amenities, and an expected rise in remote workers, a coworking office space was chosen as the flex space for the project.

fig. 51 street level view of the project site
fig. 52 aerial view of the project site
fig. 53 satellite image of the vicinity

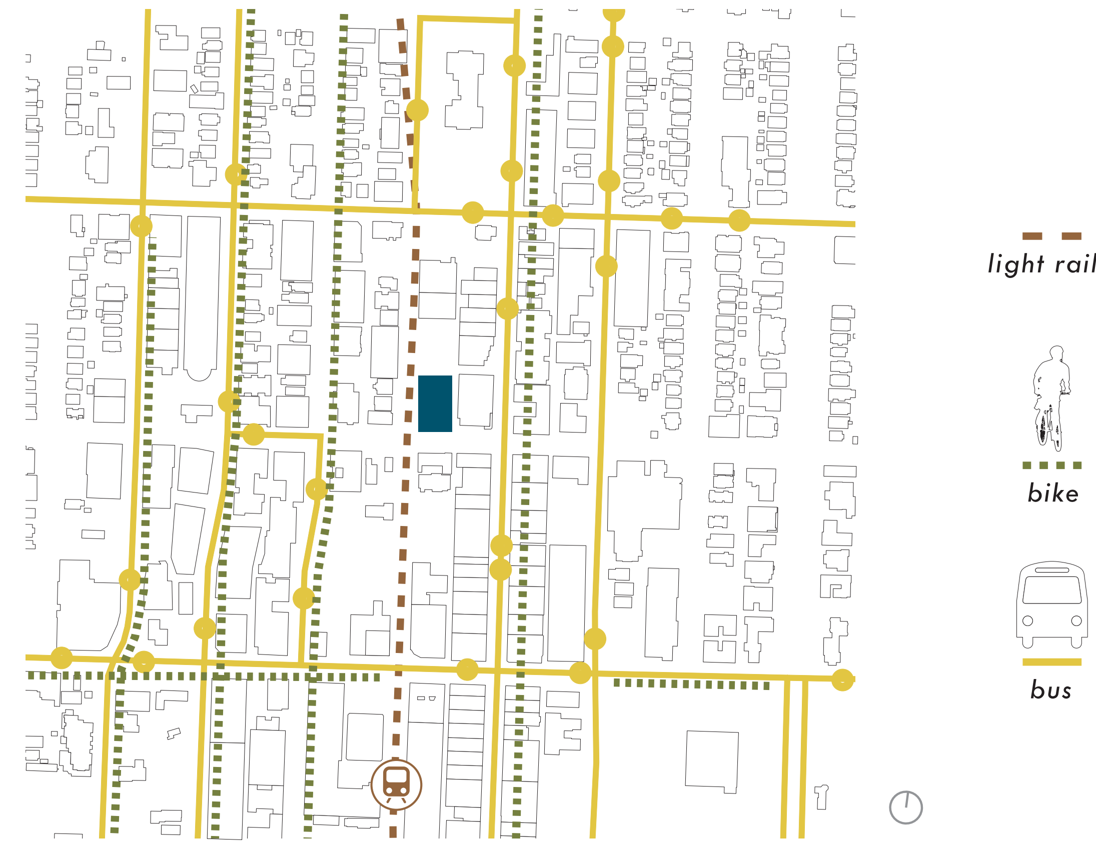
Increased density in the neighborhood is also calling for higher pedestrian, cycle, and public transit mobility. These conditions provide a prime opportunity to test the future of the gas station. The site is bordered directly to the north by a parking lot and Safeway grocery store. (fig. 56) For purposes of this thesis, the parking lot is foreseen to be developed as mixed-use multi-family housing. Across an alley to the east is a 24 foot tall brick bank building. (fig. 57) Across NE 47th Street to the south is a one-story church. (fig. 58) To the west across Brooklyn Ave NE is a new 7-story mixed-use multifamily housing building and three smaller 2-story housing buildings that is slated for parcel consolidation and redevelopment. (fig. 59) Street parking exists adjacent to the site on NE 47th St. Bikes and cars share lanes on the adjacent streets. An existing curb cut for the gas station runs the whole length of the site on the west edge along Brooklyn Ave NE. The existing one-story gas station is well under the current zoning of the site of 65 feet. Increasing building height with new construction would allow further community services and massing similar to new structures in the neighborhood.

fig. 54   map of new and proposed developments since 2012
fig. 55   existing building use surrounding the project site

fig. 56 parking lot and Safeway grocery store north of the project site
fig. 57 bank east of the project site

fig. 58 church south of the project site
fig. 59 housing building west of the project site

Bike lanes and bus routes are located one block away from the site in all directions. (fig. 60) A new light rail station is in construction a block and half to the south at the intersection of NE 43rd St and Brooklyn Ave NE. Currently, transportation options immediately adjacent to the site are limited giving current prominence to the car. Field research into the current circulation patterns on the site was conducted on a weekday afternoon for an hour. (fig. 61) Most people who entered the site were pedestrians cutting across the asphalt as a shortcut, seen in blue. (fig. 62) Most vehicle owners, in red, used both the convenience store and gas refueling. In this time period, no bicyclists, in green, came onto the site.



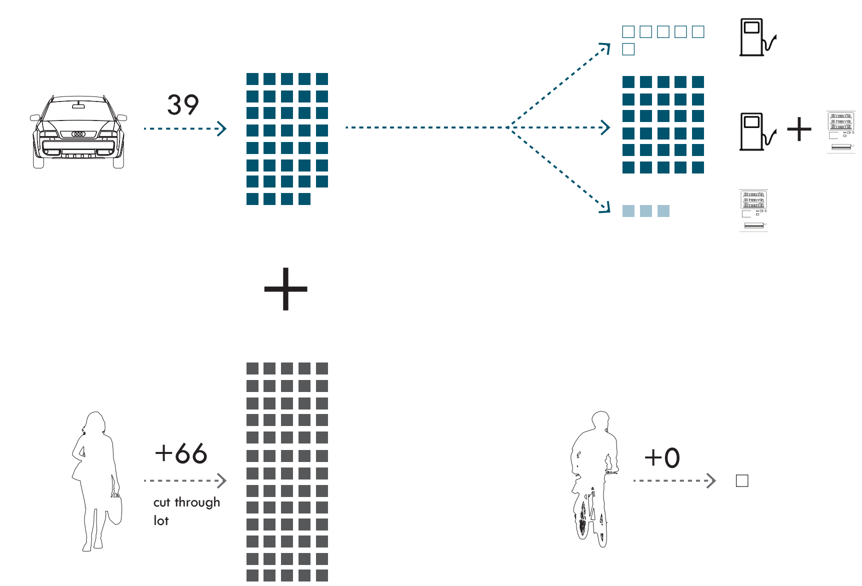


fig. 60 bike, bus, and light rail connections near the project site
fig. 61 user statistics from field observation on Wednesday, October 5th from 1pm to 2pm at the existing gas station project site

The corner placement of urban gas stations provides an opportunity for a powerful redevelopment of nodal sites that place emphasis on pedestrian and bike mobility instead of the gasoline car. Furthermore, in growing cities the gas station has become increasing obsolete in light of increasing environmental awareness and changes in mobility that allow it to transcend its fate as another housing development and continue its use in urban utility and amenity. By updating the existing program of the gas station for future trends in mobility, incorporating a neighborhood flexible component, and responding to environmental resources, the proposed Energy Commons will act as a social generator through its mixture of program. After identifying the lack of buildings that support the increasing density in Seattle, the site selection process yielded an existing gas station in the University District of Seattle as a test case of the Energy Commons larger nodal network. The physical and demographic characteristics of the neighborhood reinforce the analytical site selection process of a site within a dense, urban, and growing community.

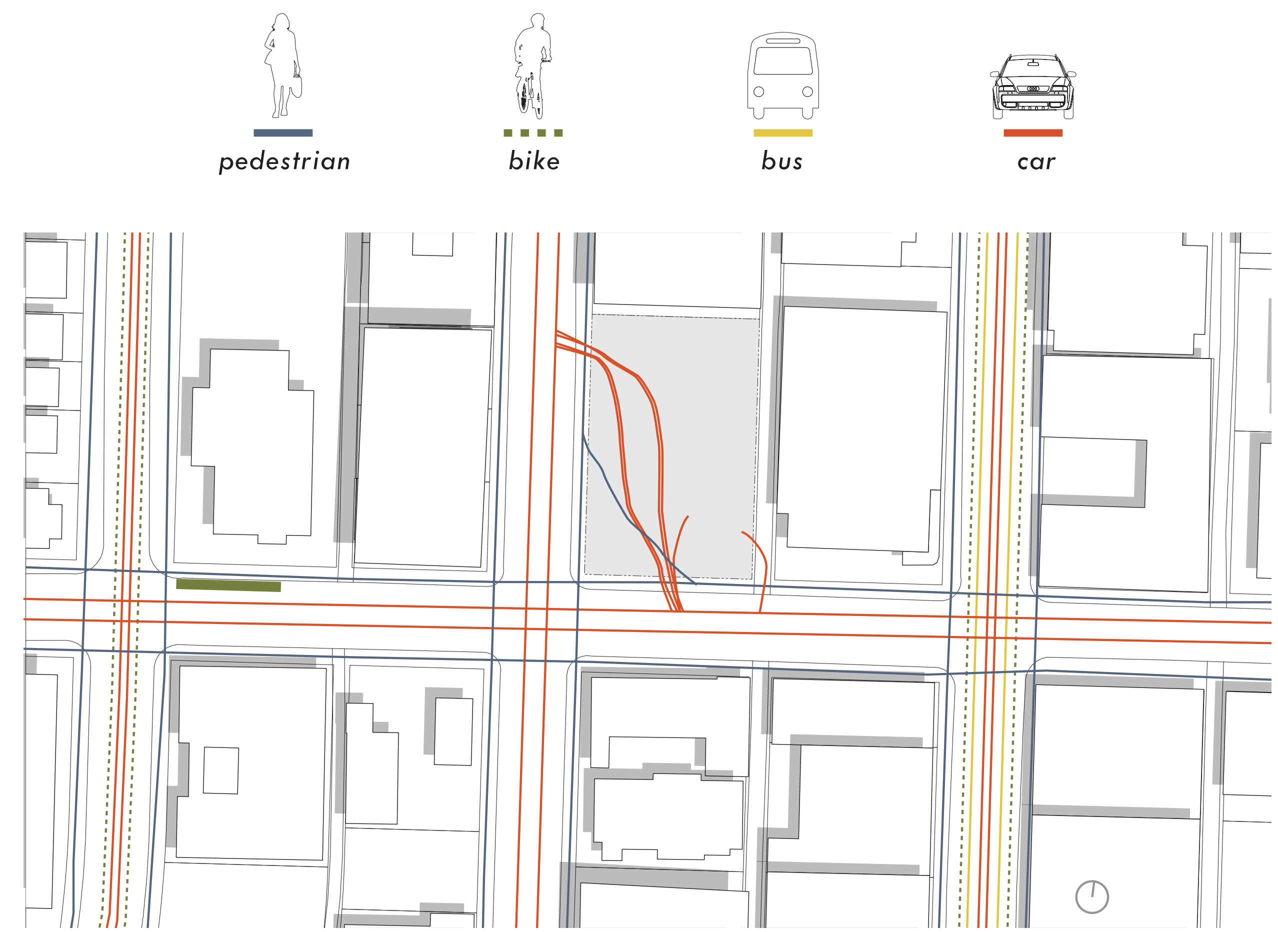


fig. 62 flows of users on and adjacent to the project site

FOUR

design proposal: an Energy Commons for the University District

4.1 Goals and Objectives

The proposed Energy Commons will act as an interface between the voids in the city fabric left by the obsolescence of the gas station and the increasing flow of traffic in the city. This new urban amenity will advance the adoption of cleaner vehicles while offering a primary and stable space in the urban fabric for pedestrians and cyclists. This reinvented building type emerges within a new nodal system through the modification of existing spatial connectivity and combining of new programmatic and environmental elements. (fig. 63)

This thesis argues that the obsolesce of the urban gas station offers the potential for a new building type that will better serve today's changing needs for transportation and distribution of energy. The proposal consists of the design for a small-scale urban amenity node, or "Energy Commons" in Seattle. This reinvented building type, will serve a range of personal transportation modes and the distribution of renewable resources in growing cities. The "Energy Commons" will provide both utility and amenity for pedestrians, bicycles, and electric vehicles, and renewable energy and water conservation systems. By redeveloping the gas station into a facility that serves pedestrians and cyclists first, the changing needs of urban dwellers can be met. The history of the gas station as nodal collector of transportation and energy will be used to advance the popularity of more environmental forms of movement. In order to advance the gas station from a place of consumption to a place of production, sustainable technology and systems will be integrated into the proposed design for the harvesting of solar energy, rainwater reuse, and waste reclamation. In its function and form, the "Energy Commons" will support urban growth and fuel human amenities.

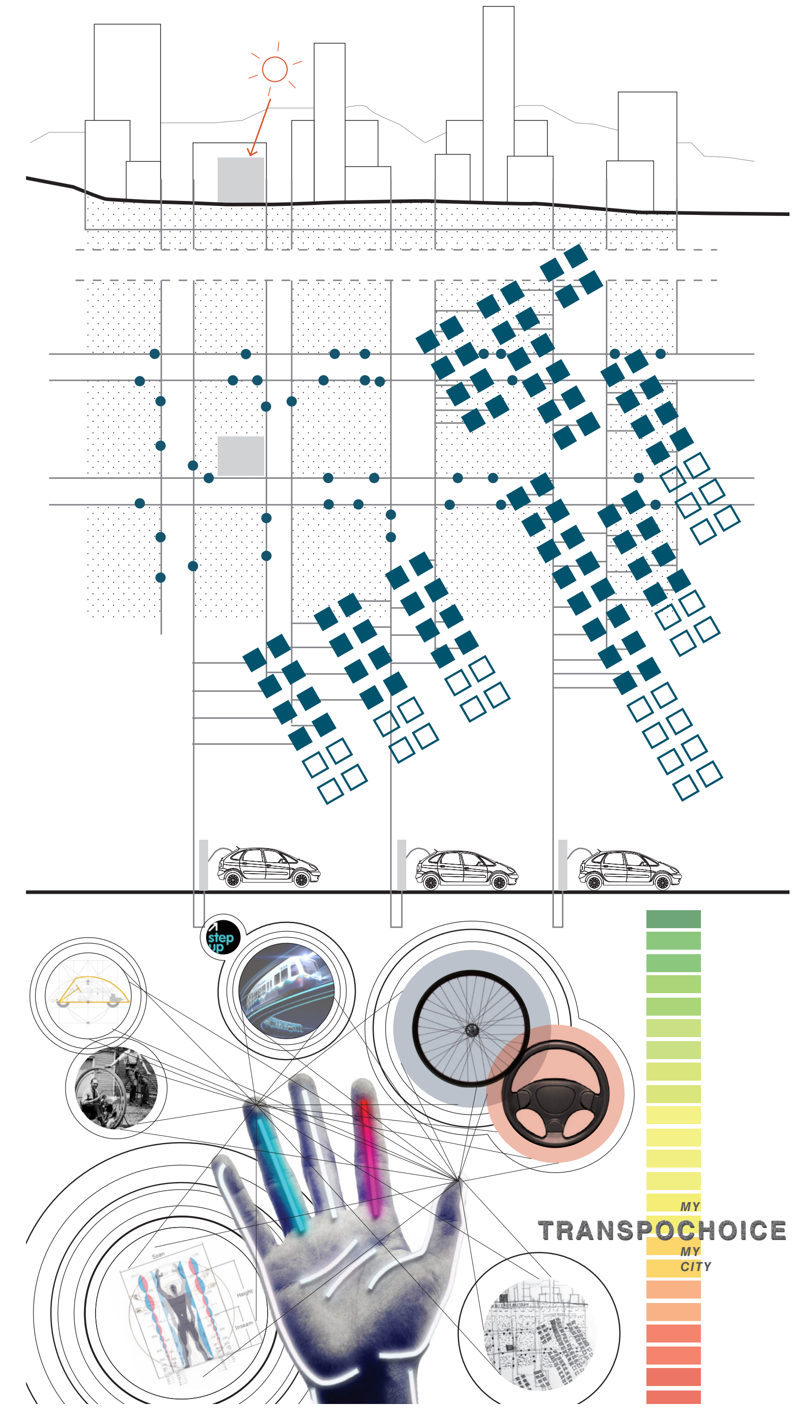
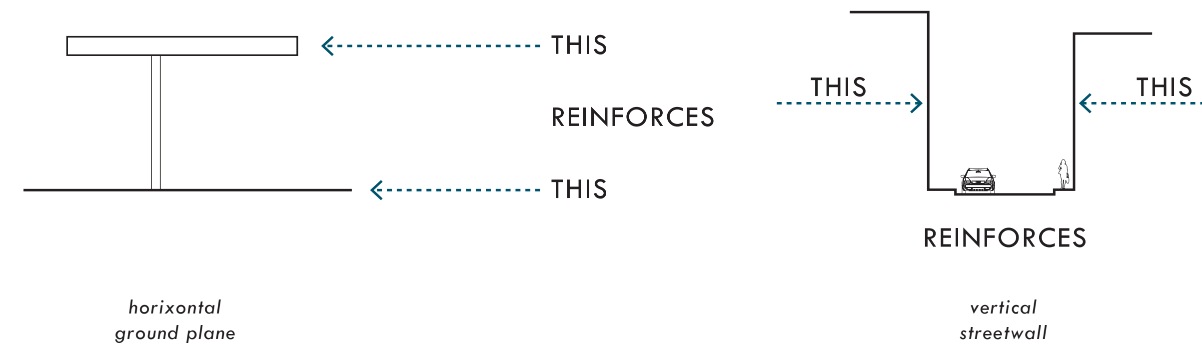
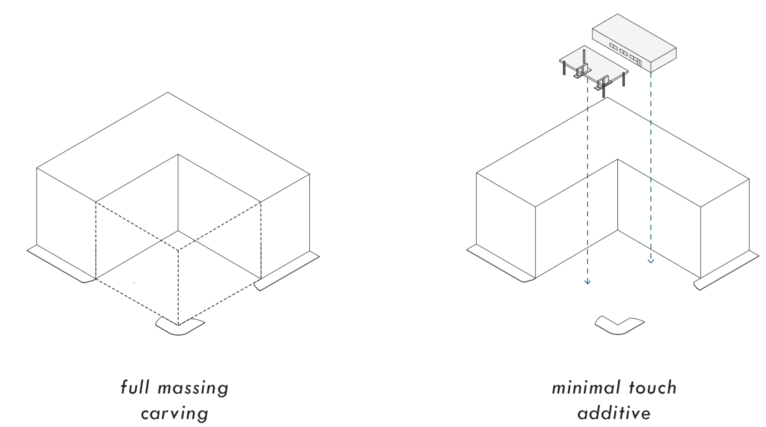


fig. 63 conceptual image of the thesis proposal as a convergence for people and vehicles in the city through new nodes of distribution and communication

In examining the legibility of the existing gas station, physical characteristics and traditional urban design vocabulary informed general design objectives. The canopy over the pumps reinforces thw horizontal ground plane of vehicle conveyance through the existing gas station site. (fig. 64) Along with the canopy often serving as marketing, this physical reinforcement of the large asphalt surface emphasizes the hole in the urban fabric and lack of building mass. This planar reinforcement is similar to streetwalls of full height massing buildings reinforcing one another for pedestrians on the sidewalk in dense urban areas. Furthermore, observation of recent developments in the Seattle area reveals that typical architectural design strategies in urban contexts start with a full build out of massing on the site with spaces then carved out in order to maximize floor-to-area ratio and profitability of rentable area. However the gas station is in direct opposition to this in being an object within the urban landscape. The void that is present between the ground plane and the canopy, and the canopy and the sky or surrounding buildings allow the existing gas station to designate itself as a distinct form within the urban fabric. (fig. 65) With growing cities, people can recognize gas stations as buildings rise around the site. While the existing gas station, in function, acts as a node, in form it is a landmark. (fig. 66) According to Kevin Lynch nodes are "strategic foci that can be entered" and are often junctions with assumed importance for the user to make decisions.[37] He elaborates by stating their success is also tied to their uniqueness. The utility offered in refueling the automobile makes the gas station essential to city dwellers who own these cars and offer a strategic function that allows them navigate the city. The function of refueling and act of entering the gas station site dictates their commute and influence their daily decisions. However, the form of the gas station, specifically the canopy and ground plane, act as landmarks within the city. Kevin Lynch describes landmarks being a singularity of "clear form and figure-ground contrast."[38] As mentioned previously, the canopy and lack of building mass, provide a visual cue of spatial prominence not achieved in fully massed buildings. This void-mass contrast and their prime location on corners result in gas stations becoming point of references within urban areas.





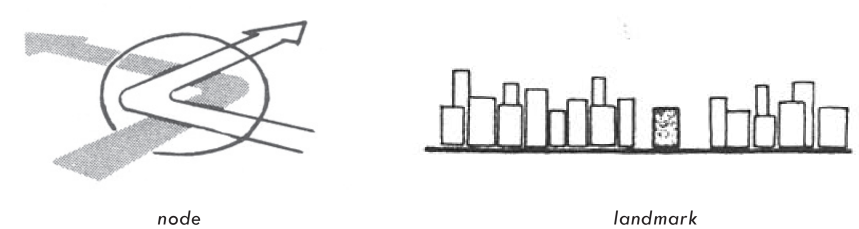


fig. 64 reinforcing planes in the urban landscape
fig. 65 typical architectural design strategies in urban contexts
fig. 66 node and landmark compared

4.2 Building Design

The guiding principles of the design included the integration of architectural forms, redefined flows of humans and vehicles, combination of utility and amenity, and a switch from consumption to production. In the vein of the current gas station, the new building merges the current discrete architectural elements into harmony through an intersection of multiple uses. From an aerial perspective, the Energy Commons is defined by a photovoltaic roof that covers the full site and western sidewalk along Brooklyn Ave NE. (fig. 67) By covering the entire site with one large roof, the project is defined as one whole at the scale of the canopy but is broken into masses at the scale of the pedestrian and driver. Openings in the roof allow sunlight to penetrate to light the faces and interior of the masses. The roof is pulled off the southern face along NE 47th St to allow the low winter sun to cast light and solar heat gain on the building. The roof has a slight slope from north to south to shed water that mimics the 2 foot grade change over the site.

To signal the continued utilitarian function of the Energy Commons, the architectural components of the proposed project retain those from the existing gas station. (fig. 68) A conceptual massing model displays the hierarchy of the elements and their associated material expression. (fig. 69) Figure 70 shows the form and role of the updated architectural elements. The canopy harvests solar energy, collects rainwater, signals and communicates the Energy Commons, and shields the boxes and ground plane from adverse environmental conditions. The masses house utilitarian functions and amenities, organize the flows of electric vehicles, bikes, and people, and define edges of public space on the ground. The ground plane remains open enough for the directed movement of users, is articulated for pedestrians, bikes and electric vehicles, and houses green stormwater infrastructure.

fig. 67 aerial view of the University District Energy Commons

canopy
mass
ground plane

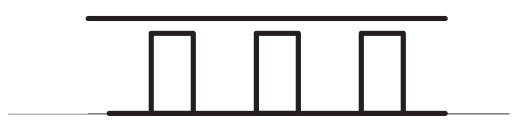


fig. 68 overview of architectural elements of the proposed project
fig. 69 massing model showing architectural elements

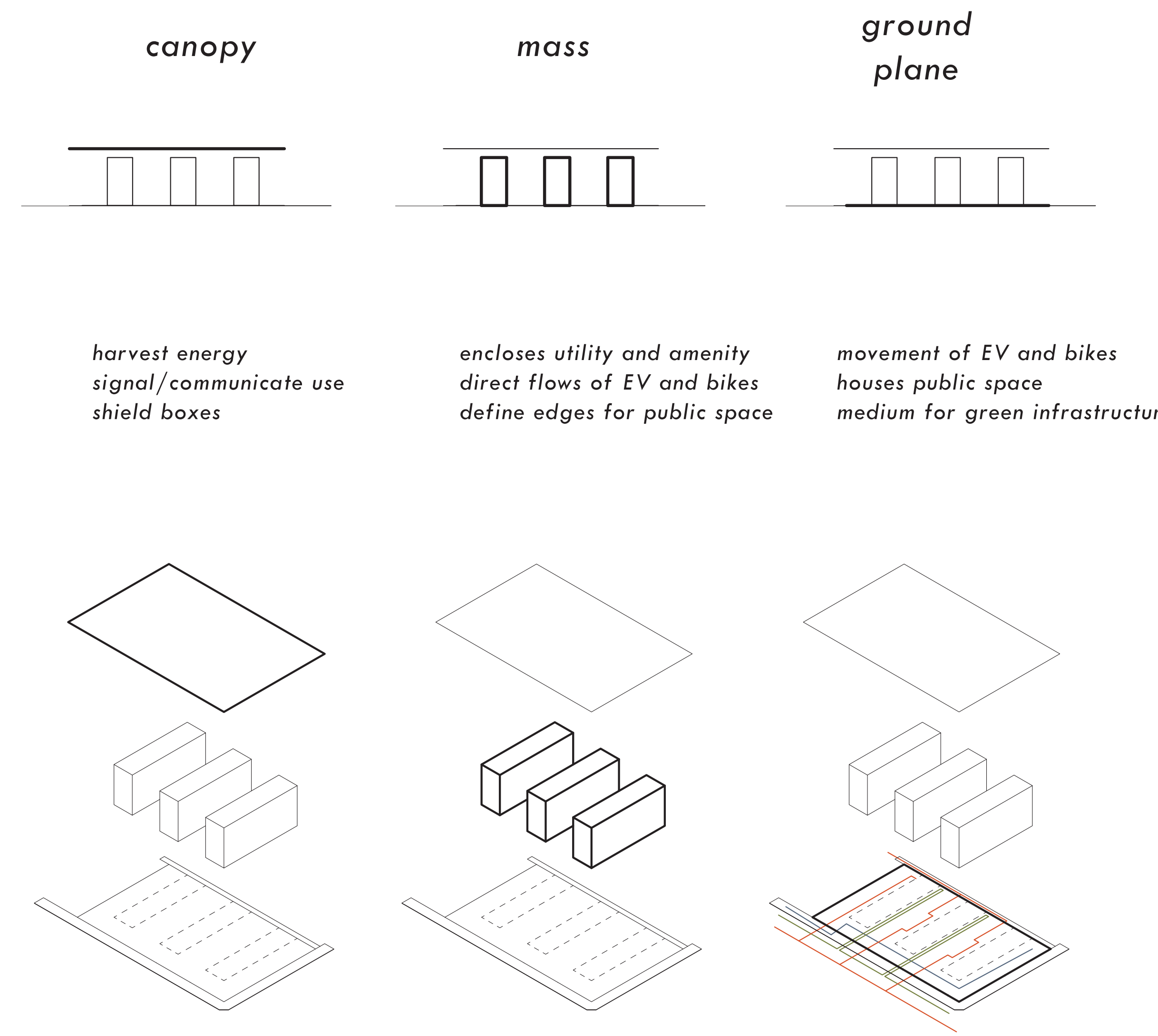


fig. 70 role of specific architectural elements of the proposed project

The enclosed program is divided primarily into three volumes of equal size. (fig. 71) Breaking up the massing allows for the movement of bicycles and electric vehicles (EV) between the building on the ground level. A 25 foot building setback from the sidewalk opens the ground plane for pedestrian circulation through the site and into the building. Swales and building edges define public space that is separated from the EV driveways.

From south to north on the ground level, the building volumes contain the updated convenience store, bike repair, and restrooms/waiting area. (fig. 72) In addition to housing a primary program component, the first volume contains the coworking office entrance on the ground level, while the remaining two have unconditioned bike rental and bike storage. The convenience store and coworking entrance are located in the southernmost volume adjacent to the area of the site with the highest foot traffic. This location along NE 47th St provides easier access to pedestrians and visitors by foot. This location on the site also provides maximum visibility from outside the site of those functions. The bike repair, bike rental and bike storage are semi-public and are placed in the middle volume for filtered access, from the street to the alley, and for visibility from outside of the site. (fig. 73) The most private program piece, the restrooms, occupy the northernmost volume because the placement of this mass is mostly obstructed by view from the street. Electric vehicle entrances, two for charging and one for car share are to the north of each volume. The coworking office space occupies the second and third levels. EV share is located below grade to provide minimize usage of the ground plane for vehicles thereby maximizing usage above ground for pedestrians and cyclists. (fig. 74) Along with the EV share, the below grade level contains the rainwater cistern and other water reuse system components. The second and third levels have various modes of coworking space. The coworking spaces on the second level are more communal in nature, focusing on collaborative work modes as the base level of the office space. (fig. 76) The third level contains meeting rooms and private work spaces. (fig. 77) Stacking the context program, in this test case the coworking space, above the ground plane adds density to the Energy Commons that the existing gas station lacks. Vertically raising this program also provides visibility of this new program mix and building type to the surrounding neighborhood.

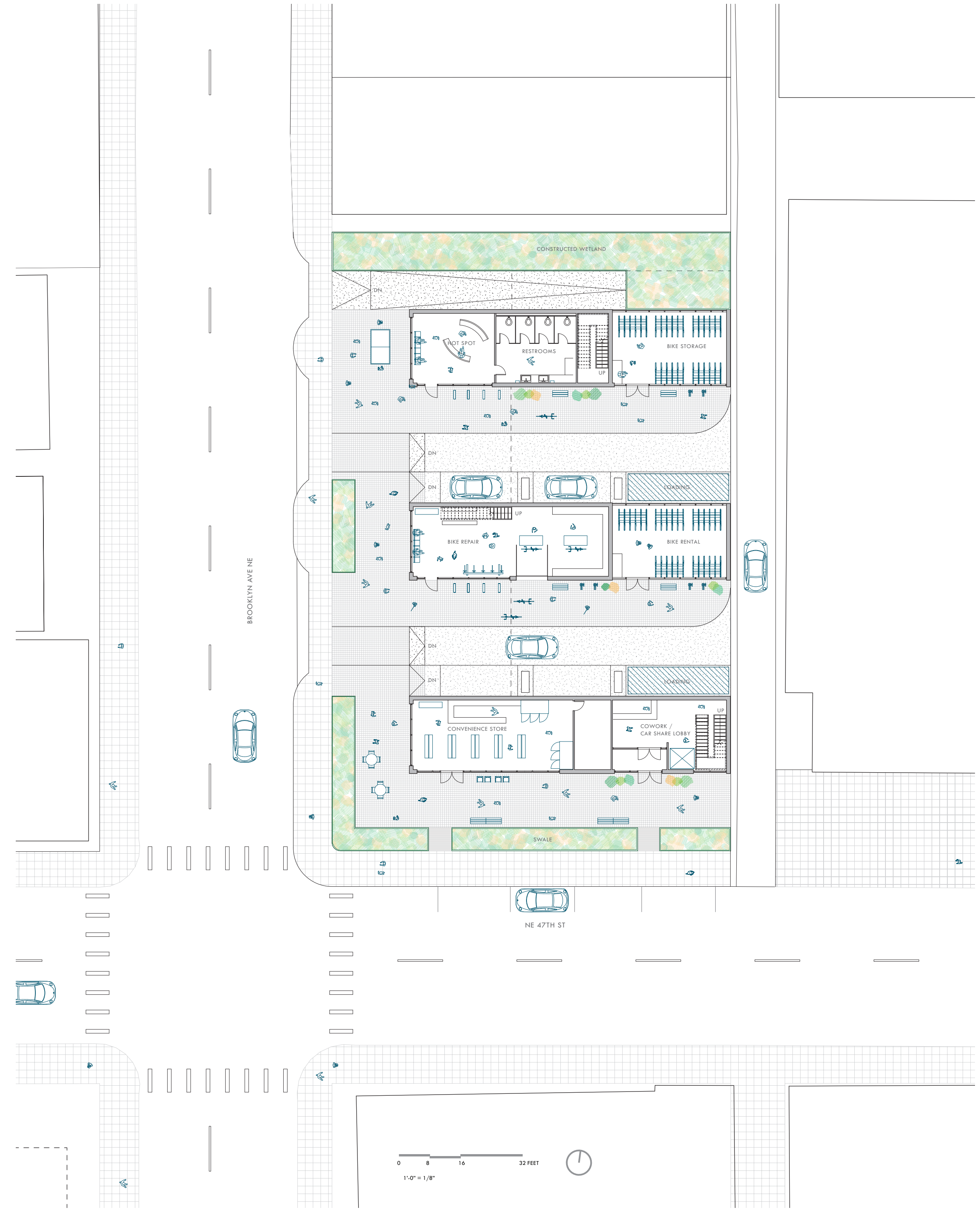


fig. 71   ground floor plan with immediate context

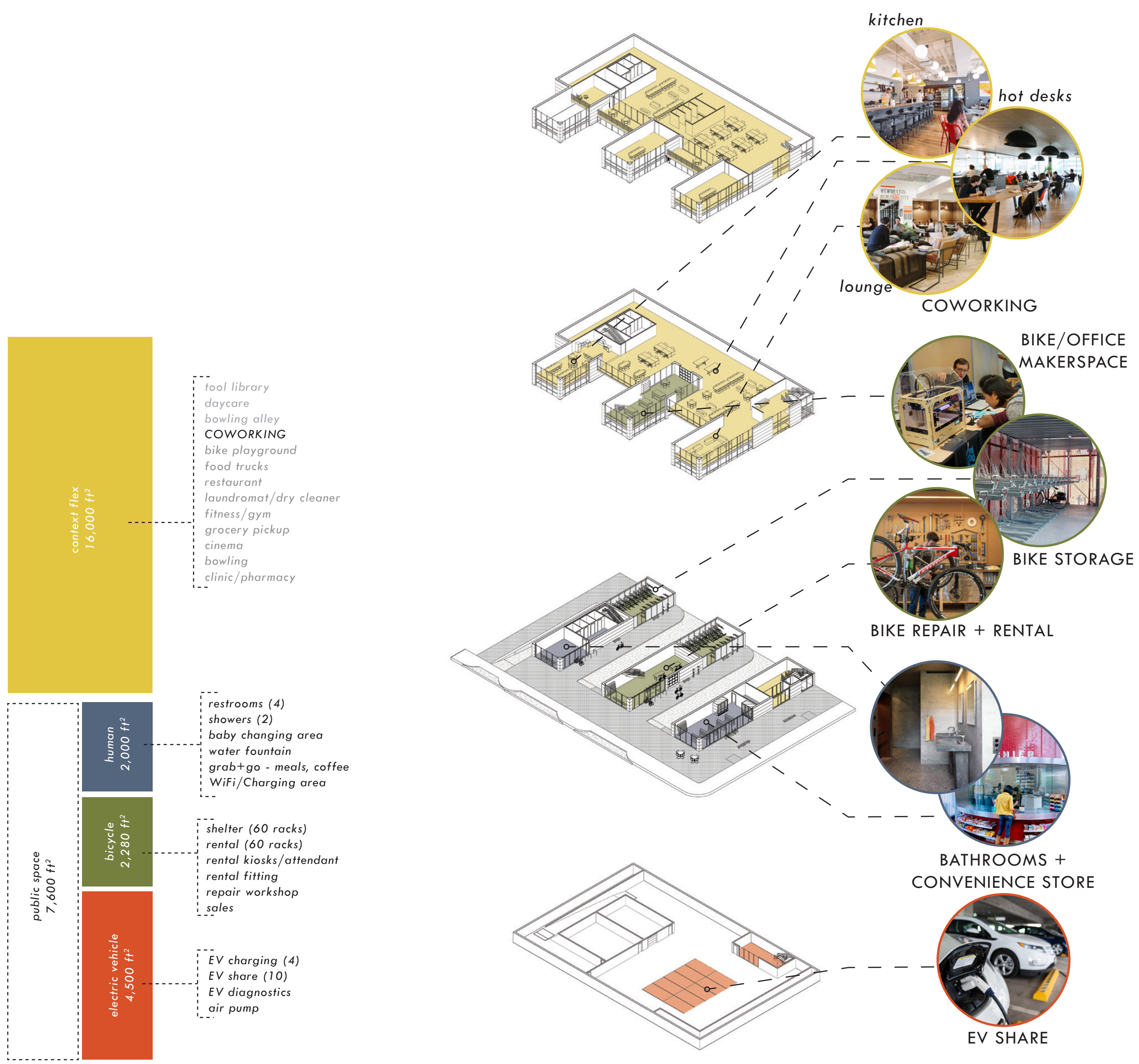


fig. 72   programmatic distribution

fig. 73   view from the sidewalk

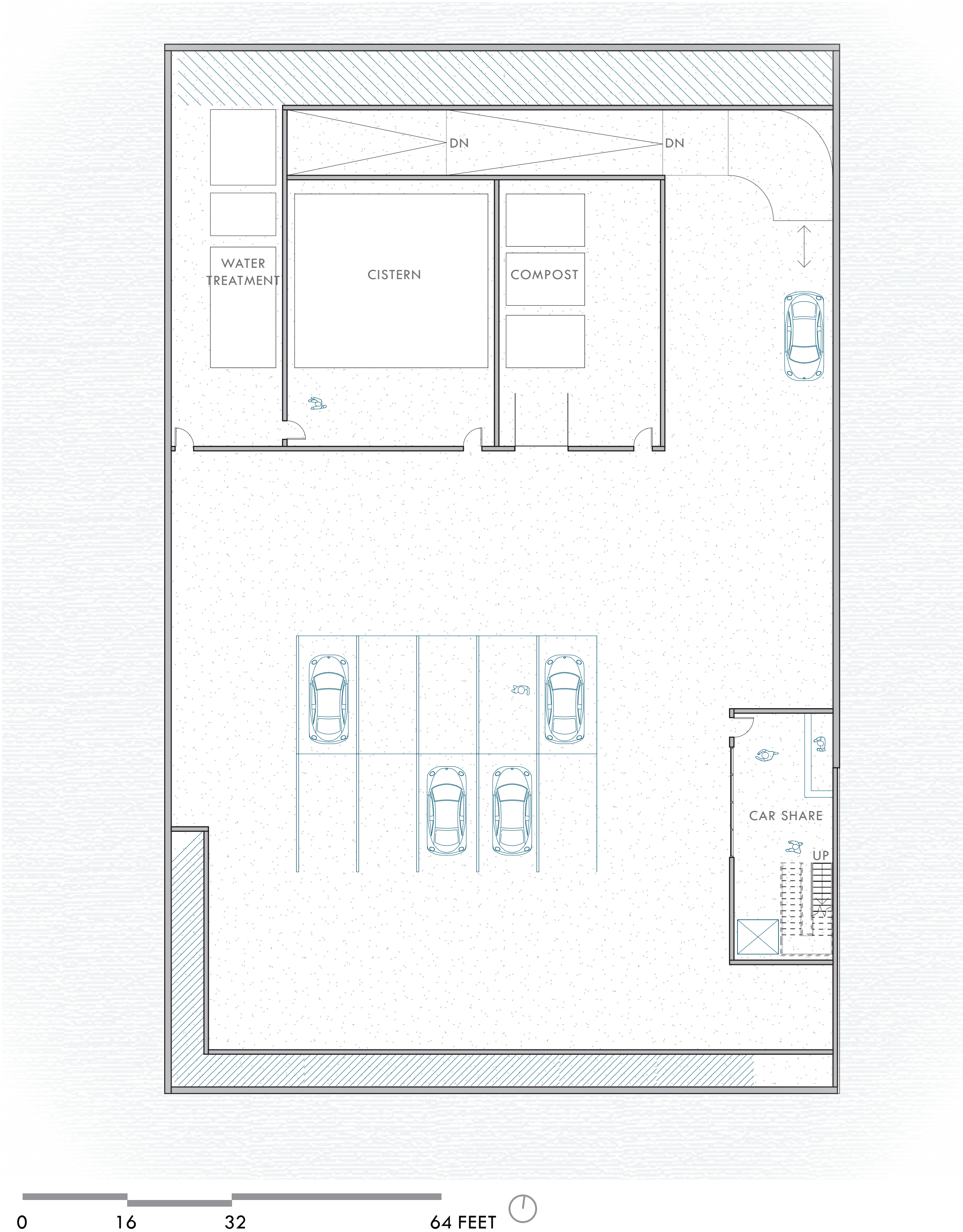


fig. 74   below grade plan

fig. 75   ground level plan

fig. 76 level two plan

fig. 77 level three plan

The user relationship of the existing gas station excludes the cyclist and separates the vehicle and pedestrian. The proposed relationship of the new Energy Commons would bring bicycles on site and place them and pedestrians higher on the ground plane. (fig. 78) Using the building massing to define the flows of people, bikes, and cars, allows for the vehicle to move from Brooklyn Ave NE to the alley on the north side of the box. (fig. 79) Surface EV charging is located to the north of the southernmost two volumes and the EV share ramp to below grade is on the northern portion of the site. (fig 80) Bikes travel to the south of each mass and can occupy these spaces for repair or as a waiting area. Pedestrians can move through on the western portion of the site. Energy Commons users occupy the inside of the building as a waiting area, for the respective uses of each volume, or the small public spaces to west. The ground plane is articulated so that people and bikes are six inches higher than the electric vehicle once on site. (fig 81) Curb cuts are reduced by combining bike and EV entrances along Brooklyn Ave NE but are delineated by scale and markings.

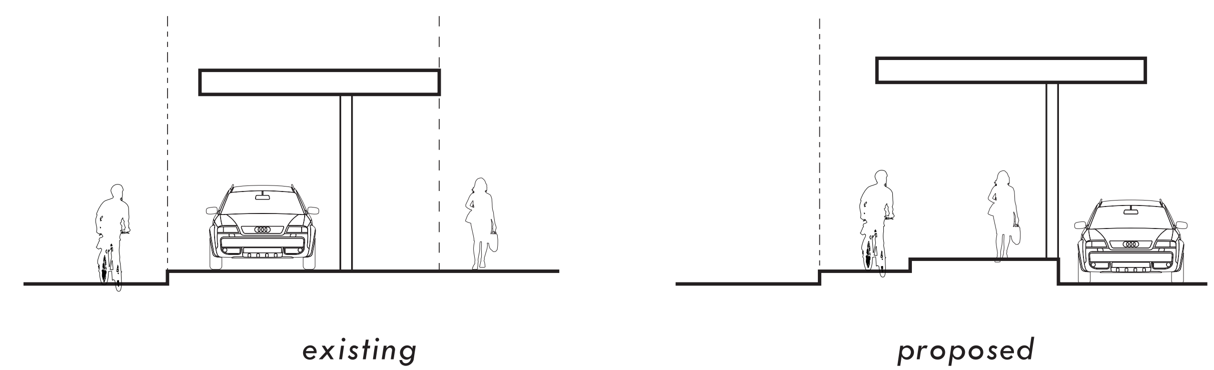


fig. 78 relationship of users for the existing gas station and proposed project

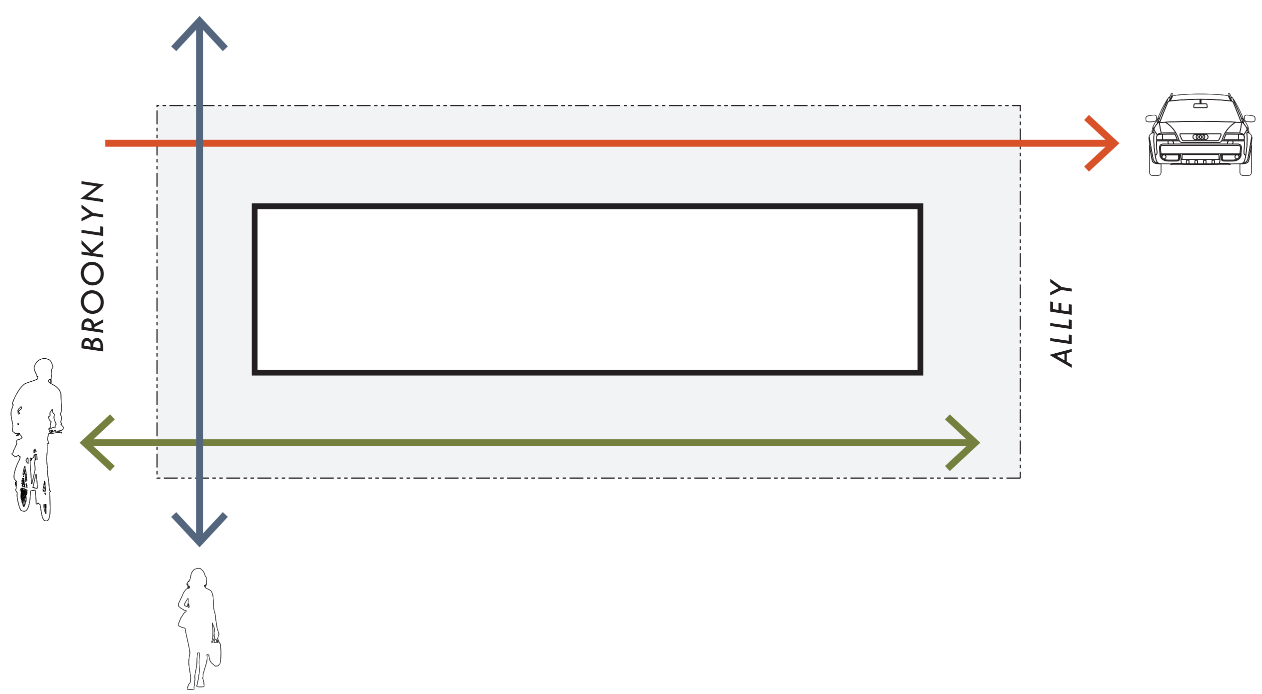


fig. 79   using building mass to define the flows of people, bikes, and cars

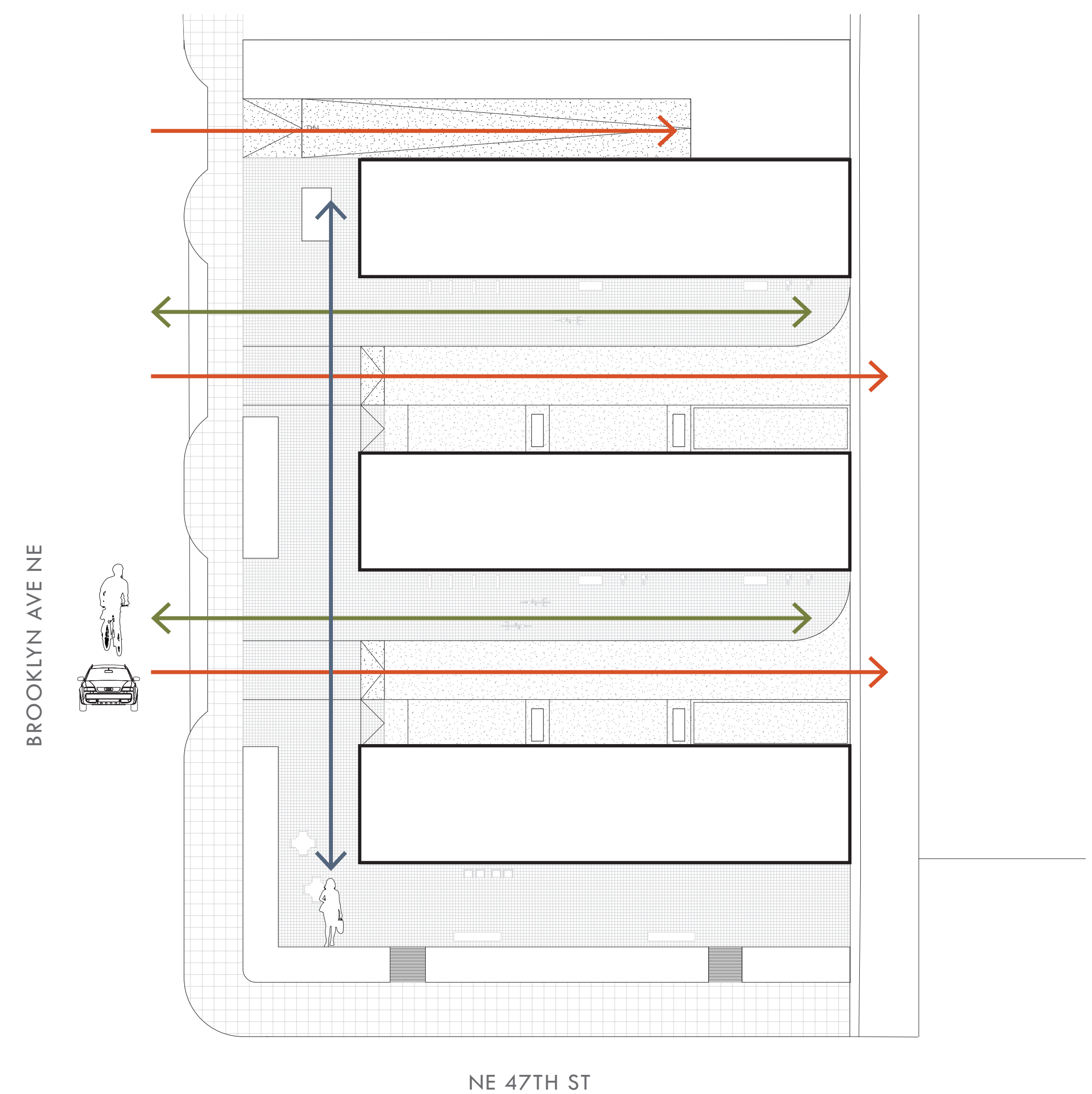


fig. 80   using building mass to define the flows of people, bikes, and cars over the whole site

Vehicle driveways pass beneath the coworking levels to visibly engage with the context program and are exterior to the building envelope. (fig. 81, 82) The second and third levels have various modes of coworking space with specific functions organized and aligned with the masses of the floor below. Walls from the primary masses on the ground level are carried up through the second and third levels and extend horizontally into the coworking space. The main work spaces of the coworking levels are then situated between the primary masses. (fig. 83) Specialty work spaces like lounges and meeting rooms are located on the upper floors in these carried up masses. On the second level of the second volume, there is a shared maker space with the bike workshop. (fig. 84) This maker space exists between the more public bike repair and the more private coworking space in order to be utilized by both program users and promote a mixture of function. A double height kitchen and dining area occupy the third volume. (fig. 85)

fig. 81 view between masses of bike porch and electric vehicle driveway

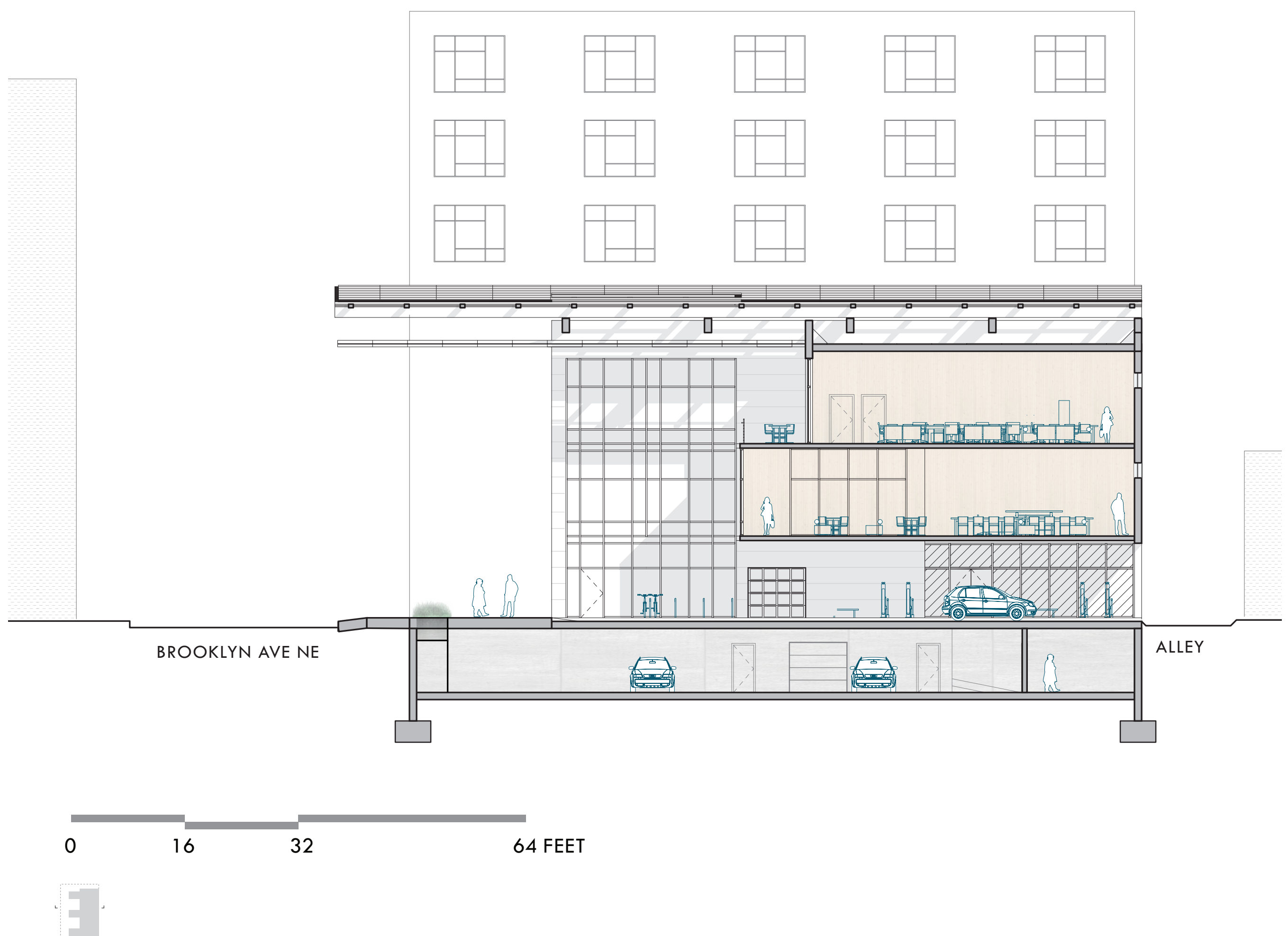


fig. 82 section through coworking and electric vehicle charging driveway

fig. 83 in coworking space looking west between volumes

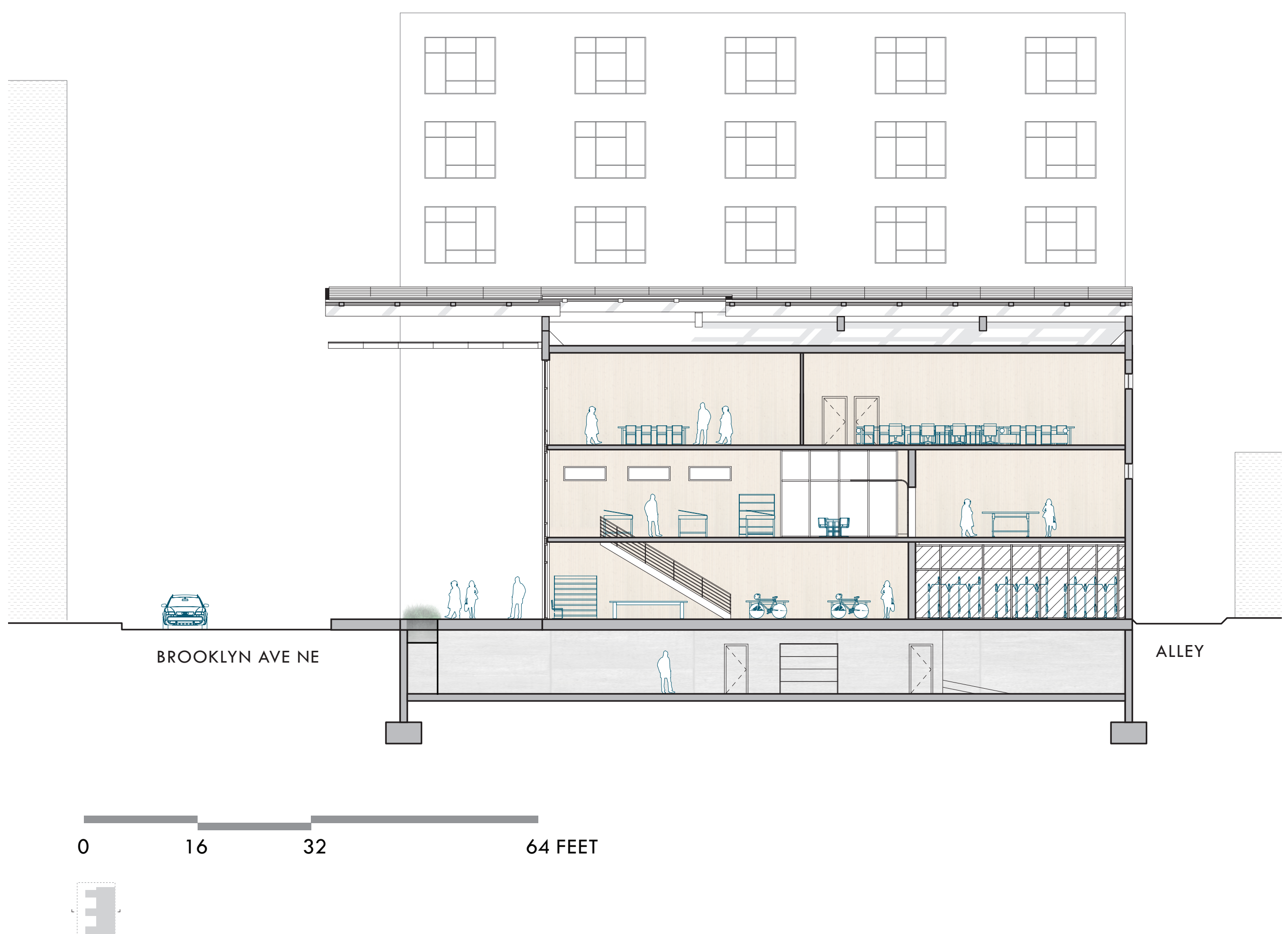


fig. 84   section through bike repair, bike rental, and shared coworking maker space

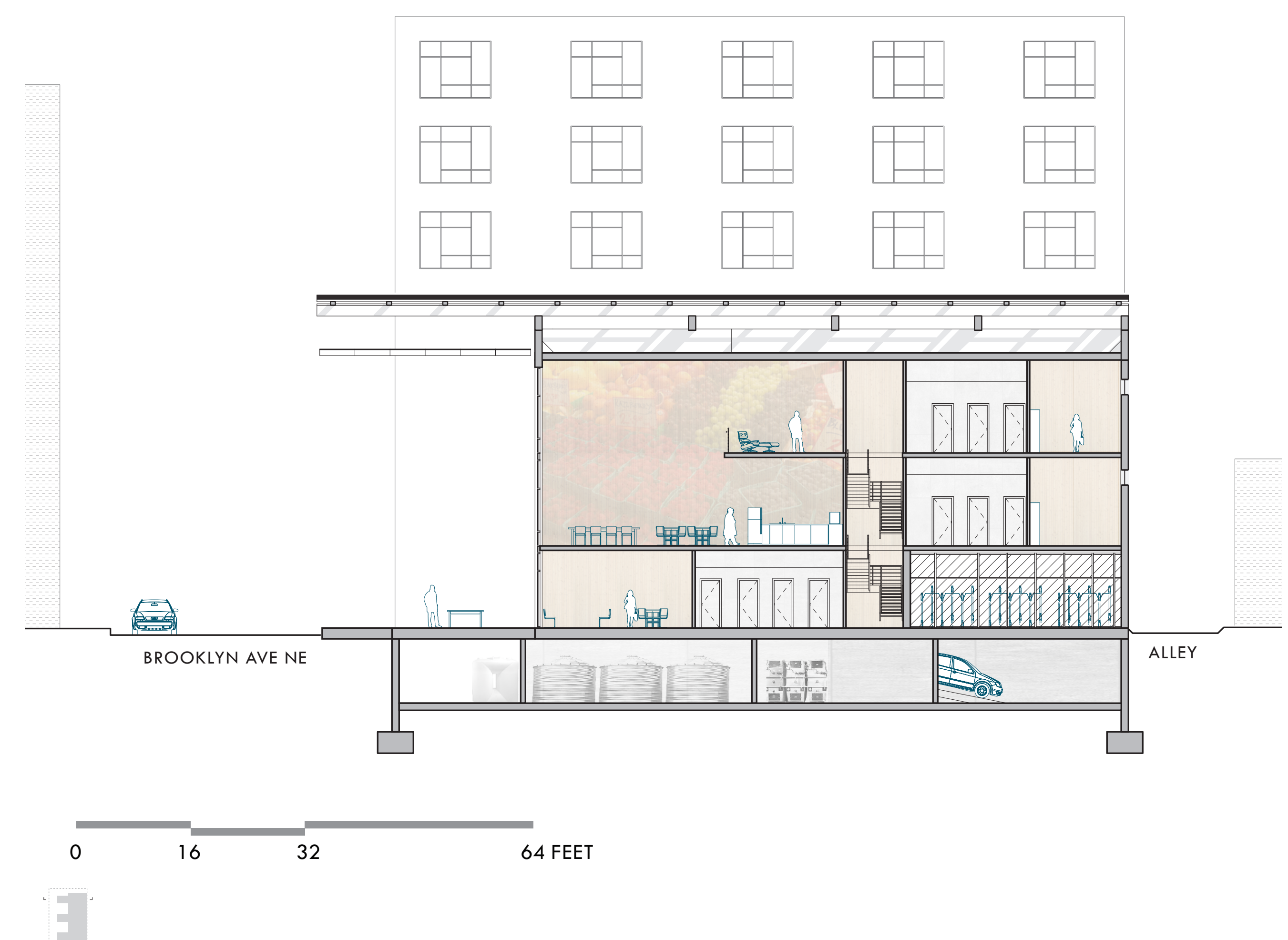


fig. 85   section through restrooms, bike storage, and coworking kitchen/dining

A goal of the project is to make the Energy Commons a place of production rather than of consumption. Covering the canopy in a photovoltaic array and providing a water reclamation system allows maximum solar harvesting and rainwater collection. This can be seen in section as power switches from unrenewable ground sources to the sky and water is stored as opposed to draining offsite. (fig. 86)

Renewable energy is harvested from the sun to power the EV kiosks and satisfy plug loads. (fig. 87) Closed loop geothermal wells supply radiant flooring in conditioned spaces and heat recovery ventilation for the building. Initial calculations were done for the energy production of the site footprint. Full coverage of the site at 1,600 square feet would provide charge to 76 electric vehicles on a yearly basis, enough to sufficiently power the EV share and neighborhood residents who live in buildings without EV charge parking. (fig. 88)

Rainwater is collected and reused within the building. Water is harvested from the PV array and from a hanging canopy gutter under the roof structure. (fig. 89) A cistern is located below grade for rainwater storage before being treated for use in sinks and showers. Waterless composting toilets are present in all restrooms. All water treatment is located below grade for easily accessible maintenance. Onsite swales and constructed wetlands will filter building and neighborhood stormwater for groundwater recharge. Flow of stormwater follows the slight natural slope of the site from northwest to southeast and supported by a similar slope direction of the roof and the drainage of treatment swales. Given climate, roof shape, effective capture area, and estimated fixtures and users, an 80,000 gallon rainwater collection tank would be required, which is roughly the combined size of three present-day underground gasoline storage tanks. (fig. 90)

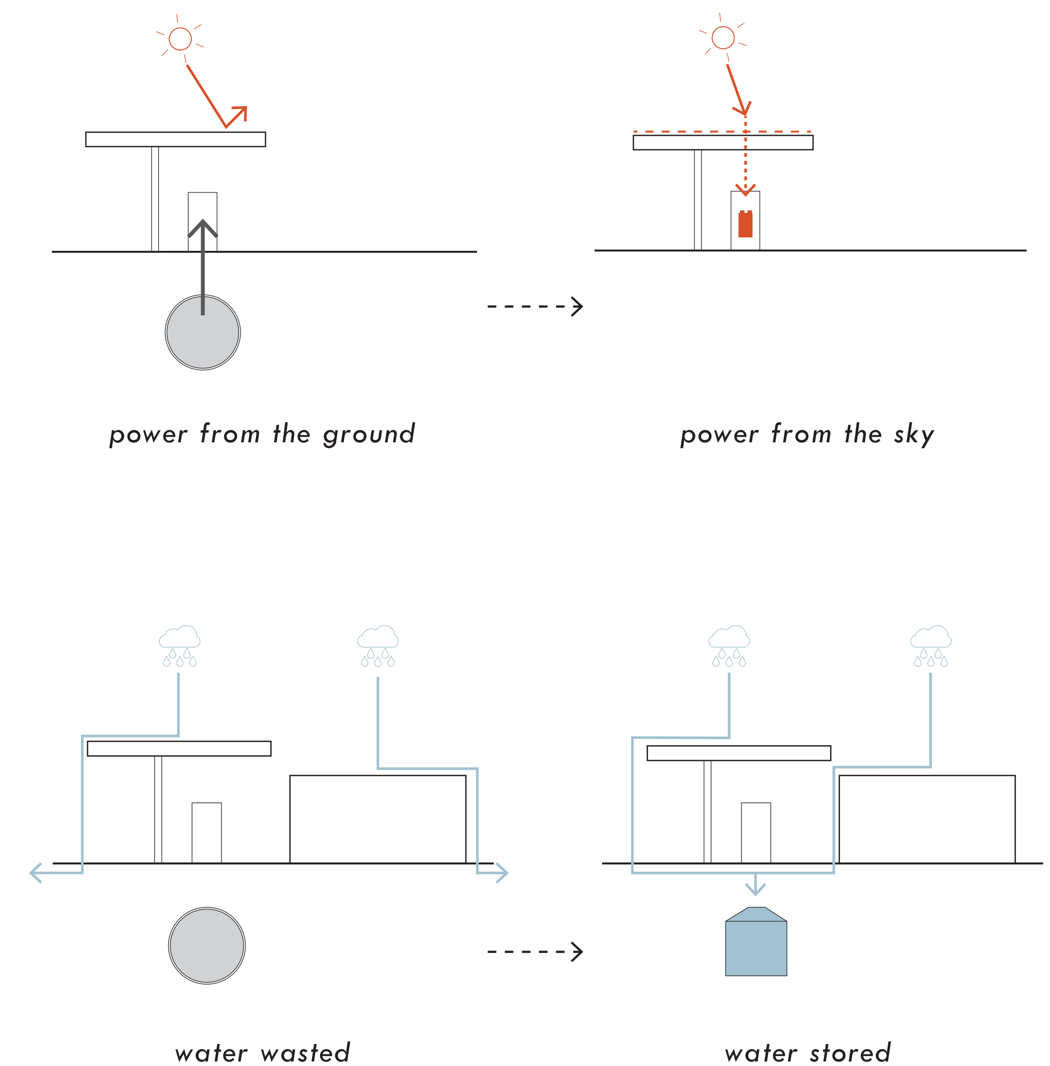


fig. 86   conversion from a place of consumption to a place of production

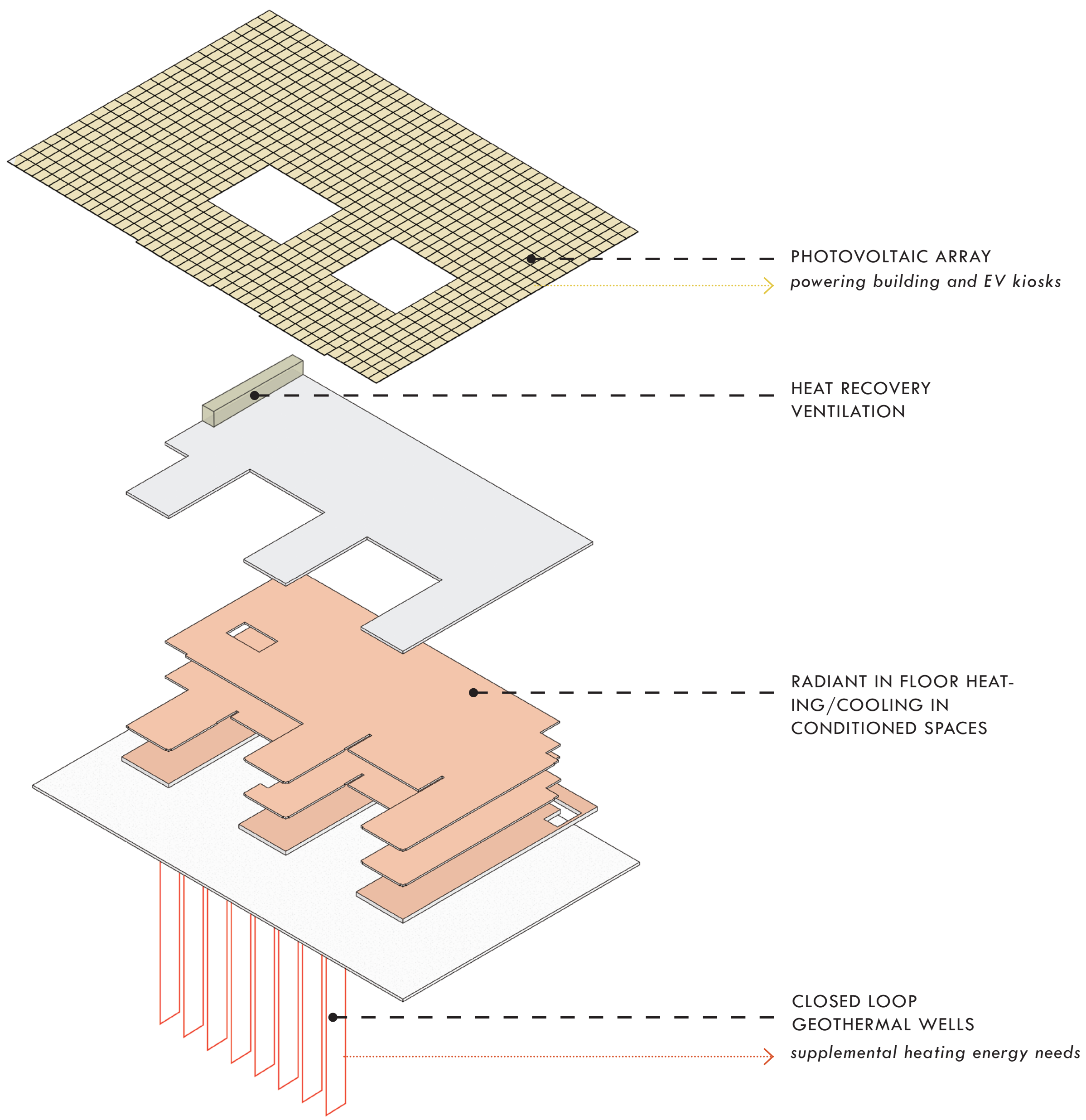


fig. 87 energy sources and uses in proposed project

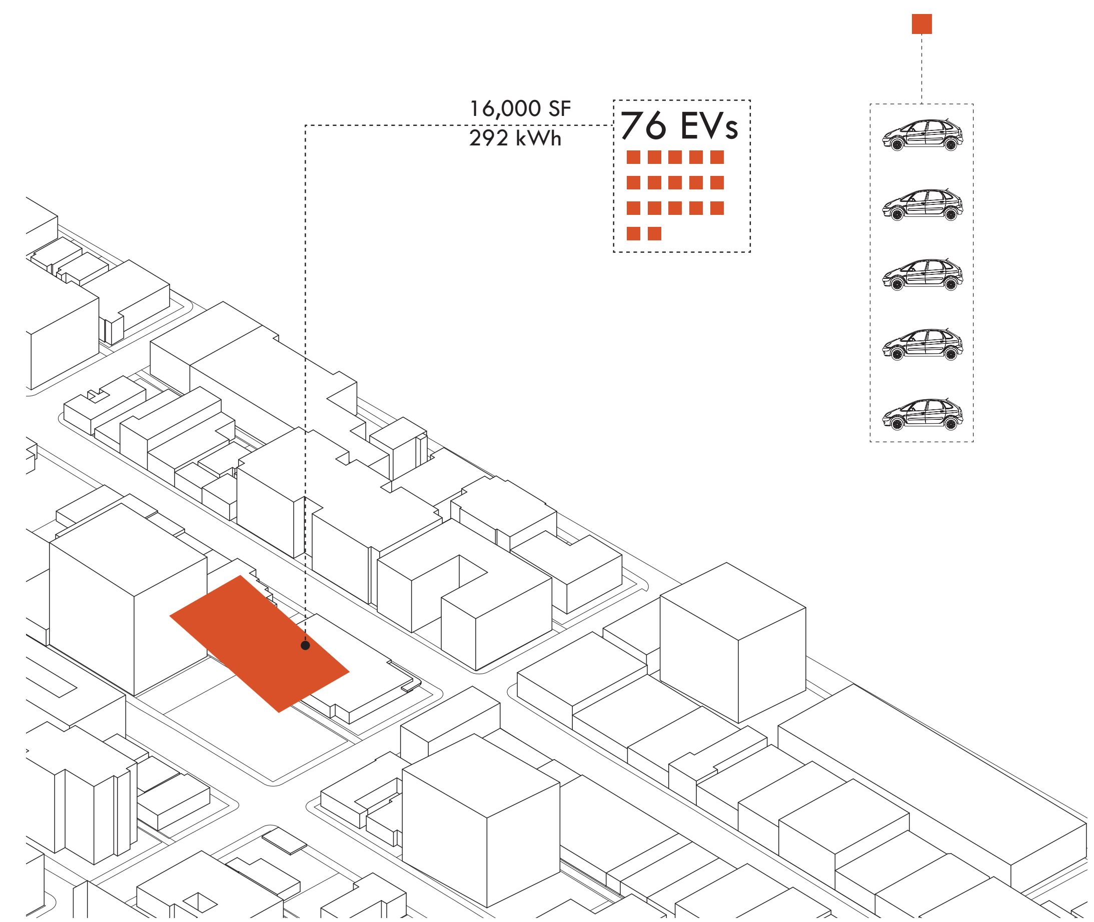


fig. 88 solar energy harvesting potential for electric vehicle charging

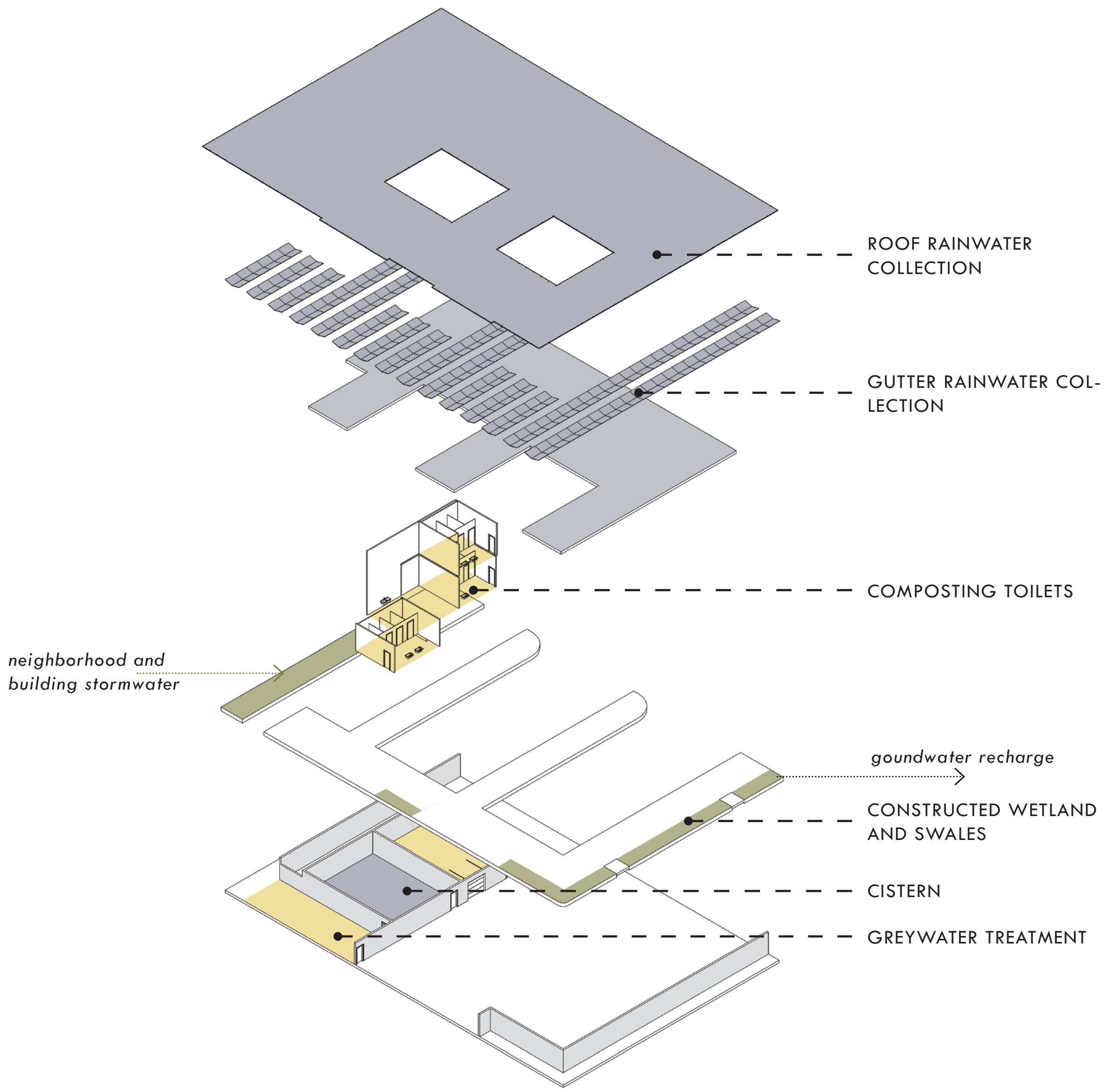


fig. 89 water sources and uses in proposed project

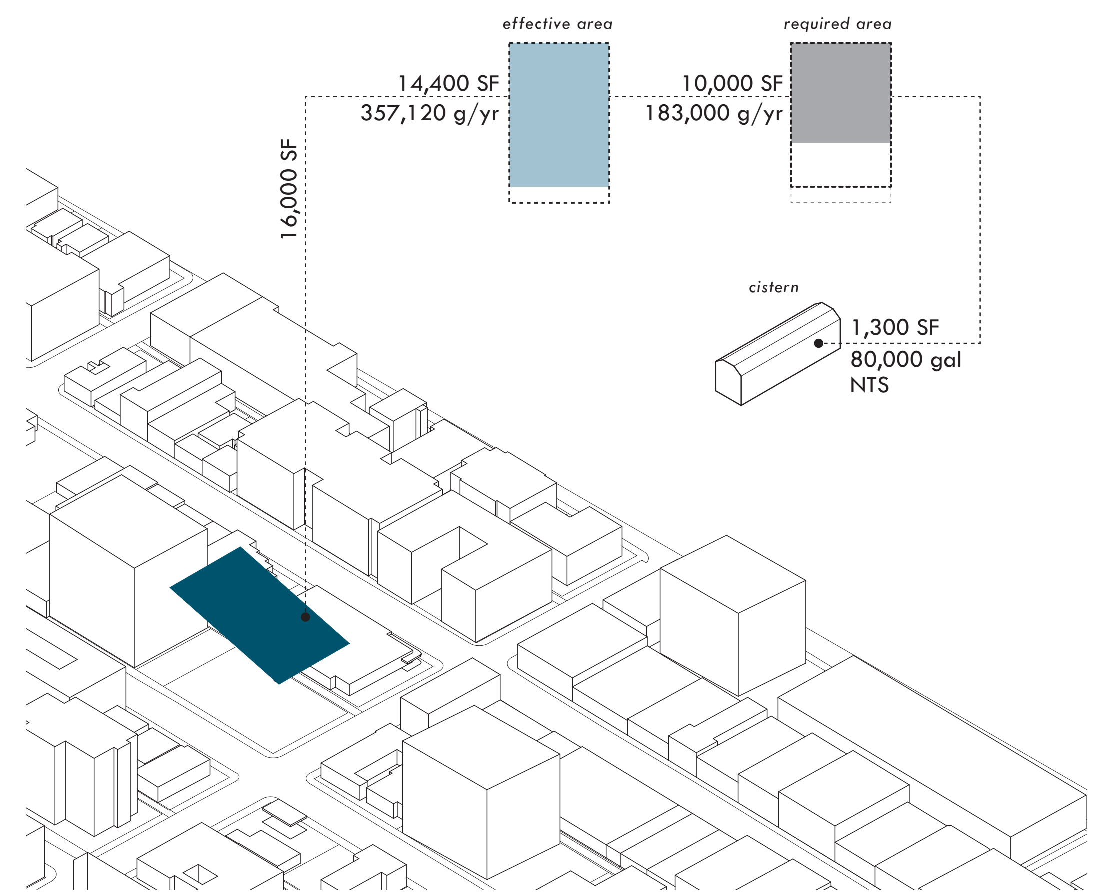


fig. 90 rainwater harvesting and cistern size required for proposed project

The primary structural system of the enclosed building is cross laminated timber (CLT) panels. (fig 91, 92) The roof is supported by a steel post and beam structure. Interior floors are CLT panels with concrete topping. Exterior walls are constructed to Passive House standards.[39] Exterior cladding is a metal panelized rainscreen system for ease of maintenance and to continue the utilitarian association of the streamlined material from the existing gas station to the new Energy Commons. As seen in a view of the bike shop, elements of the streamlined metal exterior contrast with the warmth of the uncovered CLT panels in the interior. (fig. 94) This material distinction brands the new program of the Energy Commons and the CLT provides a biophilic and human connection to the program through its material qualities. Glass curtain walls supported by an "off-the-shelf" aluminum structure provide areas of transparency and translucency for the masses. These structural components and material choices have standardized fabrication practices and come in dimensional sizes making construction and assembly inexpensive and quick, reducing the time between underutilized undeveloped site to useful urban amenity. This standardized system also allows for the structural system to be replicated more easily than a custom form for other hypothetical Energy Commons at other sites in Seattle.

The north and east sides of each mass are mostly CLT panels resulting in a solid, closed wall. (fig 69, 95) The treatment of the south and west walls vary with each mass dependent on function. (fig. 93) The restroom/waiting area is partially translucent for privacy. The bike shop opens to the bike porch for expansion of work space and the convenience store is transparent to allow for maximum visibility of goods.

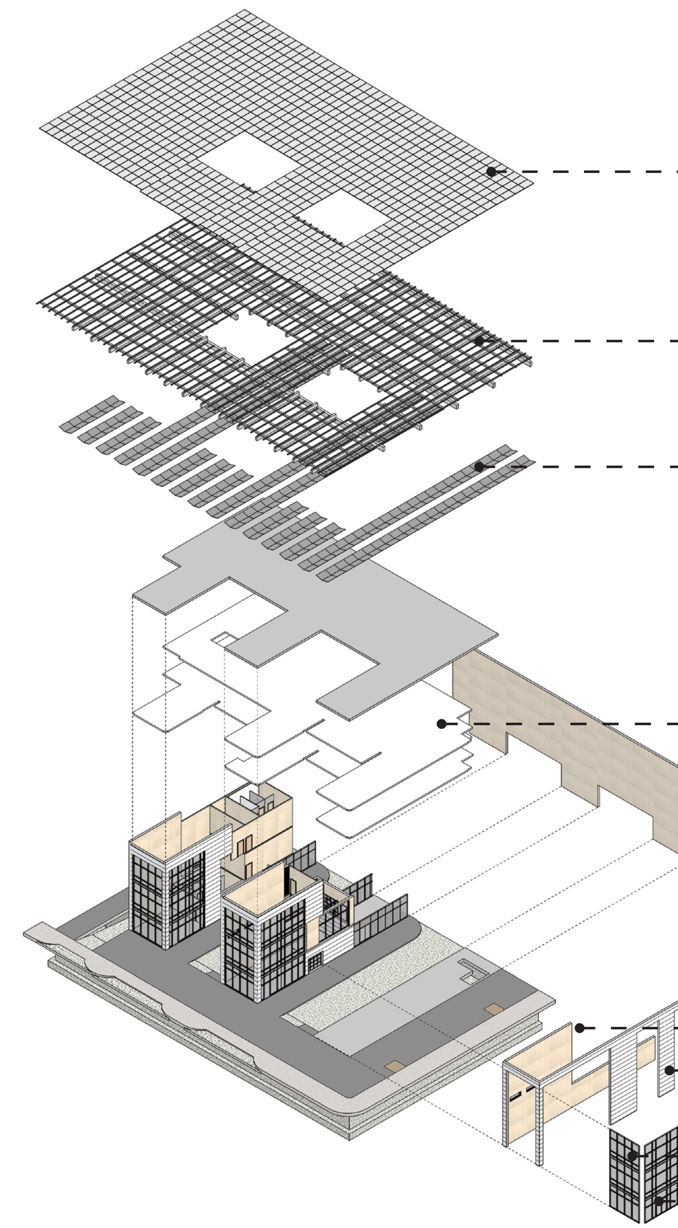


fig. 91 structural and tectonic systems for the proposed project

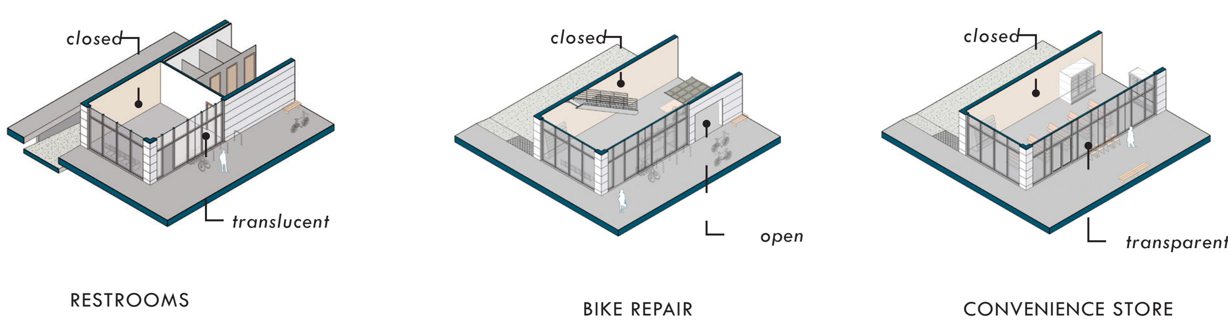


fig. 92 structural model of walls and openings
fig. 93 varied tectonic treatment of specific masses based on program and visibility

fig. 94 interior view of bike repair looking west

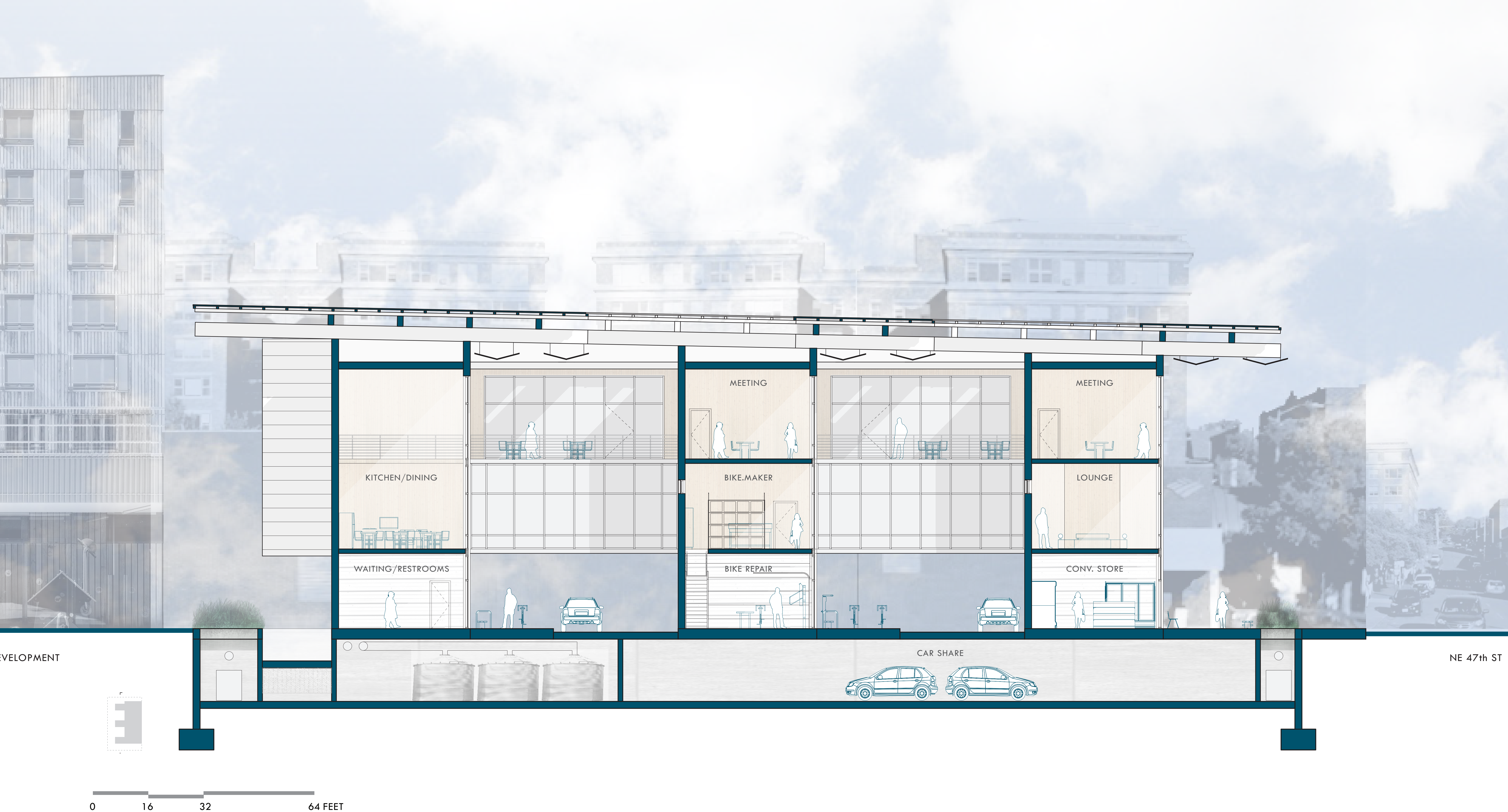


fig. 95   section through primary masses looking east showing utilitarian and amenity spaces

To further reinforce and signify the Energy Commons to pedestrians, cyclists, and cars more than form alone, material elements were designed that reveal the neighborhood and the building's specific functions in the tradition of the historic gas station. (fig. 96) On the western portion of each mass are translucent lighted glass panels that indicate the available charge in each of the electric vehicle charging stations of the Energy Commons. This allows drivers to know if a stall is occupied or if there is enough stored solar energy to charge their vehicles because this visibility has been taken away with the proposed increased density. The underside of the canopy gutters are lined with a reflective material that reflect the activities of the Energy Commons and the surrounding neighborhood based on a person's distance away from the site. The reflective material also mirrors the electric vehicle battery indicator to further assist the driver in legality of the available charge at the Energy Commons.

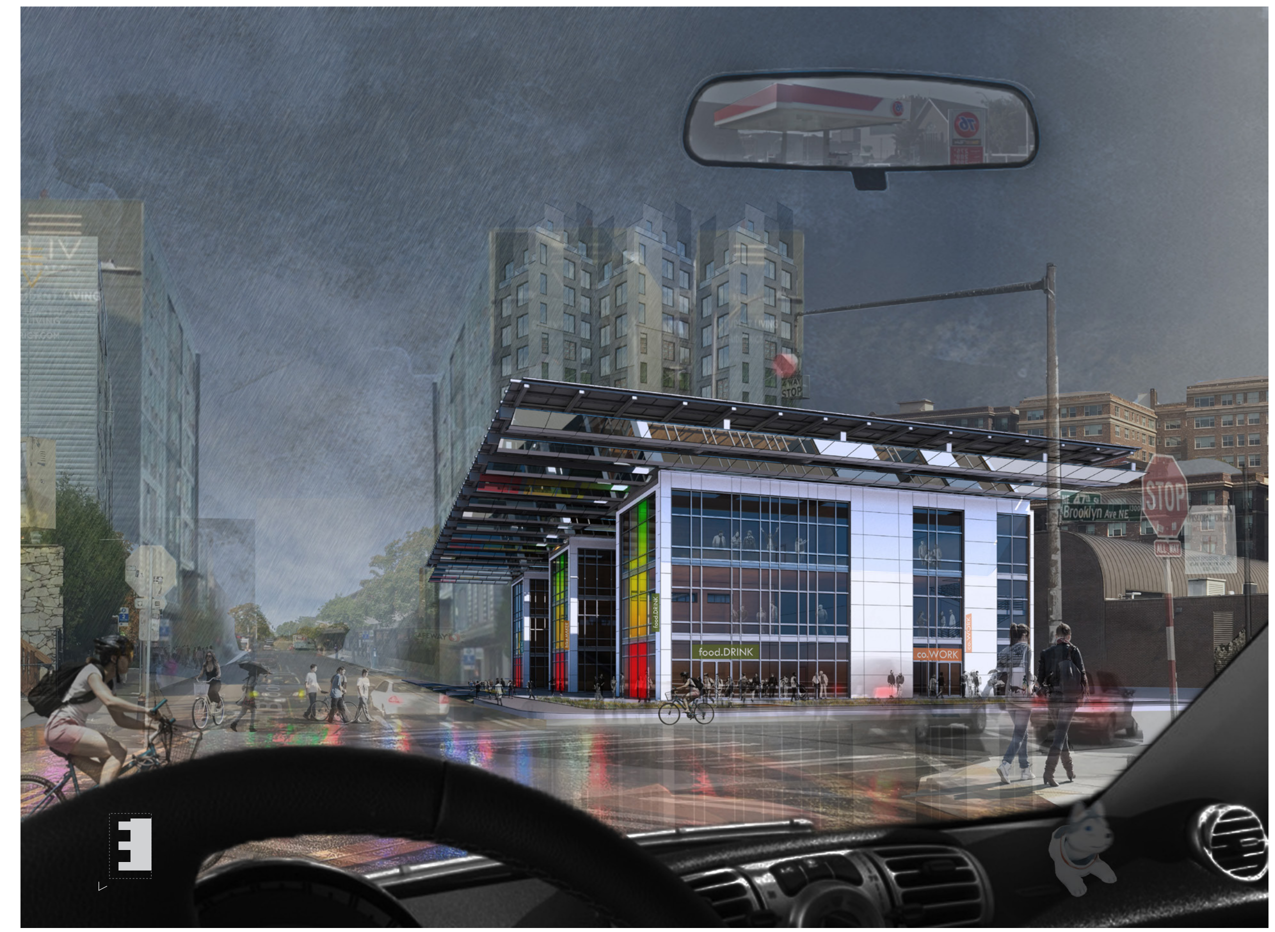


fig. 96   approaching the University District Energy Commons by electric vehicle

FIVE

conclusion

This thesis argues that urban gas stations in Seattle can be redeveloped to connect the flow of vehicles, people, and renewable resources within contemporary growing cities. Existing gas stations within the urban fabric have a negative impact on the health of people and the environment and do not reflect larger societal trends toward clean transportation and renewable resources. In response, the proposed project, the "Energy Commons" aims to change the existing urban gas station typology in which the automobile is the primary user and public and private amenities accrued informally on the site of human and vehicle utility. In identifying these sites as foreseeable redevelopment lots and the need for mediated building density in growing cities, this thesis presents a new building type that updates the utility of the existing gas station to address new technology and integrates new community-tied amenities. The thesis design is one specific solution to the currently disconnected urban response and generic architecture of existing gas stations. To this end, the proposed project, the University District Energy Commons, attempts to power and empower urban and human mobility through integrated architectural form and innovative program intersections. Specifically, the existing architectural elements of the gas station, canopy, mass, and ground plane, are reimagined to provide utility to humans, bikes, and electric vehicles, and amenity in a neighborhood-specific program component through new user relationships. In addition, the project extends the connections of flows of people and vehicles to energy and water through solar power storage and distribution, rainwater collection, and neighborhood-scale stormwater management. The goal is to transform the former car-centered and consumptive structure into a new public urban asset that is human focused and production-minded. The design proposed is performance-based rather than suggesting a new iconic form. Unlike the existing gas station where amenity accumulated onto utilitarian structures in an informal manner, a hybrid of utility and amenity is intentionally created. This experimentation connects current building forms with updated user relationships and the dynamic flows of people, vehicles, and resources.

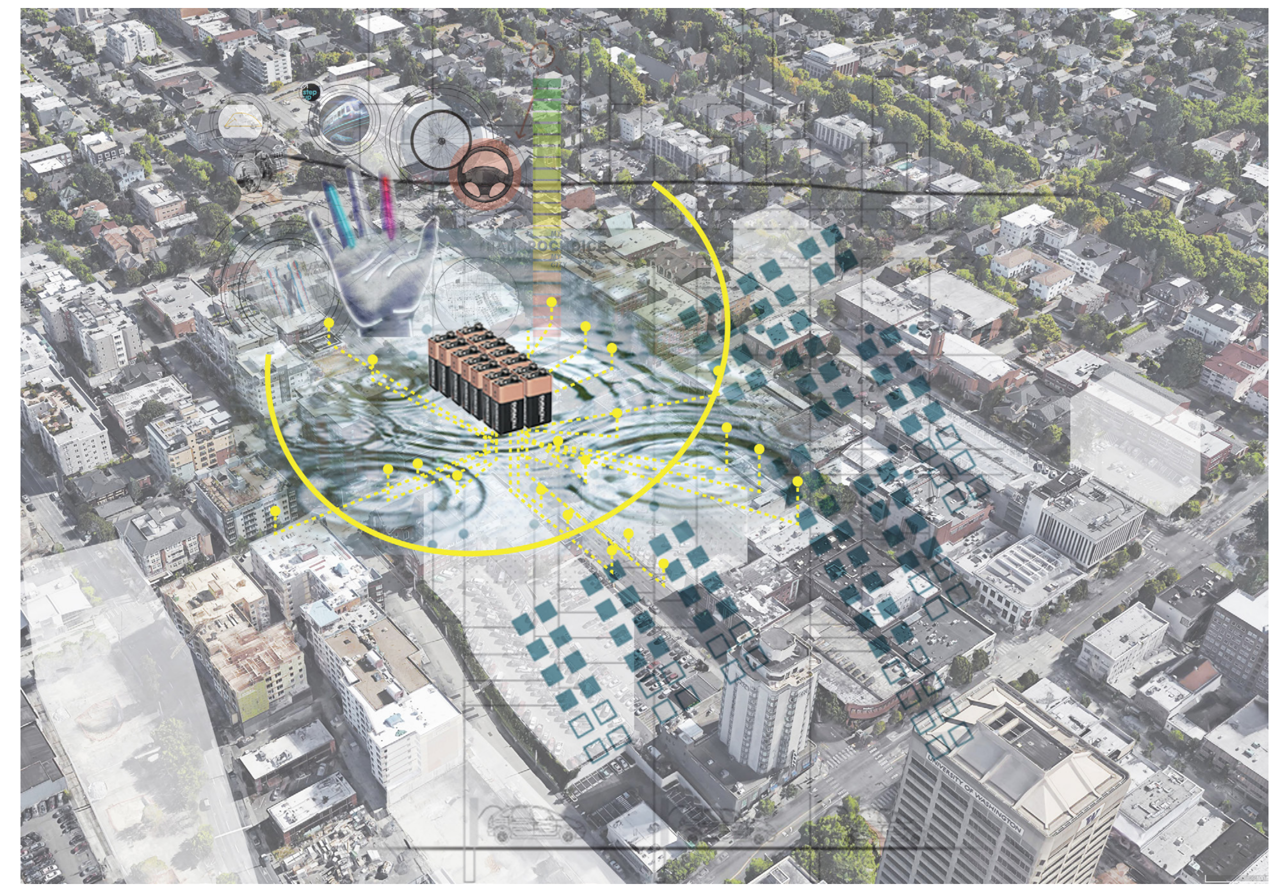


fig. 97 conceptual drawing of "energy commons" as "battery" for the surrounding neighborhood`

To further test the ideas of this thesis, multiple sites within Seattle could be examined for similar physical characteristics from which a prototype or structural module could be developed for the form of the Energy Commons. This exploration would include the design of an entire network of Energy Commons which is mentioned in the thesis but not developed. Each neighborhood would have a contextual program component that responds to its community-needed amenity and the scale of the neighborhood. Furthermore, a study could be undertaken in a city more dense or car-dependent than Seattle, where developable lots could have opportunities for denser program or present more challenges to car-less travel and the architecture than supports it.

While this investigation concentrated on the reinvention of one gas station site in Seattle, it addresses issues that are pervasive and present in most American urban areas. Cities and urban growth areas are facing similar problems with redevelopment of obsolescent utilitarian and light industrial sites and their associated environmental problems while searching for innovative answers to extreme building density, housing shortage, and lack of public amenities. When urban sites are proposed with less than full massing and maximum revenue for the completed project, conflict brews between the demands of the developer and the desires of the public and surrounding community. However, this is not the case for such low-rise building types as churches, fire stations, or libraries. In dense cities and growing urban areas, there are some amenities that are appropriate for lower development to signal their function and to provide relief from the full-height urban condition. To address these aforementioned tensions, this thesis proposes a compromise between public amenity, building density, and commercial public space. Thus the project and its generative ideas advocate that the Energy Commons could be a formal and programmatic model that could be replicated in other growing cities.

In conclusion, architecture is reactive and anticipatory in giving physical form to current societal views and future ways of living. In balancing the two, a discussion is predicated between the public, the profession, and related disciplines. The questions and uncertainties that arise from this design proposal (public versus private, building versus landscape, utility versus amenity, profitability versus believability, object versus space, etc.) are a result of contemporary tensions between architect and developer, who often treat the project user simply as a consumer and do not recognize the larger urban and public issues of only creating more maximum height, financially driven buildings. This proposal does not meet real estate pro forma nor operates in an academic vacuum devoid of practicality. Instead, it hopes for a better comprehension of modern urban issues through a dynamic, innovative, and broad look at complex future situations, rather than a narrow view of architecture entirely driven by financial viability and market forces. Architects and designers must address a broader public rather than strictly cater to the desires of real estate developers, otherwise the profession is not advanced. This thesis is submitted as one attempt at a solution, but one intended to spark a critical dialogue about disregarded sites and public amenities in future cities and a proposition charged with inspiration of where good design can go.

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APPENDIX A

precedents

Based on the neighborhood needs and specific functions that the new "Energy Commons" will address and contain, multiple typologies will be used as evidence for the design – gas station, charging technology, and alternative use of standardized commercial spaces. Certain themes were used as criteria to evaluate the study precedents: integration of form to function, degree of services offered, relationship within the urban fabric, and contextual reference.

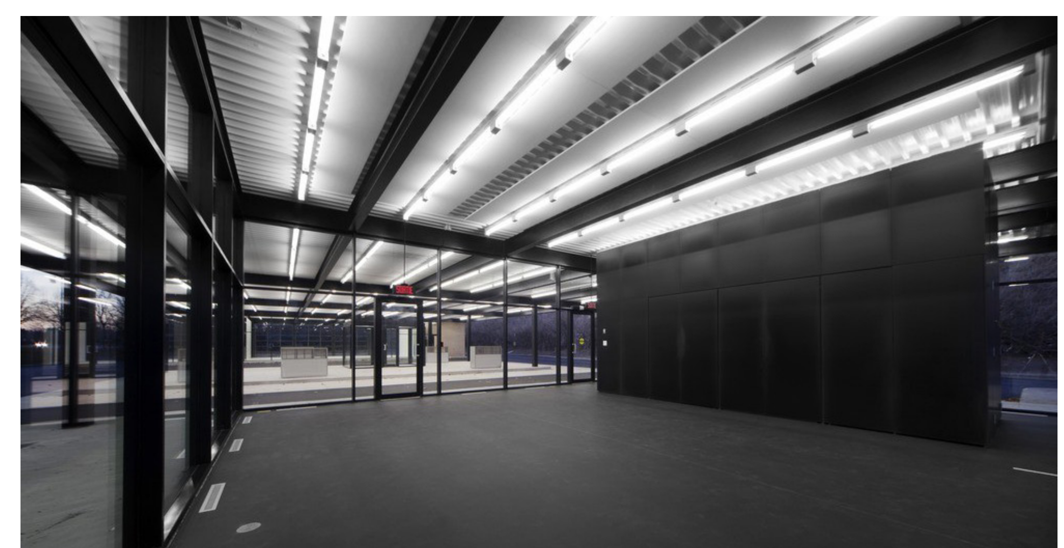
NUN'S ISLAND ESSO STATION

Montreal, Canada
1968 (Original), 2012 (Renovation)
Mies van der Rohe (Original), Eric Gauthier (Renovation)

New urban development of Nun's Island in Montreal, Canada in 1962 led to the commission of Mies van der Rohe for three apartment towers. Additionally Standard Oil contracted him to design a prototypical gas station in 1968. The station is composed of two volumes – one for servicing vehicles and the other for automobile-related sales. The pumps are located in the void between these volumes. A low roof of steel members covers the pumps as a canopy and unites the volumes. Like the modern streamlined boxes of gas station of the era, this station is made of steel with expansive walls of glass. The structure is painted black to contrast with the white steel decking, fluorescent lighting, and glass.

The station ceased to be operational in 2008. After listing it as a heritage building in 2009, the City of Montreal commissioned Eric Gauthier of FABG Architects to renovate the building to house a youth and senior activity center for basic communal activities. The flexible program, playing games, preparing communal meals, dances, lecture, and parties fits well into the open plan in each separate form of the original station. Site work had to initially be done to address the contaminated soil. The envelope was restored to repair the eroded curtain wall. New electrical and mechanical systems were installed as well as geothermal wells. The original simple formal unity was reinforced with the linear rhythm of florescent lighting, long axis transparency using low-iron glass, and updated black and white paint of the steel structure.

fig. 98 conversion of Mies van der Rohe Gas Station, Les Architectes FABG



UNITED OIL GASOLINE STATION

Los Angeles, CA
2009
Kanner Architects

The United Oil Gas Station in Los Angeles's car-dominated Mid-City neighborhood is a 12-pump gas station, convenience store, and car wash. The station's form draws reference from freeway interchanges and the speed and movement of the automobile similar to the gas stations of the 1960s. The primary move results in two sweeping planes of the canopy and ground plane. The chamfered, white and grey canopy is suspended on V-shaped columns links the spaces and functions of the station as it acts as roof. The canopy provides shade in the Southern California heat and serves as eye-catching and dramatic marketing device. Steel and glass are the primary materials to provide lightness and visibility. The second sweeping plane is a concrete ramp that takes vehicles up and behind the convenience store and to the car wash.

The interior is bright and colorful making reference to a mod-century diner. The station does not offer alternative fuels. A pocket park is located to the store to relieve the neighborhood from the expanses of asphalt. The station is located the corner of two major arterials and provides maximum access in the urban residential neighborhood. On every corner of the intersection of Slauson and La Brea, there exists a gas station from a different oil company. This suggests that another use could have been possible. Building height is similar to single family residences in the area.

fig. 99 United Oil Gasoline Station, Kanner Architect

HELIOS HOUSE

Los Angeles, CA
2007
Office dA

The Helios House is a gas station located in West Central Los Angeles, CA. In response to the demand of refueling and dependency of the car in Los Angeles, there is a standardized Shell gas station and convenience store diagonally across the intersection from the Helios House. According to the architects, the purpose of the design was to “reinvent the gas station” as “green” and to be the “[gas] station of the future”.

The form of the Helios House is similar to the previously mentioned typology of the modern streamlined box. There is a large, single-material canopy over the fueling pumps to protect the consumer from the elements while refueling. A small rectangular box in the back of the lot houses public restrooms. The Helios House uses a triangulated skin to incorporate the canopy, columns, and attendant booth into a seamless whole. The parametric steel plate cladding unifies the individual pieces of the column with the canopy. This combined and innovative form integrates branding through its iconic form in the urban landscape of Los Angeles. Two billboards rise above the canopy and are integral to the overall form of the Helios House. Because of their orientation in opposite directions, the billboards allow drivers from all sides to help identity the progressive canopy form below as a gas station.

fig. 100   Helios House, Johnston Marklee

The main function of the Helios House is to store and dispense gasoline for refueling of automobiles. This is accomplished through underground storage tanks and on grade pumps - covered by a large spanning canopy. Along with the pump, there are spaces for an attendant on duty in a kiosk under the canopy and public restrooms in a rectilinear form in the background. Unlike contemporary gas stations, the Helios House does not contain a convenience store. Therefore, all revenue is solely from the sale of gas. Because of the architect's and client's goals of environmental stewardship, the Helios House incorporates solar energy harvesting and rainwater collection into its function using the recognizable canopy form of the gas station as a framework for sustainability. The Helios House uses the typical form of the gas station to fulfill utilitarian functions and elevates subtleties in its cladding and structure to meet other uses.

The form of the Helios House marks its presence in the urban fabric and communicates itself as a gasoline marketplace. Because the surrounding neighborhoods are car-focused, the demand for gasoline refueling is present. Like many other gas stations, the Helios House is located on a corner to allow two edges for car access. The geometric form of the canopy and columns of this gas station fits the bold and metropolitan character of the city as whole. Because of the adjacent residential character, however, the shiny triangulated shelter of the Helios House stands out among the neutral tones of plaster and siding of its rectilinear neighbors. This difference in materiality and form allows this gass station to market itself as a gas station through its sophisticated form. The canopy fits seamlessly with the heights of the multifamily and commercial strip buildings directly surrounding the site. The billboards that rise above the station proper engage the urban, car-oriented culture of Los Angeles as a landscape for brand communication. The size and height at which they are placed use the scale of signage as architectural invention of commercialization.

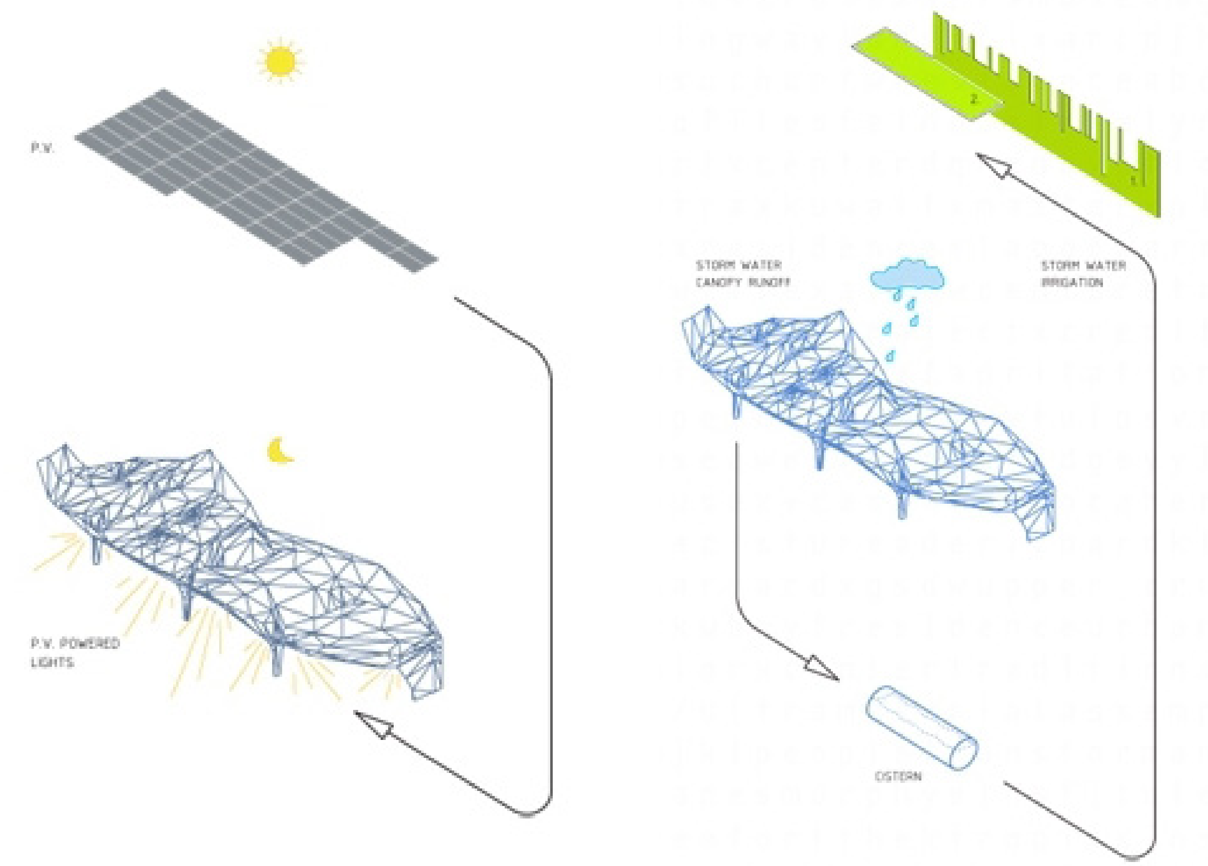


fig. 101 Helios House, Johnston Marklee

CHARGEPOINT

Global
2009
Coulomb Technologies

ChargePoint operates an electric vehicle (EV) charging network through a series of one-off charging "pumps". They also design the technology that supports this EV charging network. Originated in California, the company has expanded its network to Europe, Middle East, Africa, and Australia.

The charging kiosks are located on streets in public parking areas and in office complexes and buildings. The public charging stations require a subscription plan. ChargePoint also provides assistance in utility grid management for public and private electric companies to regulate grid demands. They have also started selling the kiosks to home owners through partnerships with automobile manufacturers. US Department of Energy has also provided grants to supply cities throughout the country with the charging kiosks.

Because the stations are one-off at street level, an "app" or online access is required to locate them as they are not easily identified from driving by. Their form is unrecognizable and is not successful in immediately communicating their function. The public and roadside kiosks require a charge waiting time but rely on the surrounding urban fabric to occupy users time while the EV charges.

fig. 102   ChargePoint Technology

ENERGY NODE CLOUD

Chile
2015
raumspielkunst architecture and design

The Energy Node Cloud is a next-generation gas station proposal by the German firm raumspielkunst in Chile. The station is located at the intersection of two commuter roads, one of which leads to urban Santiago and the other the natural settings of the Pacific Ocean and Andes Mountains. The roof resembles a cloud and is a pneumatic structure composed of white, translucent textile. Thin steel piloti support the roof structure. The cloud-like canopy covers a concrete and glass L-shaped box. The enclosed portion of the station contains a 24-hour food market, bakery, pharmacy, attendant kiosk, café, and wine shop. Given the light structure and translucent canopy, the gas station glows at night and creates a beacon and oasis in the dark.

The Energy Node Cloud aims to be a self-sufficient gas station using solar and wind energy to generate its own electricity. Solar panels are implanted in the textile roof. A portion of the columns contain wind turbines that collect energy from the changing internal pressure of the pneumatic roof structure. The other columns others aid in water collection as rain is directed through the geometry of the roof. Rainwater is collected in the creases of the textile surface and then routed through the columns before being treated.

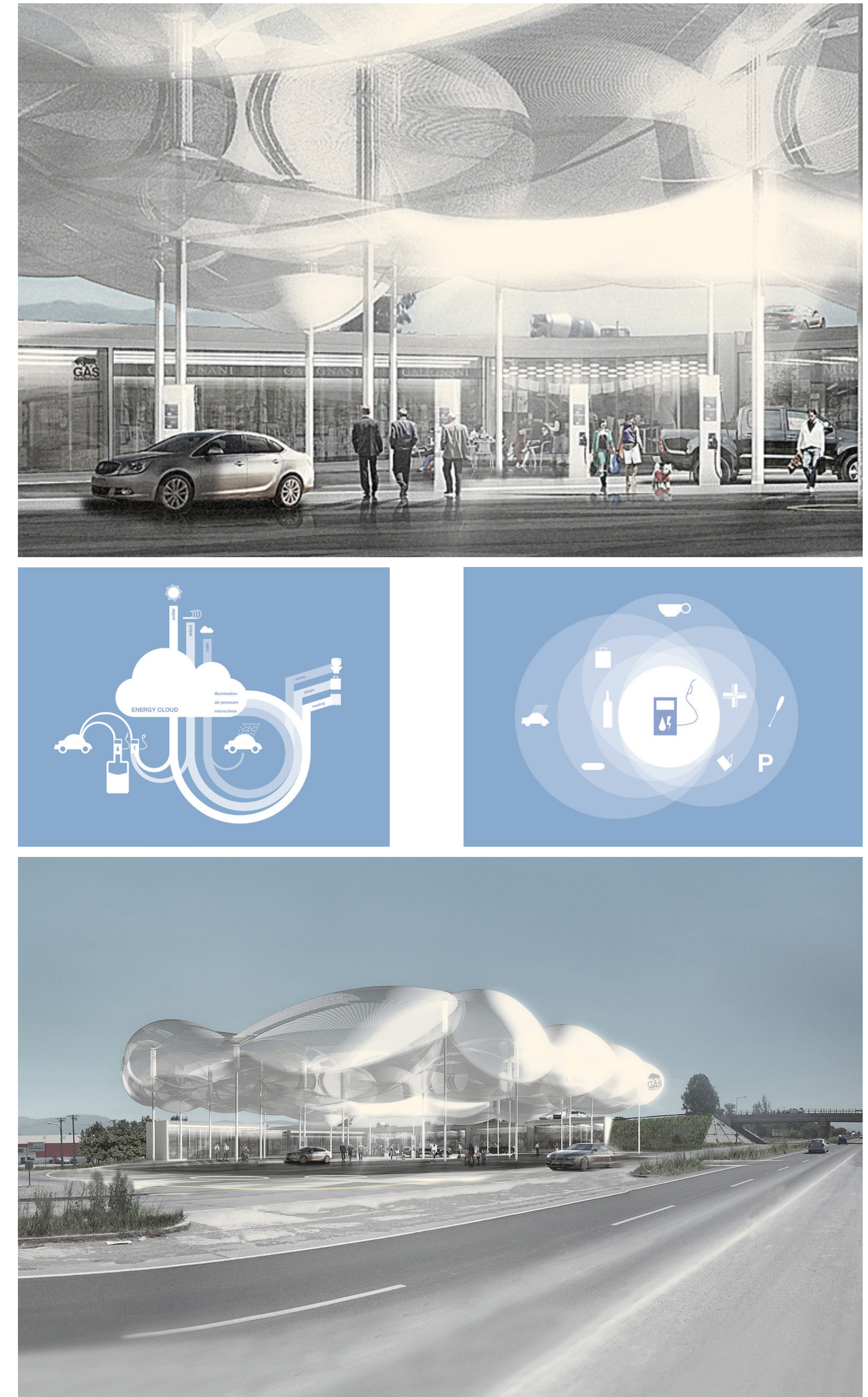


fig. 103 Energy Cloud - a next generation of gas station

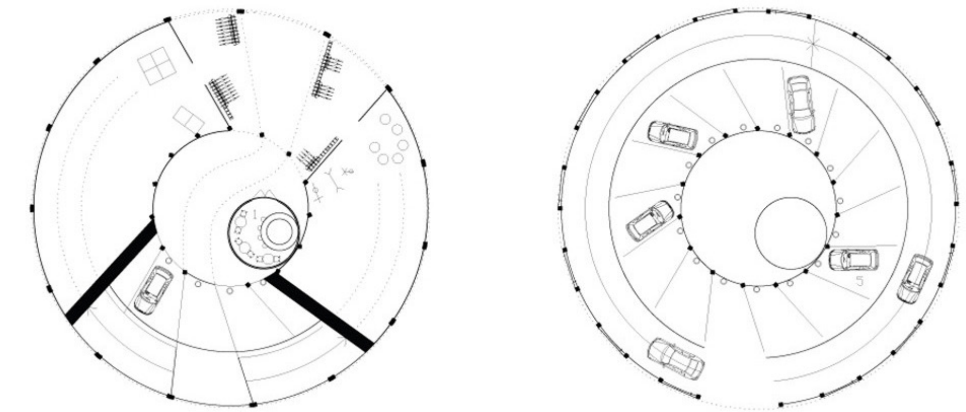
EV CHARGING STATIONS

Gothenburg, Sweden
2013
Kjellgren Kaminsky Architecture

In the past few years, electric car sales in Sweden have risen. To address this movement to EVs, Kjellgren Kaminsky Architecture in conjunction with the Gothenburg Traffic Department developed a prospective series of charging stations. The focus of the charging stations would be to use solar power to charge EVs, bikes, and scooters. The firm and city also intended the station to be distributed through the city. Therefore, setting up a similar formal language was essential to the concept so the station could be recognizable by residents and act as a symbol in the city.

The station is composed of locally sourced Forest Stewardship Council-certified wood in a circular form. The elevated ramps separate the automobiles form bikes and scooters. The spirals help in directing traffic and maximizing space. The roof contains south-facing solar panels. Amenities are provided for drivers as they wait for their vehicles to charge. A WiFi courtyard, café, bike repair shop, and outdoor gym are integrated into the structure.

fig. 104 Loading Station, KKA

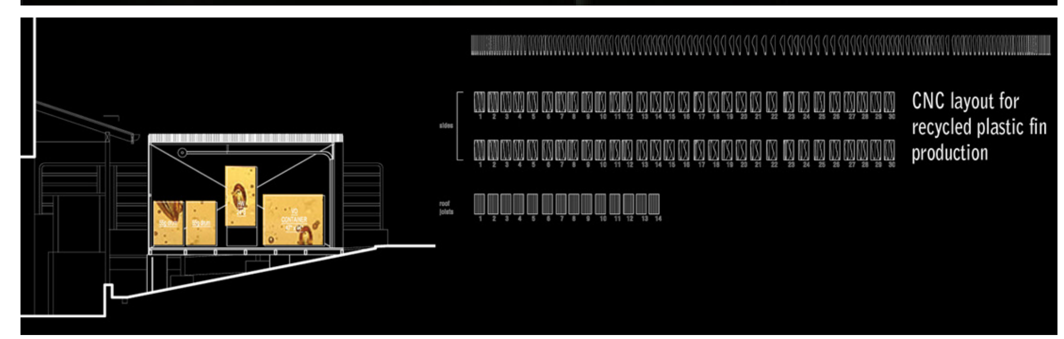


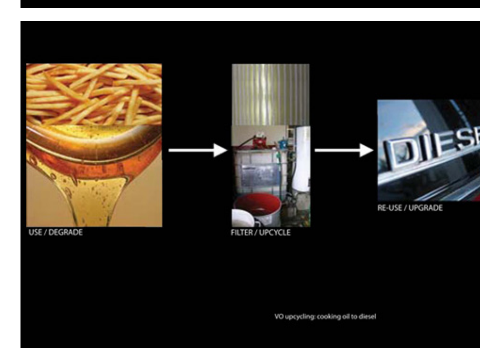
VO SHED

Atelier Jones
Seattle, WA
2009

The project began as a way to rethink using discarded vegetable oil rather than dumping it as waste. It is traditionally hard to harness waste materials and upcycle them into new energy sources. The solution is a small shed for filtering and housing used vegetable oil as part of a storage and distribution center for a Seattle biofuel cooperative. The process of use, filter, and reuse of vegetable oil is parallel to the chemical properties of the material degrade, upcycle, and upgrade. This development is mirrored in the material of the shed's skin, which is constructed of translucent fins made from recycled milk jugs.

The VO Shed is single use in its recycling and not a place of dwelling. The process of recycling the vegetable oil is cradle to grave. The project could be stronger with a cradle-cradle or closed loop approach. The use of the jugs is innovative and adds an element of beauty to a utilitarian singular function.





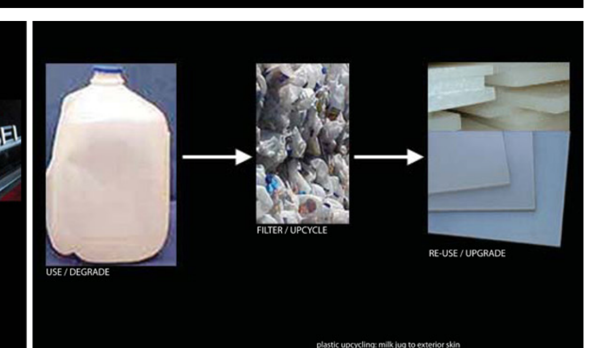


fig. 105 VO Shed, Atelier Jones

BUMPER CROP

The Miller Hull Partnership
Scottsdale, AZ
2009

This project started from a problem that strip malls are car-centered and contain large amounts of surface-parking that trap heat. These problems combined diminish the physical and experiential qualities of neighborhood. The solution calls for elevated and movable aeroponic crops above the parking lot in conjunction with a city sewer water reclamation system. The architectural intervention also results in several environmental benefits including shading the ground plane, reducing heat-island effect, producing food and revenue from the on-site agricultural yield, and maximizing reuse of greywater through the new water infrastructure. Because the planters are suspended above, cars can still use the parking lot. A reconfiguration of the parking lot and service alley reclaims some of the ground plane for pedestrian and community use. The strip mall is thus changed to be a more hospitable and multi-use environment that is community oriented.

The Bumper Crop was generated from a hypothetical future problem. The design solution applies to a typology can be emulated at multiple sites. Context is limited to the typology and site boundaries rather than making specific connections to the neighborhood and city beyond. The actual effects of light, heat, and ventilation of the parking lot underneath the canopy could be a practical issue.

fig. 106 Bumper Crop, Mill Hull Partnership

APPENDIX B

formal design development

Initial investigations into form were explored through iterative modeling and sketching. Digital and physical models focused on different variations of the architectural elements of the existing gas station. A spectrum between iconic and performative sketches yielded the design of the proposed project that integrated the canopy, mass, and ground plane. Documentation of the formal design development process follows.

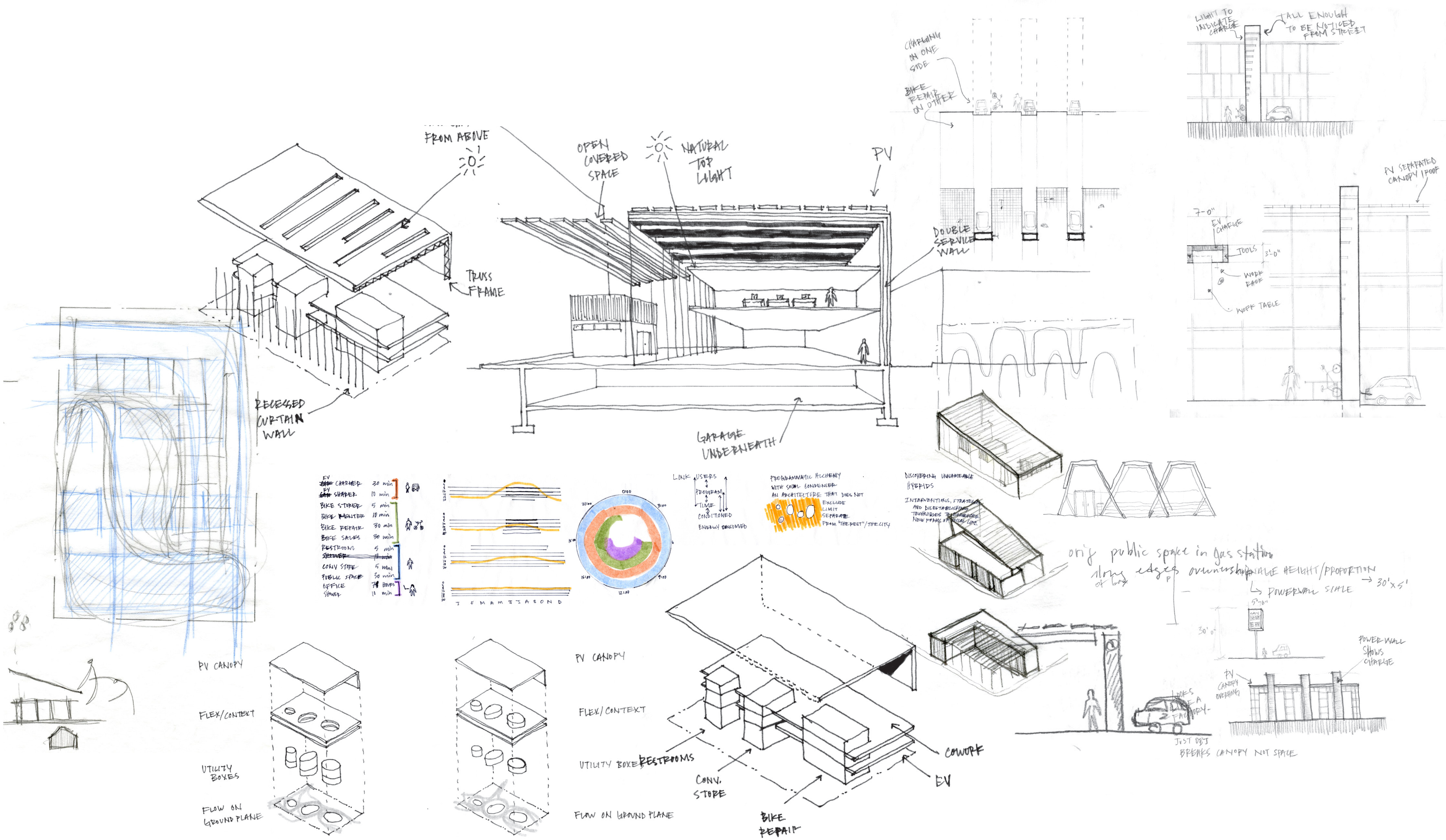


fig. 107   design development sketches of formal response to circulation, users, program, and environment

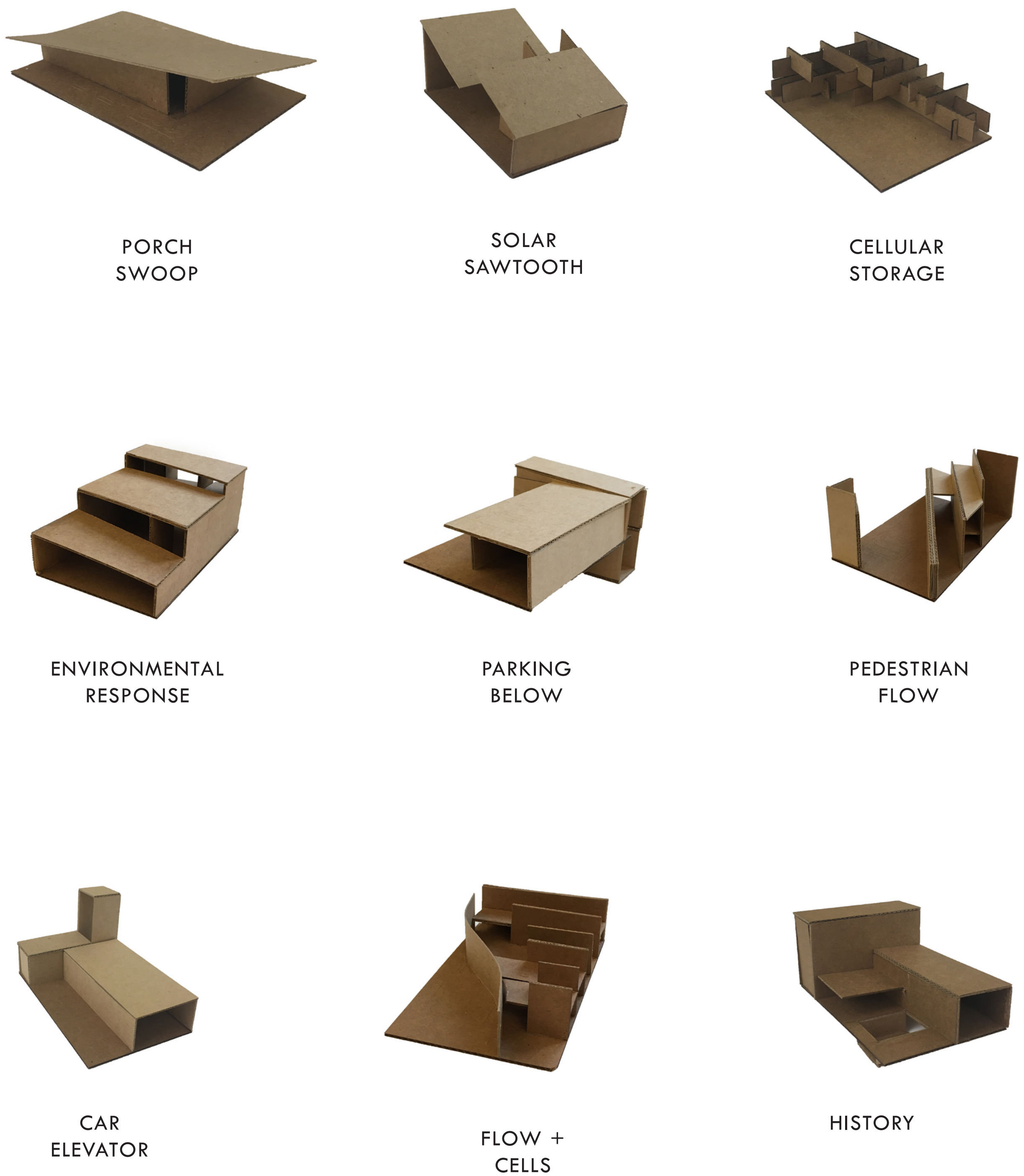


fig. 108   initial physical model iterations exploring different aspects of formal response

fig. 109   physical models of schemes as a response to sketch explorations and formal recognition

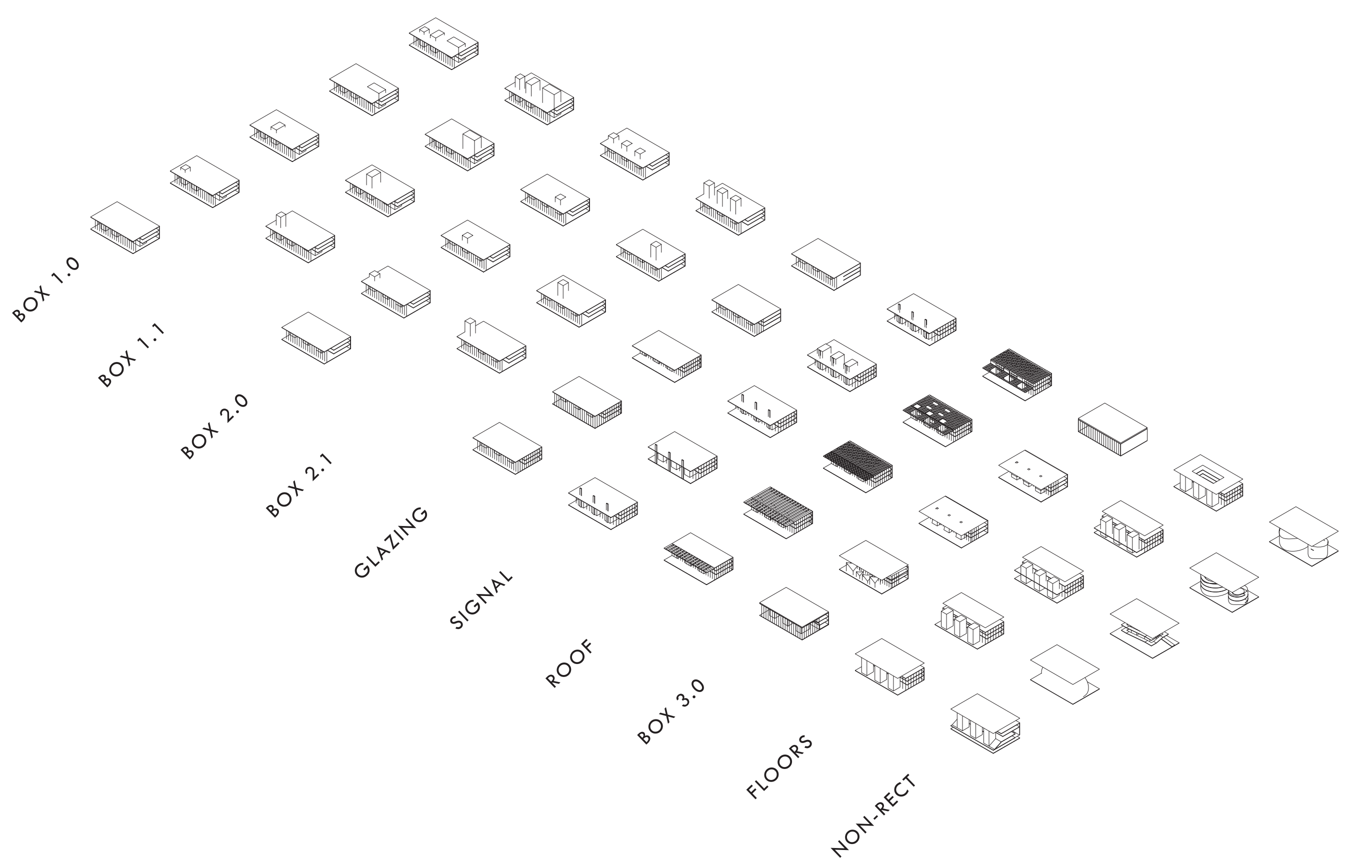


fig. 110   overall digital model iterations exploring four architectural elements

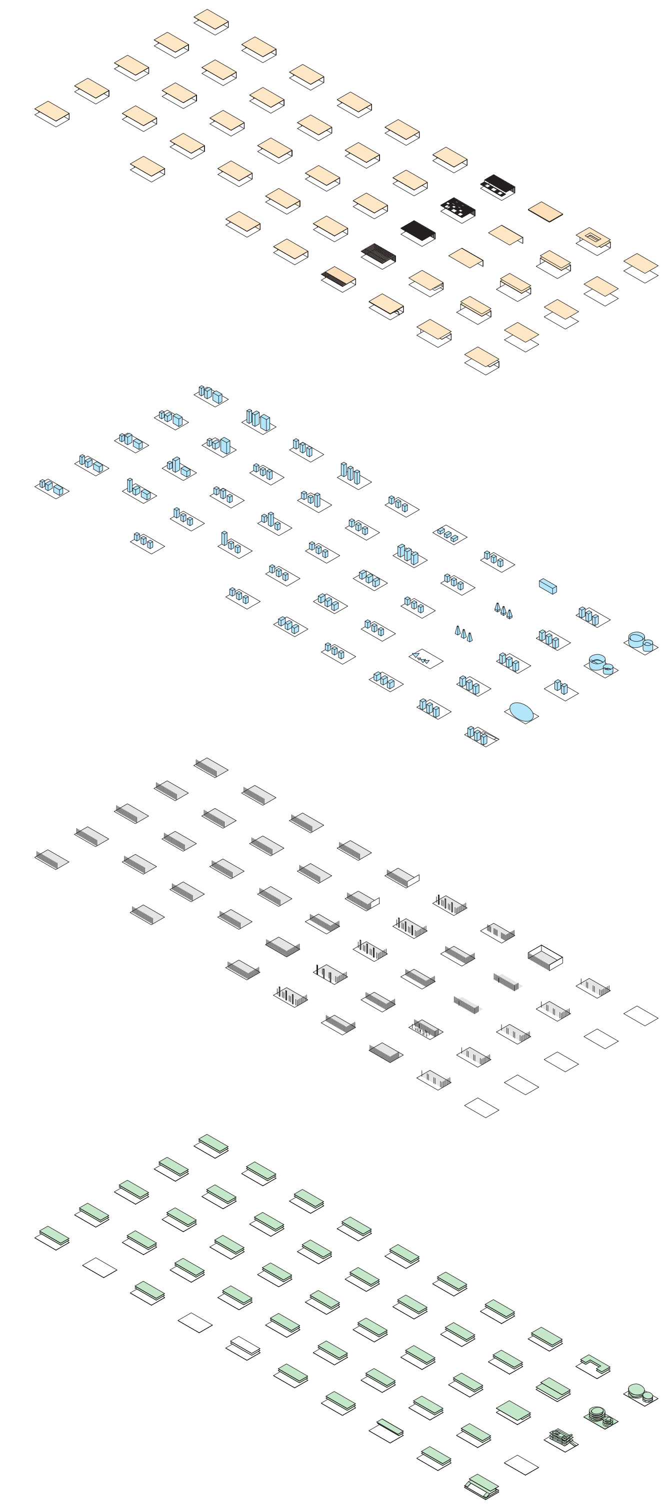


fig. 111   digital model iterations exploring four architectural elements: roof, mass, enclosure, floors

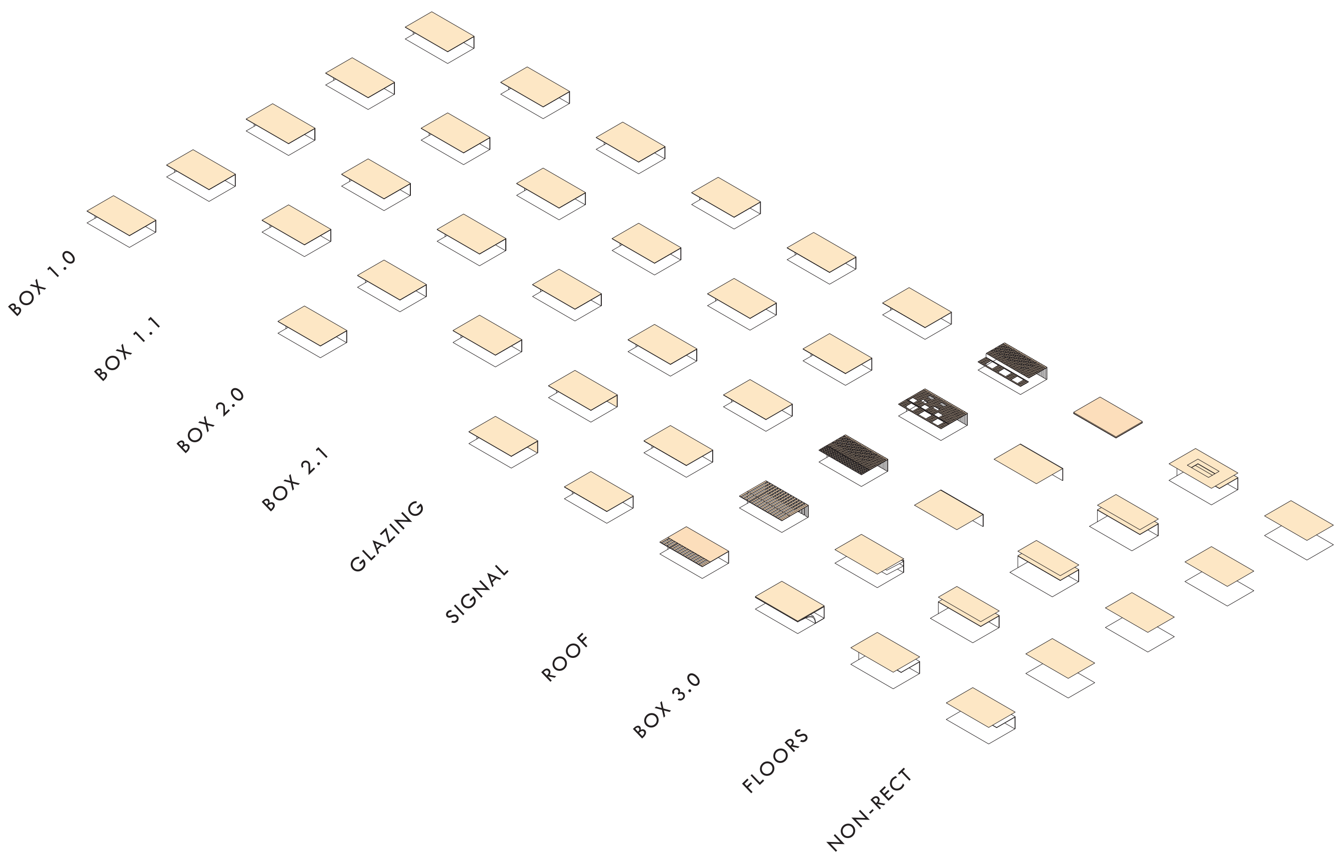


fig. 112   digital model iterations exploring roof

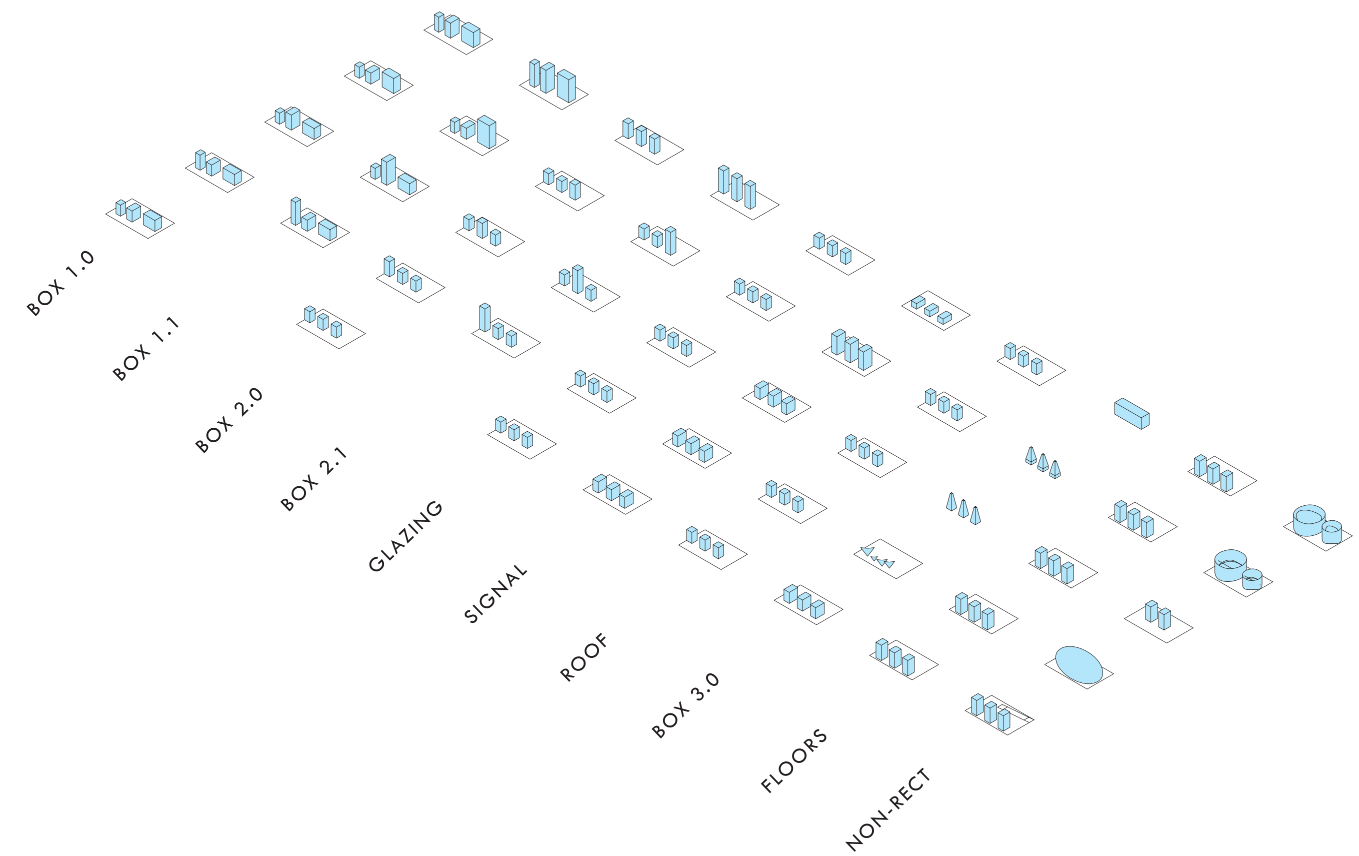


fig. 113   digital model iterations exploring mass

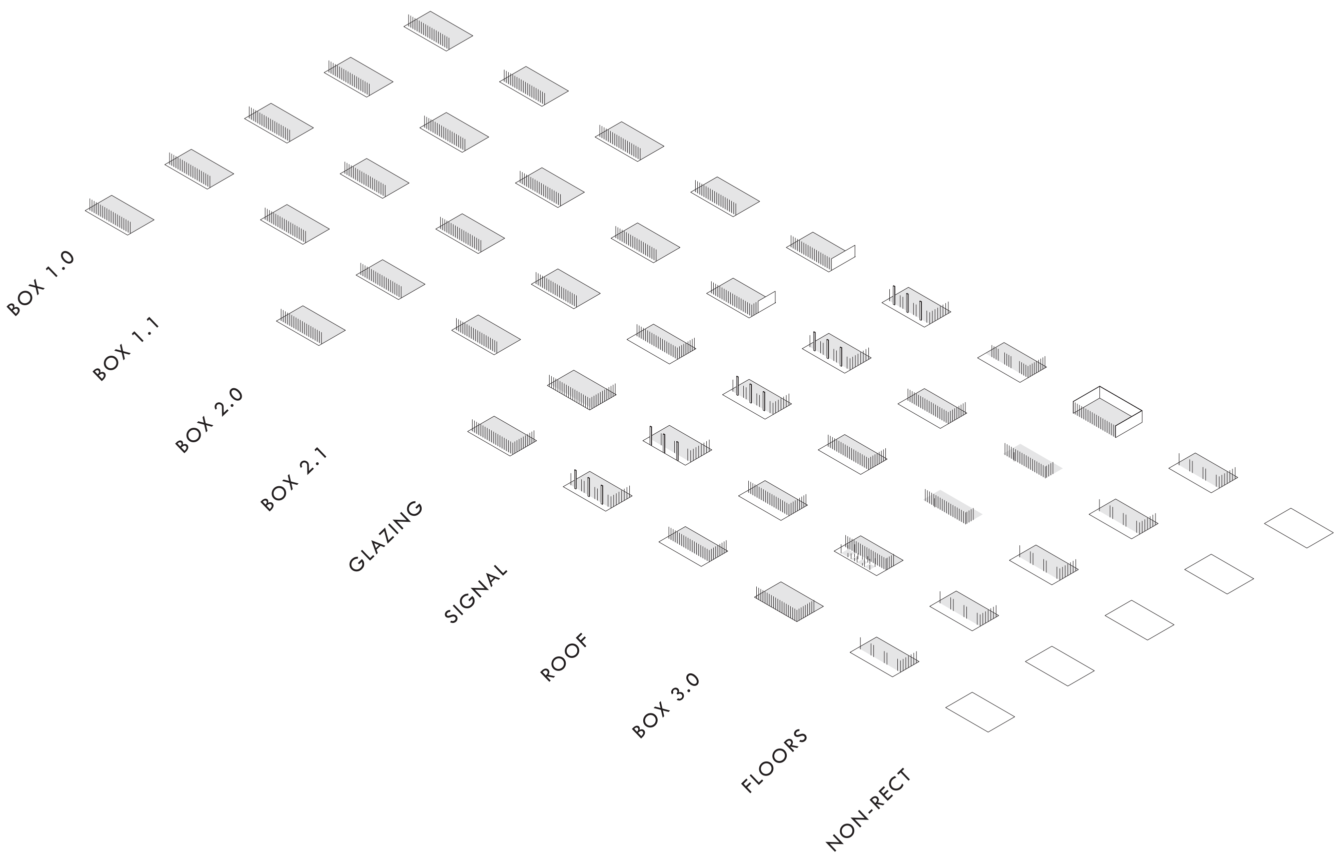


fig. 114 digital model iterations exploring enclosure

fig. 115 digital model iterations exploring floors

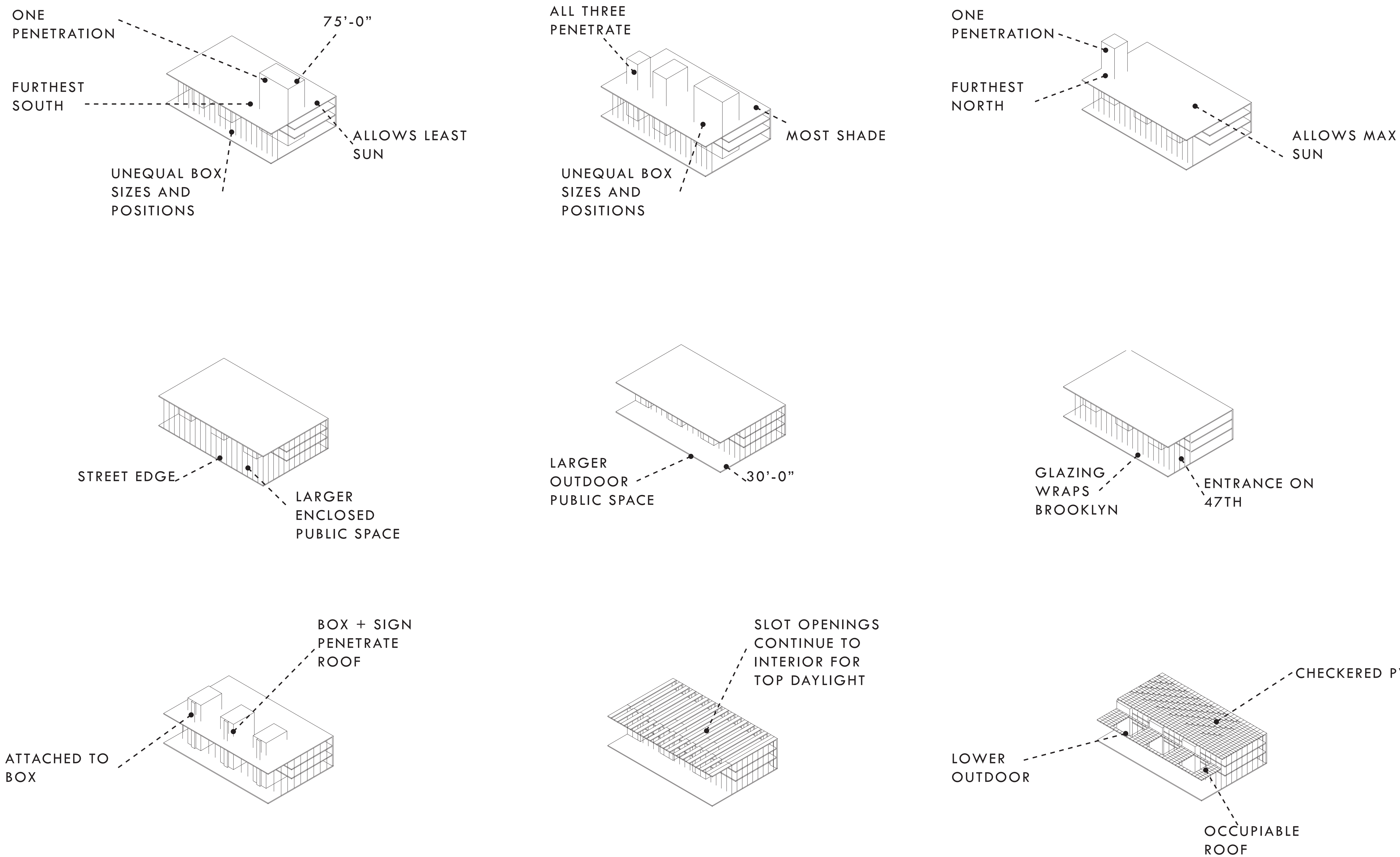


fig. 116 selection and analysis of select digital model iterations

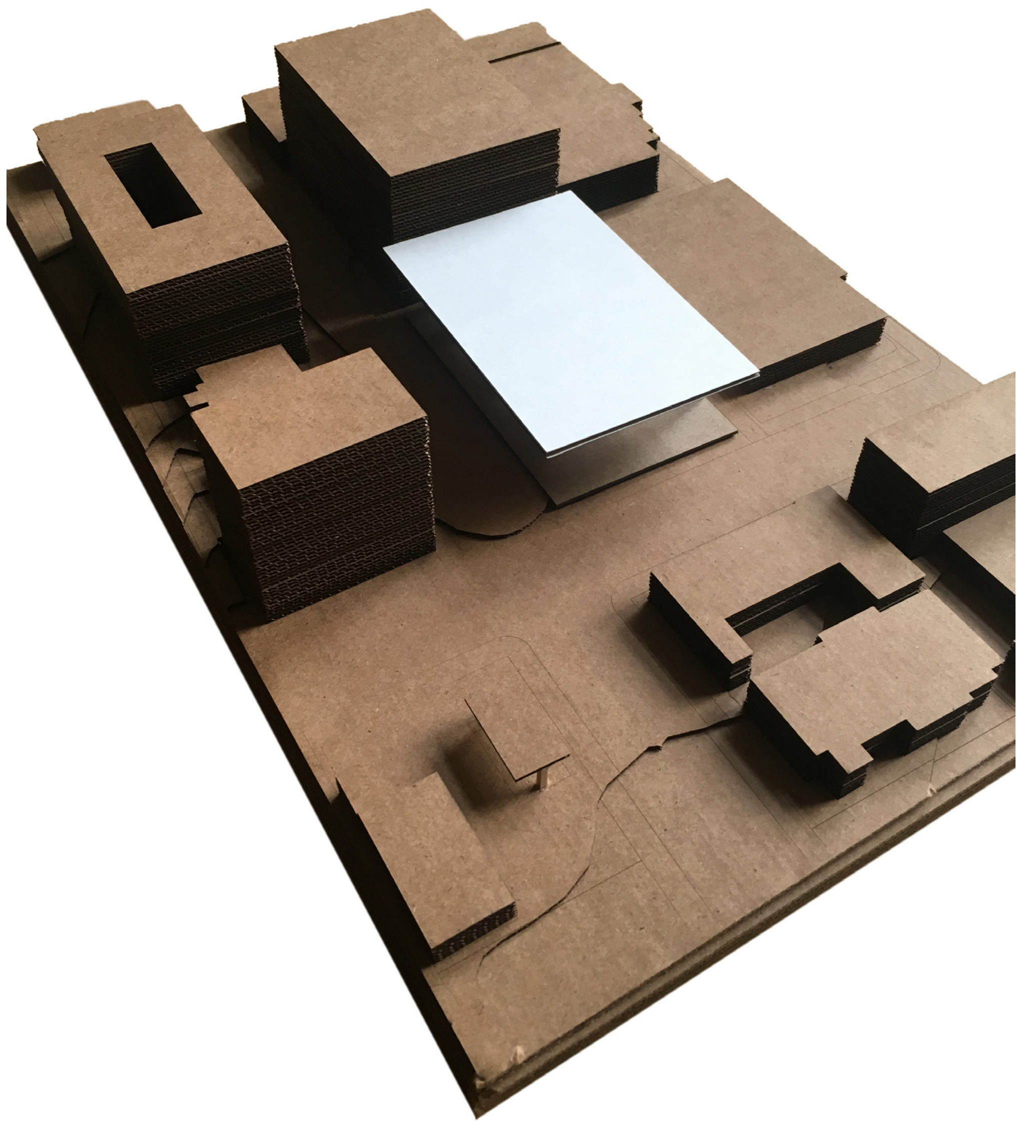
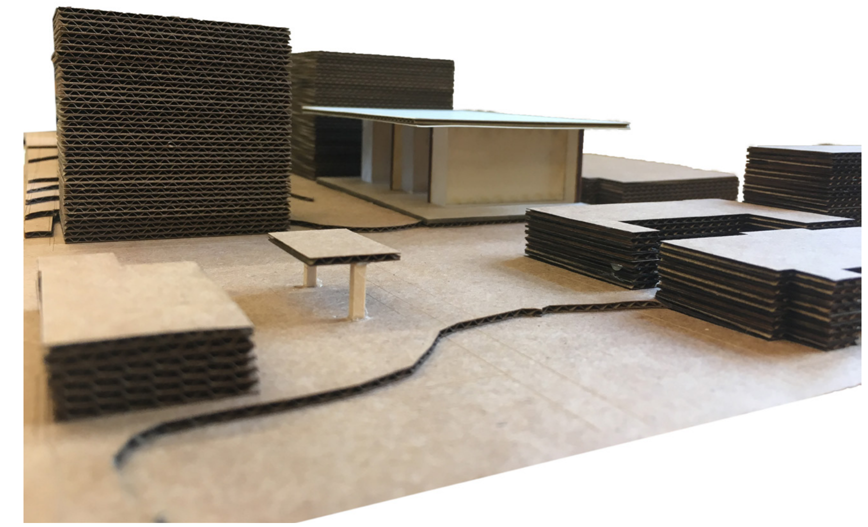


fig. 117   massing and site model



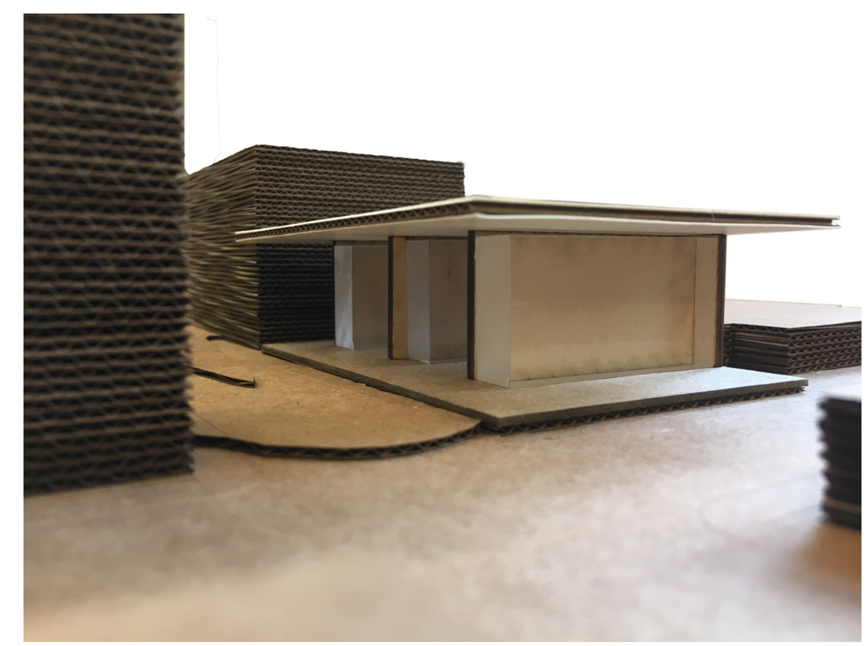


fig. 118   massing model on site model seen from existing gas station
fig. 119   massing model on site model looking northeast

APPENDIX C

building performance calculations

A goal of the project is to make the Energy Commons a place of production rather than of consumption. Initial calculations of photovoltaic energy production and rainwater collection yielded estimates for the number of electric vehicles charged on a yearly basis and required cistern size.

Based on current technology exhibited at nearby sites, full coverage of the site at 1,600 square feet would provide charge to 76 electric vehicles on a yearly basis. The Bullitt Center in Seattle, WA, a few miles south of the project site harvests 244.38 kW over 13,400 SF of photovoltaic panels, which is equivalent to 0.018 kW/SF or 54.8 SF/kW. The average EV requires 30 kWh to drive 100 miles. The average American drives their car 12,000 miles a year. Therefore 360 kWh is required to power an EV for an entire year (12,000 miles divided by 100 miles multiplied by 30 kWh). Dividing by 365 yields a needed 9.86 kWh per day. For Seattle, 3.57 solar radiation per day yields an effective 2.76 kWh (9.86/3.57). The PV panels have a conversion efficacy of solar radiation to electric power of 0.72. Dividing the effective 2.76 kWh by EF results in 3.84 kW array required to power one EV for an entire year. Therefore, if one wanted to power 100 EVs for an entire year, a 384 kw producing array would be required. Multiplying by the Bullitt Center production of 54.8 SF/kW results in a required 21,044 SF PV array for 100 EVs in Seattle. The project site footprint of 1,600 SF multiplied by 0.018 kW/SF from the Bullitt Center production results in a maximum solar production of 291.97 kW. Dividing this output by the area needed to power 100 EVs (384 kW), results in 76 EVs available to be charged for the average distance an American drives per year.

Bullitt Center Baselines	
Roof catchment area:	13,400 SF
PV production:	244.38 kW
	54.8 SF/kW (0.018 kW/SF)
Average EV Usage	
Energy required for 100 miles:	30 kWh
Average mileage of a car per year in America:	12,000 miles
Energy required for a full year of driving:	12000/100*30 = 360 kWh (9.86 kWh/day)
Effective PV Production	
Solar radiation per day in Seattle:	3.57 solar radiation per day
Effective radiation harvested for one day of required energy:	9.86/3.57 = 2.76 kWh
PV efficacy rate:	0.72 EF
Daily effective production required for one EV:	2.76/0.72 = 3.84 kW array
Required PV array production for 100 EVs:	3.84*100 = 384 kW
Required PV aray size for 100 EVs:	384*54.8 = 21,043.2 SF
Required PV aray production for project footprint:	16000 SF * 0.018 kW/SF = 291.97 kW
Number of EVs powered annually by project:	291.97/384 = 76 EVs

fig. 120 photovoltaic production calculations

A spreadsheet to calculate rainwater catchment provided by University of Washington Associate Professor Rob Peña was completed to optimize the size of the rainwater cistern for the project. First, the project footprint (16,000 square feet) and monthly rainfall amounts for Seattle (37.19 inches annually) provide baseline estimates of catchment yield (185,463 gallons) for a flat roof. Values for estimated water requirements given the use of the proposed building were referenced from Table 18.2 from Mechanical and Electrical Equipment for Buildings. Per capita daily usage is 10 g/cd multiplied by population of 50 (six EVs and 44 office employees) yields a 500 gallons of rainwater used daily. Multiplied by 365 days, estimated annual water need is 182,200 gallons. Assuming conservatively, that a "dry" year will have two-thirds the precipitation of an average year, the design precipitation is 24.8 inches (37.19 inches multiplied by two-thirds). Assuming a 75% retention rate of rainwater from the roof due to evaporation or spillage, the required catchment area to satisfy 100% of the annual demand is 9,814 square feet (182,500 gallons per year divided by 75% of the 24.8 design precipitation). However the cistern also needs to be large enough to store water for a dry period of 155 dry days, or days with negligible rainfall of less than 1/2 inch in Seattle. A 77,500 gallon cistern would be required for the daily usage of 500 gpd and 115 dry days. Finally using a conversion of one gallon to 7.48 cubic feet, the required cistern would need to be 10,361 cubic feet. Given climate, roof shape, effective capture area, and estimated fixtures and users, a conservative estimate of an 80,000 gallon rainwater collection tank would be required for the project.

Part I: Montly Rainwater Catchment

Month	Rainfall (in.)	Catchment Yield (gal)	Usage (gal)	Net (gal)	Cumulative (unlimited) water stored (gal)
January	5.38	26,830	15,500	11,330	11,330
February	3.99	19,898	14,000	5,898	17,227
March	3.54	17,654	15,500	2,154	19,381
April	2.33	11,620	15,000	-3,380	16,001
May	1.7	8,478	15,500	-7,022	8,978
June	1.5	7,480	15,000	-7,520	1,459
July	0.76	3,790	15,500	-11,710	-10,251
August	1.14	5,685	15,500	-9,815	-20,066
September	1.88	9,375	15,000	-5,625	-25,691
October	3.23	16,108	15,500	608	-25,083
November	5.83	29,074	15,000	14,074	-11,009
December	5.91	29,473	15,500	13,973	2,963
Annual	37.19	185,463	182,500		

Option 1: Find the amount of Rainwater Harvested from a certain roof size

Average Annual Rainfall	37.19
Design Rainfall (2/3 x ave. annual)	x 2/3
Catchment Area or Roof Size (see horizontal area of catchment - in square feet)	16,000
Total Catchment Yield (gallons)	185,463

Or use the chart above to estimate the total catchment yield

fig. 121 monthly rainwater catchment

Part II: Rough Sizing of a Cistern (see MEEB 10th page 861)

		1 - From Table 20.2, find the quantity of rainwater to be used daily:
g/cd:	10	g/cd x population = gpd
pop:	50	Service stations: 10 per car, 50% for recycling (6*10*0.5)
gpd:	**500**	
		2 - Convert this quantity to the yearly **need for water**:
gpd:	500	gpd x 365 days = gal/yr
days/yr:	x 365	(L/d x 365 days = L/yr)
gal/yr:	**182,500**	
		3 - Assume, conservatively, that a "dry" year will have two-thirds
ave.precip:	37.19	the precipitation of an average year; this measurement is the
	x 2/3	"design precipitation." (Average annual precipitation x 2/3 = design precipitation)
design precip:	**24.8**	(from http://www.wrcc.dri.edu/summary/climsmnca.html)
area (sq.ft.)	**9,814**	4 - Required catchment area to satisfy 100% of annual demand (75% retention)
		(Figure 20.5 - next worksheet - can also be used to estimate catchment area)
		5 - Roughly size the cistern (storage) capacity by estimating the
		dry period (in days of negligible rainfall, or less than 1/2 inch)
dry days:	155	(Seattle: 155 days with measurable rain)
capacity (gal):	**77,500**	cistern capacity = gpd x days of dry period
		6 - Convert capacity (gallons) to volume (cubic feet) by the formula:
gal:	77500	1 cubic foot stores 7.48 gallons of water
gal/cub.ft:	/ 7.48	
cubic ft.:	**10361**	Rough Size of Cistern
square ft.	**16,000**	7 - Actual roof Size or catchment area (from a roof plan of the building)

fig. 122 rough sizing of a cistern

TABLE 18.2 Planning Guide for Water Supply[a]

Building Usage	Per Capita (as Listed) Daily Usage Gallons	Liters
Airports (per passenger)	3–5	11–19
Apartments, multiple-family (per resident)	60	227
Bath houses (per bather)	10	38
Camps		
Construction, semipermanent (per worker)	50	189
Day with no meals served (per camper)	15	57
Luxury (per camper)	100–150	378–568
Resorts, day and night, with limited plumbing (per camper)	50	189
Tourist, with central bath and toilet facilities (per person)	35	132
Cottages with seasonal occupancy (per resident)	50	189
Courts, tourist, with individual bath units (per person)	50	189
Clubs		
Country (per resident member)	100	378
Country (per nonresident member present)	25	95
Dwellings		
Boardinghouses (per boarder)	50	189
Additional kitchen requirements for nonresident boarders	10	38
Luxury (per person)	100–150	378–568
Multiple-family apartments (per resident)	40	151
Rooming houses (per resident)	60	227
Single family (per resident)	50–75	189–284
Estates (per resident)	100–150	378–568
Factories (per person per shift)	15–35	57–132
Highway rest area (per person)	5	19
Hotels with private baths (two persons per room)	60	227
Hotels without private baths (per person)	50	189
Institutions other than hospitals (per person)	75–125	284–473
Hospitals (per bed)	250–400	946–1514
Laundries, self-service (per washing)	50	189
Livestock (per animal)		
Cattle (drinking)	12	45
Dairy (drinking and servicing)	35	132
Goat (drinking)	2	8
Hog (drinking)	4	15
Horse (drinking)	12	45
Mule (drinking)	12	45
Sheep (drinking)	2	8
Steer (drinking)	12	45
Motels with bath, toilet, and kitchen facilities (per bed space)	50	189
With bed and toilet (per bed space)	40	151
Parks		
Overnight, with flush toilets (per camper)	25	95
Trailer, with individual bath units, no sewer connection (per trailer)	25	95
Trailer, with individual baths, connected to sewer (per person)	50	189
Picnic		
With bath houses, showers, and flush toilets (per picnicker)	20	76
With toilet facilities only (per picnicker)	10	38
Poultry		
Chickens (per 100)	5–10	19–38
Turkeys (per 100)	10–18	38–68
Restaurants with toilet facilities (per patron)	7–10	26–38
Without toilet facilities (per patron)	2.5–3	9–11
With bar/cocktail lounge (additional quantity per patron)	2	8
Schools		
Boarding (per pupil)	75–100	284–378
Day, with cafeteria, gymnasium, and showers (per pupil)	25	95
Day, with cafeteria but no gymnasiums or showers (per pupil)	20	76
Day, without cafeteria, gymnasiums, or showers (per pupil)	15	57
Service stations (per vehicle)	10	38
Stores (per toilet room)	400	1514
Swimming pools (per swimmer)	10	38
Theaters		
Drive-in (per car space)	5	19
Movie (per auditorium seat)	5	19
Workers		
Construction (per person per shift)	50	189
Day (school or office, per person per shift)	15	57

Source: U.S. Environmental Protection Agency (1975).

[a]These values may be reduced as follows: with flow controls, up to 25% reduction; with water recycling, up to 50% reduction.

fig. 123 planning guide for water supply