Surviving the Coldest Capital:
Integrated Housing Approach in the Ger District of Ulaanbaatar

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Abstract

Surviving the Coldest Capital:
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This thesis will explore the existing socio-economical and environmental condition of Ger District of Ulaanbaatar and well understand the key needs of the people, and suggest an architectural solution to solve the ongoing issues that the Ger District residents have been experiencing for years. The design insight of this thesis project mostly relies on architectural strategies rather than technological methods to solve the current environmental, social, and infrastructural problems. Vision for this project is to be used as a design guideline for the future development that suggests an integrated, sustainable, and climate friendly housing method that also addresses and fulfills the socio-cultural needs of the local residents.

SURVIVING THE COLDEST CAPITAL

INTEGRATED HOUSING APPROACH IN GER DISTRICT OF ULAANBAATAR

CONTENTS

INTRODUCTION

The geographical location and the extreme climate conditions of Central Asia formed the unique nomadic lifestyle on the highlands and extended steppes of Mongolia for thousands of years. Such nomadic heritage and cultural backgrounds have been thriving in the society yet constantly influencing the lifestyles of nomadic people for generations. However, in the last few decades, the rapid migration trend toward the urban center has formed especially within the younger generation of nomadic herders in pursuit of better living conditions, higher education, and financial advantages. This increased movement from the countryside to the urban city over the years has affected the nation's capital city, Ulaanbaatar, in numerous ways including overpopulation, lack of housing, insufficient public services and infrastructure.

Ulaanbaatar (UB), the capital city of Mongolia is the single largest city of the nation. Characteristically, Ulaanbaatar is a vibrant, modern city aspiring to be one of the trade / tourism hubs of the region, but still holds its traditional nomadic charm as well as the buildings of the Soviet Era. However, parallel to the Ulaanbaatar's ambitions, the city is struggling with the ongoing built environment challenges due to the extreme population growth. The city's population has increased around 70 percent

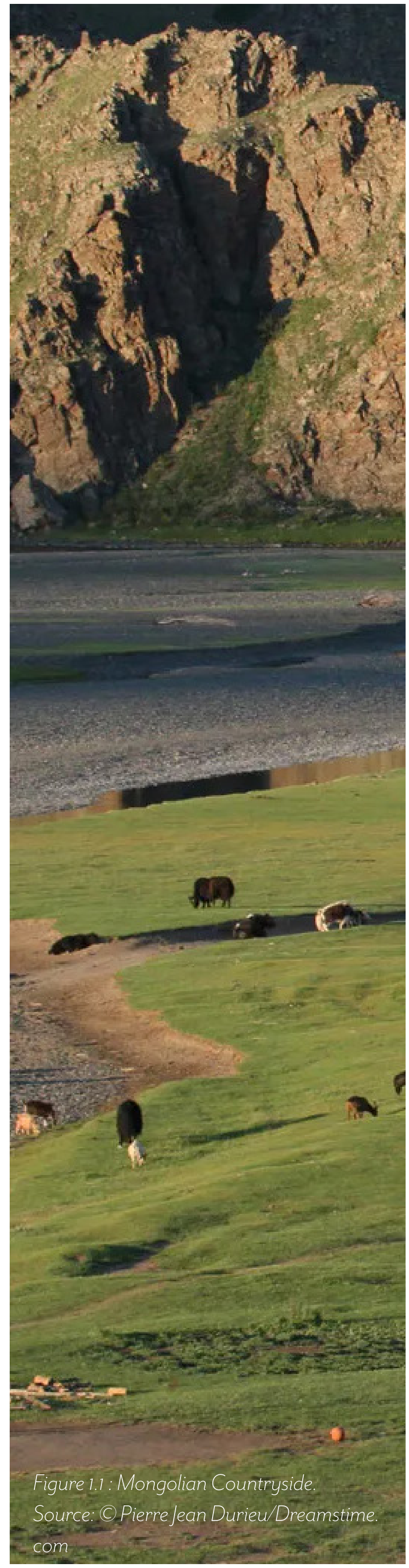


Figure 1.1 : Mongolian Countryside. Source: © Pierre Jean Durieu/Dreamstime.com

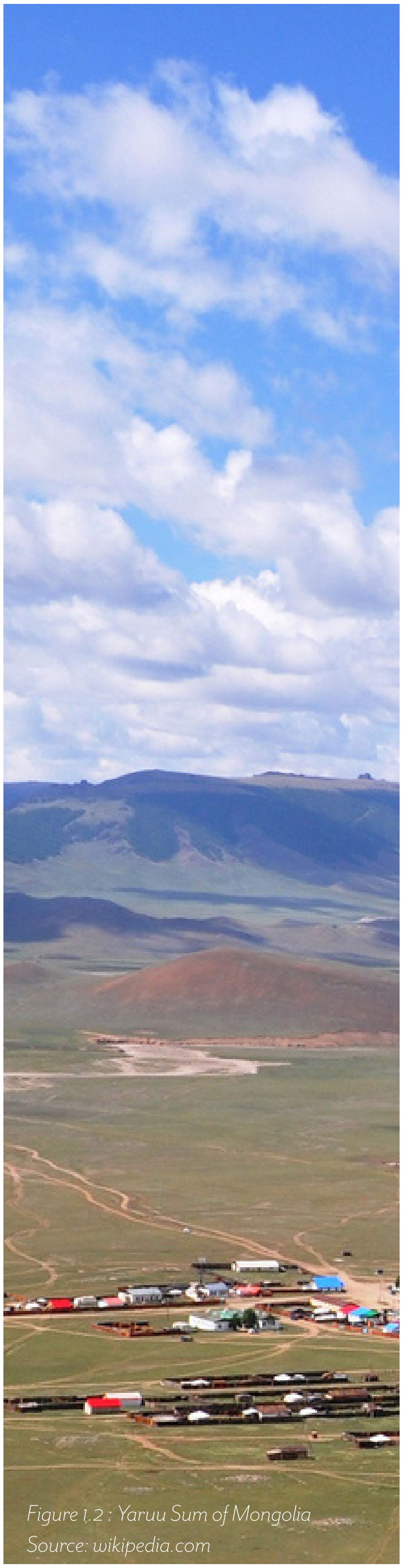


Figure 1.2 : Yaruu Sum of Mongolia
Source: wikipedia.com

in the past 20 years and the total administrative area of the city is now 5 times larger than its original plan. While more than 65 percent of the whole country's population lives in Ulaanbaatar (1.7 million), approximately 60 percent of this population still live in peri-urban small settlement areas also known as Ger (Yurt) Districts. Ger districts critically lack basic infrastructures that include sophisticated heating systems, fresh water access, sanitation facilities, paved roads, and public transportation. Because of these infrastructural insufficiency, the wellbeing of hundreds of thousands of people are directly impacted by the severe environmental pollution.

Thus, the main goal of this thesis project is to well understand the key needs of the people of Ulaanbaatar, and suggest an architectural solution to solve the ongoing issues that the Ger District residents have been experiencing for years. This project mostly relies on architectural strategies rather than technological methods to solve the current environmental, social, and infrastructural problems. The vision for this project is to be used as a design guideline for the future development that suggests an integrated, sustainable, and climate friendly housing method that also validates and addresses the socio-cultural needs of the local residents.

GER DISTRICT

The Ger District (Ger Khoroolol) surrounds the built urban area (Downtown Ulaanbaatar) and is characterized by low density non-aligned fenced property streets that have informal housing structures consisting of traditional felt yurt and small detached houses. Migrants from the countryside or a province center typically claim an empty lot, install a fence that is regulated sized (0.7ha) and build a ger or a detached brick house. According to the survey taken by the World Bank Task Team in 2009, more than half of the residents of the ger district said they were not satisfied with the housing situation with lack of privacy, and lack of kitchen space. However, according to the same survey, more than 90 residents expressed their frustrations for the lack of public infrastructure that includes water supply, drainage, road access, neighborhood safety, and basic sanitation. In terms of preferred dwelling types, 65 percent of the residents responded they would prefer to modernize the dwellings either into integrated housings or apartment complexes. The government has been taking actions to build new apartment complexes to accommodate the residents of ger district, however facing the financial and resource constraints the modernizing effort has been much slower than the demand.

Figure 1.4: Ger District Area. Source: GIS Library of Ulaanbaatar

Figure 1.3 : View of Ulaanbaatar, Mongolia
Source: Reuters/B. Rentsendorj

CHAPTER 01: PEOPLE AND PLACE

PEOPLE

The socio-economic conditions of ger district are significantly different from the urban area in that the households are larger, less educated, and financially challenged or even reliant on social services. The average size of a single household in the ger district is 4.5 where the average household in the urban area is merely 3.2. The 2016 Household Socioeconomic Survey reported that approximately 55 percent of the ger district population migrated from outside of the city and of those migrants' 93 percent were either herders themselves or children of the herders. According to the National Statistics Office's 2021 report, the average age of ger district residents is 27.9 which is 6.3 years younger than the urban population with the average age of 34.2. Age distribution in ger district is also significantly young that slightly more than half of the population is under the age of 30.

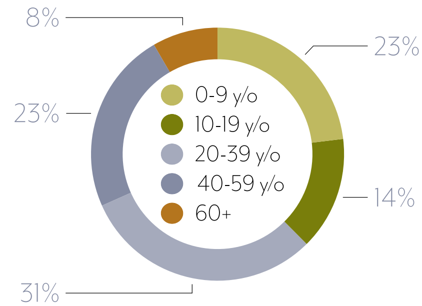


Figure 1.5: Ger District Age Group.
Data source: Statistics Office of Ulaanbaatar

With their lack of education and financial disadvantages, finding a job is quite difficult as only 51 percent of the residents are employed compared to the national employment average of 72 percent.

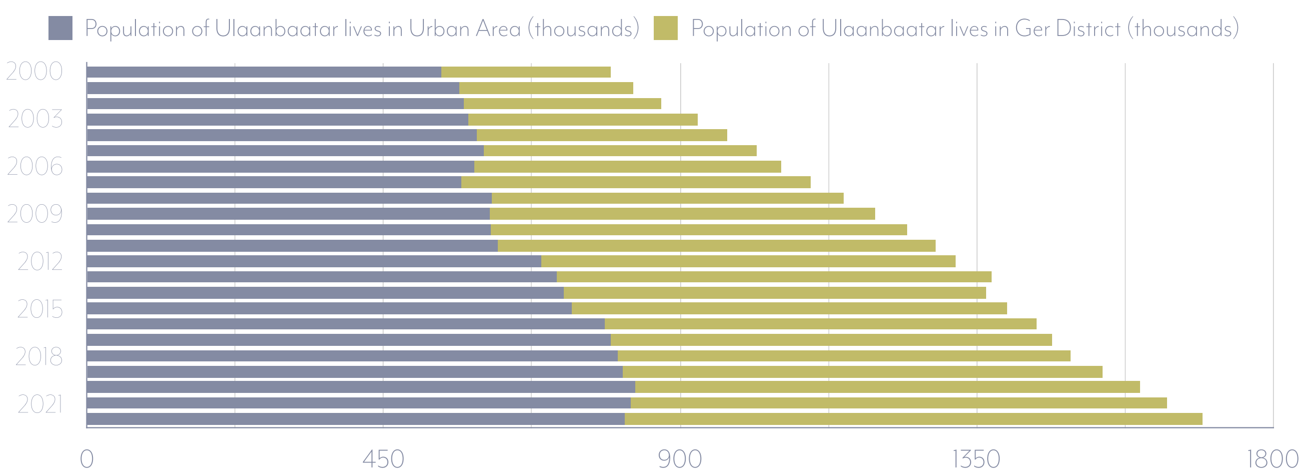


Figure 1.6: Population Growth of Ulaanbaatar 2000 -2021
Data source: National Statistics Office of Mongolia

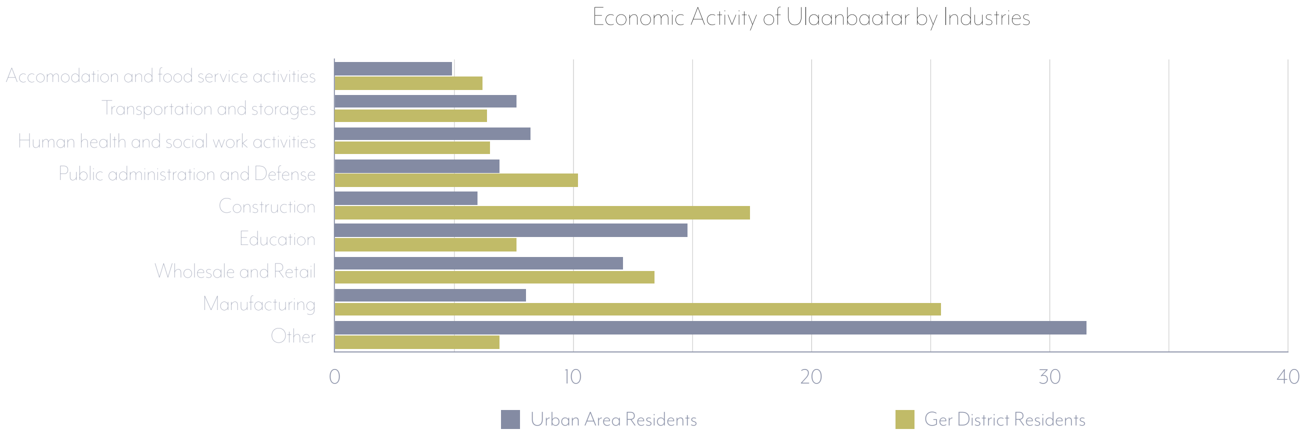


Figure 1.7: Ger District Economic Activity
Data source: Statistics Office of Ulaanbaatar

According to the National Statistics Office of Mongolia (NSO), of those employed people who live in ger district, 30 percent work in the construction and manufacturing field, 12 percent in wholesale and retail field, 11 percent in trade and repair, and followed by 10 percent in public administration. Most of those workers in manufacturing, trade, repair, and retail asked to work longer hours, yet their job site is located far away from their home. The lack of public transportation and road access makes the situation even more challenging that taking care of their children and elderly members of their family almost becomes nonexistent.

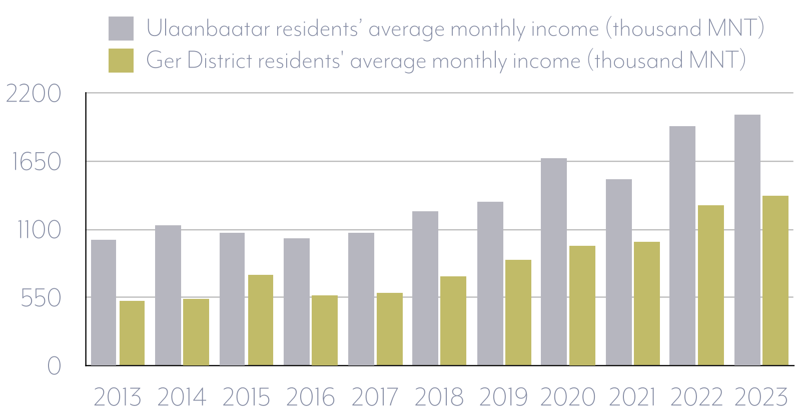


Figure 1.8: Monthly Income. Data source: Statistics Office of Ulaanbaatar

The contrasted income distribution in Ulaanbaatar further shows the unbalanced socio-economic status of ger district residents. Median household income in ger district in UB is 1,425,800 MNT ($413 USD) which is at 32% less than the urban area households. Even the 80th percentile income household in the ger district makes 17% less than the average urban household.

PLACE

Infrastructures in the ger district are severely insufficient in numerous different categories including heating and air ventilation systems, waste management, water supplies, and even in some areas - electricity is limited. Currently, more than half the households receive their water through 550 public kiosks across the districts.

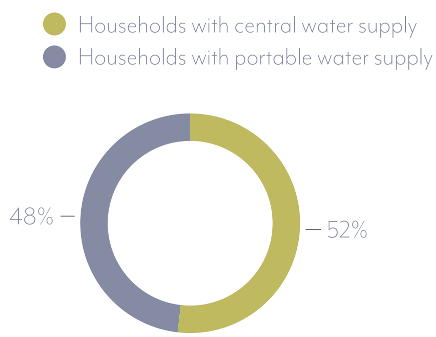


Figure 1.9: Water Supply Access
Data source: Statistics Office of Ulaanbaatar

According to "Managing Urban Expansion in Mongolia : Best Practices in Scenario-Based Urban Planning, World Bank Publications" by Takua Kamata, currently more than half of these public kiosks are supplied by water trucks that limits the capacity of the kiosks and further struggling to meet the increased demands of the residents. Residents travel up to half a mile to access these kiosks that follow the schedule of 10:00am - 7:00pm. Although it is ponderous to carry 15-30 gallons of water from kiosks to their homes at least a few times a week in an extreme hot / cold climate, residents are concerned more about the other problems including lack of solid waste management, sanitation facilities, and wastewater drainage.

Figure 1.10: Water Containers on trolley

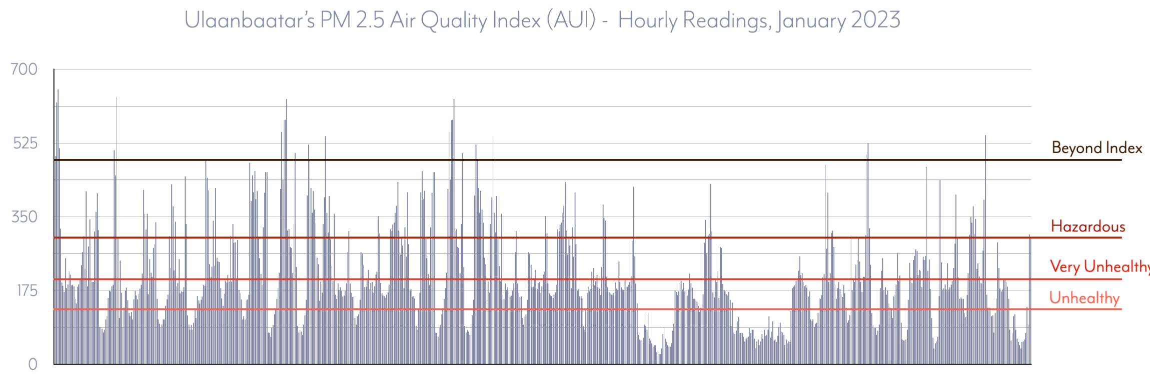


Figure 1.11:Air Quality Index of Ulaanbaatar. January, 2023

On the other hand, the air pollution in Ulaanbaatar has been affecting its entire population for the last few decades. It has become alarmingly unhealthier day by day as newcomers migrate into the city and increasing the population who uses coal burning stoves to survive the cold winter in the city. According to the World Bank's published book "Air Quality Analysis of Ulaanbaatar: Improving air quality to reduce health impacts", The main sources of ground-level air pollution are coal and wood burning for heating of individual residences in ger areas and the suspension of dry dust from open soil surfaces and roads, representing 75–95 percent of PM concentrations. The annual average concentration of PM 2.5 particulate matter in the Ger district is 200-300 µg/m3 where the World Health Organization states any amount exceeding 150 µg/m3 is unhealthy for the general population. During the winter, the PM particulate measures at alarmingly high levels that some days range in-between 3,612–4,360 µg/m3. Moreover, even during the cold winter months, the intraday range of PM fluctuates and the peak smoke hour falls during the dinner time where the majority of the people either cook or come back from work and heat their home.

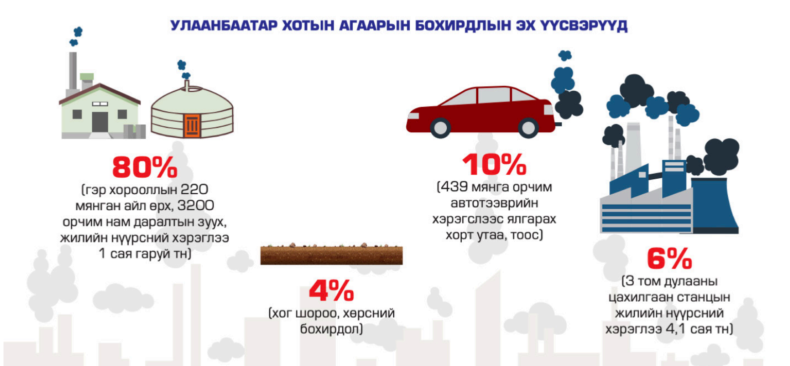


Figure 1.12:Air Pollution Sources. Source: Agaar.mn

The climate in Ulaanbaatar is an extreme steppe climate with elements of desert climate characteristics combined with subarctic regions. There are four distinct seasons with great high and low temperature fluctuations throughout the day, low humidity, low precipitation, and the high altitude of 4140 feet above sea level. Particularly for Ulaanbaatar's climate, the winter duration is rather longer than the fall and spring seasons where the average temperatures get below zero Fahrenheit from November to February. Influenced by the harsh continental climate, Ulaanbaatar gets little to no precipitation during the winter and receives more than 70% of its annual precipitation from May to September.

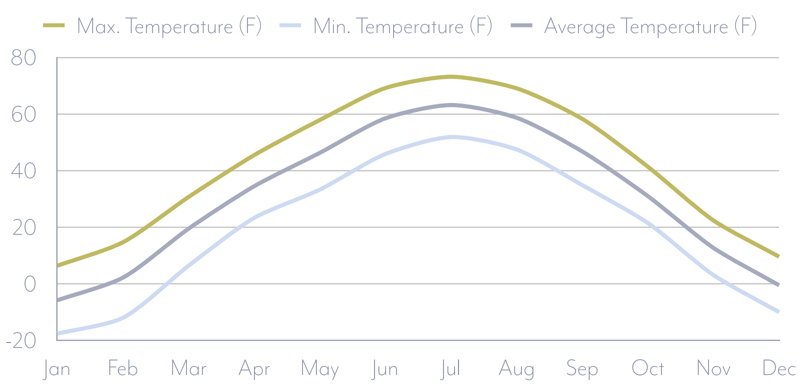


Figure 1.13: Annual Temperature of Ulaanbaatar

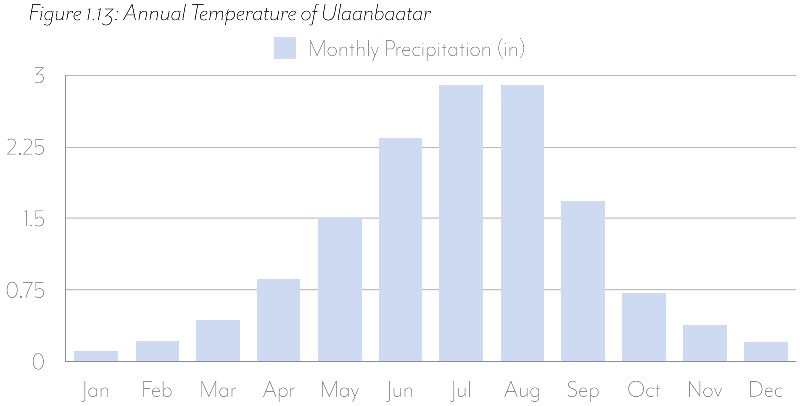
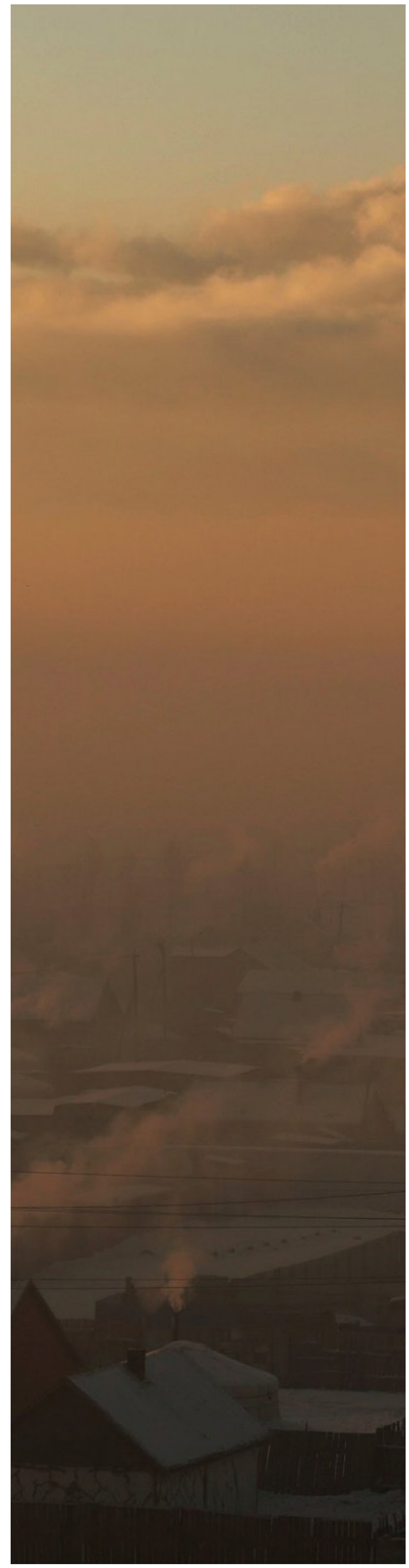


Figure 1.14: Annual Precipitation of Ulaanbaatar



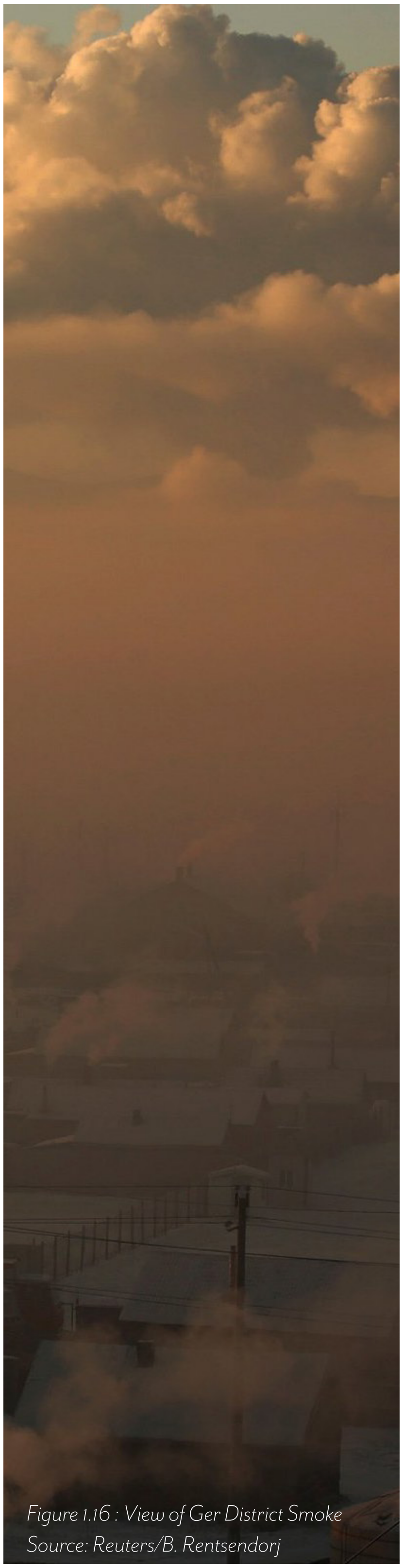


Figure 1.16 : View of Ger District Smoke
Source: Reuters/B. Rentsendorj

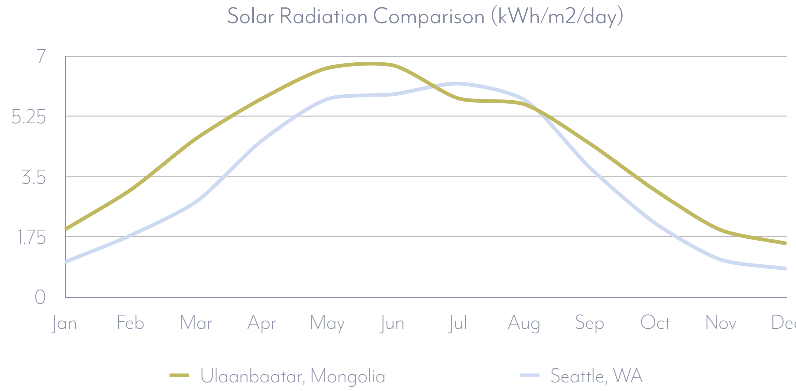


Figure 1.15: Solar Radiation Comparison. Ulaanvaatar vs Seattle, WA

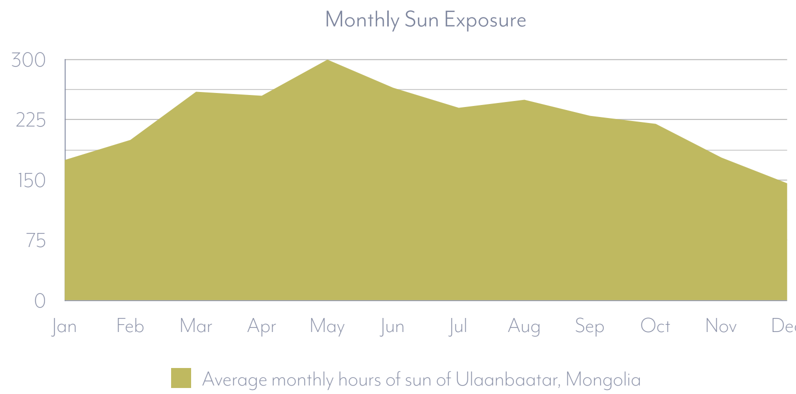


Figure 1.16: Monthly Solar Exposure of Ulaanbaatar

Although the temperature is extreme and Ulaanbaatar experiences freezing winters, it receives an abundant amount of solar exposure throughout the year. Average monthly sun exposure is 218 hours per month. At the least, in December it receives about 149 hours of sun and during the peak it receives up to 300 hours of sunlight.

Compared to Seattle, WA which is located on the same latitude as Ulaanbaatar (47 Degrees North) Ulaanbaatar receives approximately 15-20% more sun exposure than Seattle. Overall, these environmental factors simply makes Ulaanbaatar a prime candidate for solar energy development yet solar energy could play a major role in meeting the city's growing energy needs.

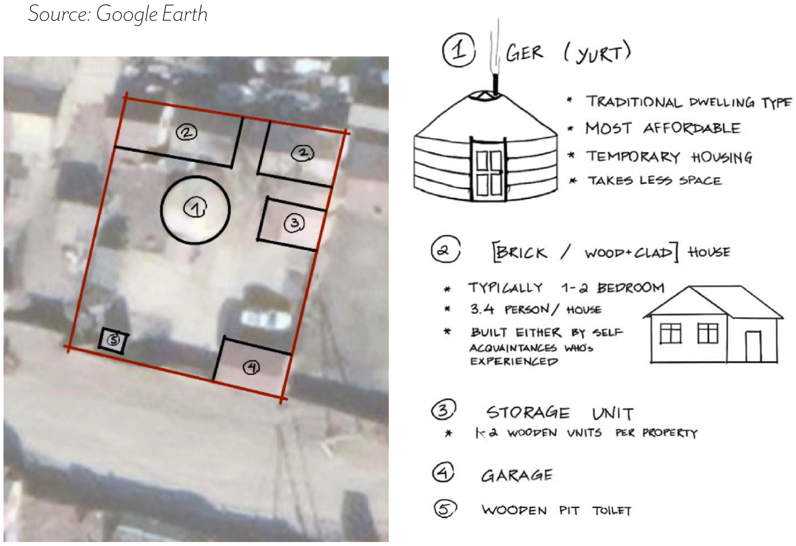
CHAPTER 02 : CONCEPT AND FRAMEWORK

CULTURALLY ADAPTIVE DESIGN

The geographical location and the extreme climate conditions of Central Asia formed the nomadic lifestyle on the highlands and extended steppes of Mongolia. The ever-moving lifestyle of livestock herders were directly influenced by the limited water and natural resources around the year. In search of food and shelter from the extreme temperatures, the migration occurs seasonally throughout the land. Bold argues in his article "Socio-economic segmentation -

Khot-Ail in nomadic livestock keeping of Mongolia" the specific need of migration demands the certain social organization of herders to overcome the natural challenges for hundreds of years. These groups were called "Khot-Ail" which consisted of livestock herding families mutually supporting each other with necessary labor, equipment, and knowledge. Although the concept of "Khot-Ail" started as a group of families coping with the harsh climate, it also formed a social setting of living in a group while sharing and supporting each other. This specific characteristic from nomadic heritage lasted for generations and still is present within the social environment of modern Mongolia.

Figure 2.1: View of Ulaanbaatar, Mongolia
Source: Google Earth



Regardless of the nomadic lifestyle once the herders had in the countryside, the ger district dwelling compound in the urban city environment has become quite different from the traditional "khot-ail". The typical walled compound unit in the ger district consists of a yurt, informal settlement, storage or garage unit, and wooden pit. Majority of the compounds have two or more dwellings within their walls yet residents typically live with their extended families or relatives.

CLUSTER HOUSING:

Cluster housing or Cohousing is a typology that is strongly characterized by its sense of community, shared resources, and tight knit social relationship. Globally cohousing takes various forms from multi-unit buildings to single family homes with shared common areas and community amenities.

In this thesis, I'll be exploring the practical yet potential version of clustered housing typology that would fit in my chosen site location. McCamant, Kathryn, and Charles Durrett's book "Creating Cohousing : Building Sustainable Communities" details the characteristics of cohousing, different approaches to cohousing and addresses the cohousing communities across the world. In the chapter "An Old Idea - A Contemporary Approach", the authors specifically highlight the contemporary versions of cohousing communities that have a balanced privacy and communal space in the modern world. While cohousing still maintains a number of advantages of the traditional community, the design still adapts into the ever-changing modern way of living (McCamant, Kathryn, and Charles Durrett, 2011).

In his book "A Pattern Languages", Christopher Alexander wrote "People need support and confirmation from people who have reached a different stage in the life cycle, at the same time that they also need support from people who are at the same stage as they are themselves" (1977).

Figure 2.2: Orkhon Valley. Source: AudreyTravels.com

Environmental Benefits of Cluster Housing

One of the impactful advantages of cluster housing is their environmental benefits that includes the shared resources, reduced energy consumption, and reduced land use. Jingling Yang's book "Cohousing Communities: Designing for High-Functioning Neighborhoods" specifically addressed the high functionality and resource sharing benefits in its chapter "What Components Lead to High-Functioning Neighborhoods?. The effective site plan certainly is considered as one of the focus of this thesis' design proposal which then would form a strong neighborhood relationship while saving the land. Land conservation not only economically benefits the community but more importantly it would reduce the need to clear the natural habitats for housing development that effectively impacts the biodiversity within the urban realm (Yang, 2022).

Another benefit of cluster housing communities is the increased energy efficiency of the individual homes. By sharing the common spaces and resources residents of the cluster housing community could reduce their energy consumption significantly. The proximity of the cluster homes allow easier implementation of renewable energy systems including solar panels. Living in close proximity to one another encourages the residents to adopt a shared / carpooling mode of transportation which then would benefit the community environmentally but also economically.

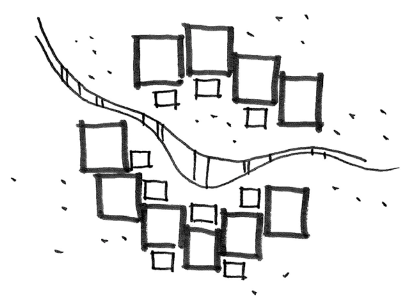
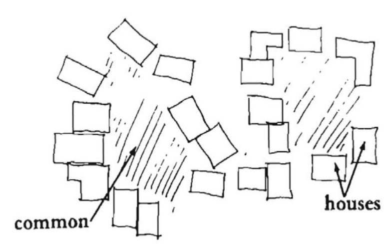


Figure 2.3: Cluster Homes Sketch



Social Benefits of Cluster Housing

One of the strong characteristics that defines the cohousing typology is the community collaboration and sense of belonging.

McCamant, Kathryn, and Charles Durrett have emphasized the importance of design decisions that encourage the social encounters and further development of the community bonding which this thesis will address and primarily focus on during the design phase. Guity Zapata, Nestor Agustin, and Wendy M. Stone addressed the social impacts and benefits of cohousing communities in their article "Home Motivations and Lived Experiences in Housing Cooperatives and Cohousing Communities: a Two-Contexts Scoping Review." According to the article the shared open spaces in cluster housing developments specifically serve as a gathering place for neighbors to socialize and interact with one another which can lead to increased social capital (Guity Zapata, Nestor Agustin, and Wendy M. Stone, 2022). The term social capital has been linked to a number of positive outcomes, including increased civic engagement, better mental and physical health.

On the other hand, Alexander emphasized in his book "A Pattern Language" that present housing types and patterns seemed to keep different demographics of society segregated from each other. Studio and one bedroom apartments near the urban center attracts young professionals while 3-4 bedroom single family homes in the suburban area attract families with children while 2 bedroom houses in quieter neighborhoods attract older generations.

CLIMATE RESPONSIVE DESIGN

PASSIVE SOLAR HOUSING

The concept of passive solar housing requires a clear understanding of the relationship between the building orientation and heat absorbing mass in the building. The nuance between the thermal mass - a thick heat absorbing wall and the glazing - south facing windows to let the solar heat penetrate into the home. Finding the right amount of glazing to collect the heat during the colder days while balancing the adequate solid walls to prevent the overheating during the hot summer days is emphasized yet explained in detail in Daniel D. Chiras' book "The Solar House". Every piece of design elements in the house could contribute to its solar heating performance while also contributing to the overall quality of the indoor life of the residents. James Kachadorian in his book "The Passive Solar House" highlights "A home must be comfortable in summer as well as winter".

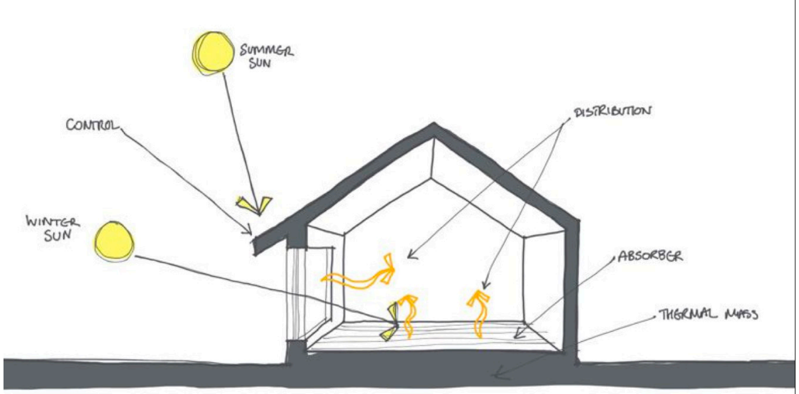


Figure 2.4: Passive Solar House Diagram

A south window could indeed collect much needed sunlight during the clear day on a winter day while also providing the surrounding view and natural connection. However it is crucial to consider that glazing could also be an element that leads to heat loss during the winter. In the summer, operable windows could play an important role in indoor air circulation that cools the space, but there is a downturn of overheating through the window glazing. Thus learning the surrounding environment, landscape, and the site of the house while carefully orienting the building suitable for solar heating are essential principles of passive solar housing - in other words integrated housing (Chiras, 2002).

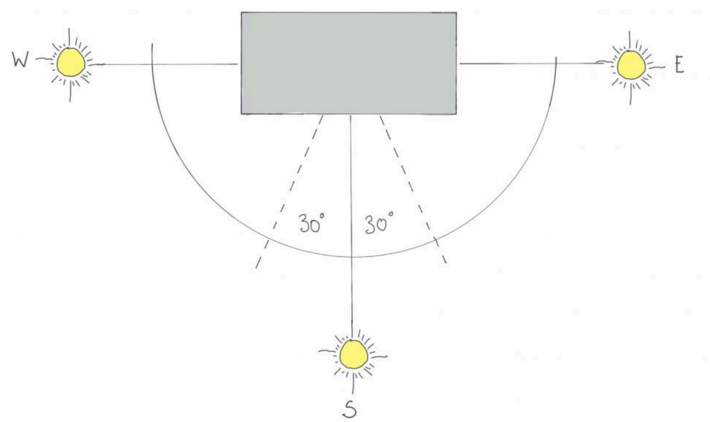


Figure 2.5: Solar Orientation Diagram

Orientation of the Building

In order to "store the sun's free heat for nighttime use", the building site needs to be carefully chosen for the maximum effectiveness. In an ideal situation, the south facing facade would collect most of the solar heat from the sun yet the north facade could be either a thermal wall or window that faces an evergreen tree or a hillside to protect the building from the harsh north wind. Orienting a house to the south means orienting its longer axis east and west so that the house would get maximum solar exposure. Thus the overall shape of the building is ideally with a rectangular floor plan with 1:3 to 1:5 ratio.

Chingeltei District's 13th khoroo (subdistrict) is located at 47 degree North, 106 degree East on a slope of a hill facing to the south, an ideal location and orientation for passive solar housing. Regardless of its south facing slope, the site is still considered as challenging to build a passive solar building with its extreme climate.

Ulaanbaatar's weather is directly affected by its high mean altitude of 4430ft, and land locked sub siberian topographical location. The temperature extremes range from -43C (-45F) during the winter to +43C (+110F) during the summer. The annual average temperature is 0.7C (33.4F) compared to the earth average of 14.4C (57.9F) (Sabloff, 2011). With its high altitude, the daily temperature fluctuates significantly in Ulaanbaatar ranging from 10-20C low to high.

Window Location, Glass to Floor Ratio, Solar Shading

As noted earlier, the solar collectors on the south facade (windows and patios) is an essential part of the passive solar home. During the winter times, when the sun angle is low the sunlight potentially could reach up to 20 ft into a house which could significantly impact the interior thermal performance. Although it is crucial to have an adequate amount of windows and glazings to reach the ideal interior temperature, finding a balanced amount is equally important to prevent overheating in the summer. South facing glass ranges from 7-12% of the total floor space depending on the site location and orientation. The three types of passive solar design includes: direct gain, isolated gain, and indirect gain.

Direct Gain - It is the most used passive heating strategy which involves a straightforward approach with direct south facing windows to let low angles solar exposure penetrate into the house. Then the sunlight could be absorbed by the thermal wall and floor to later heat up the space. Depending on the climate, the direct solar gain system could provide 50%-80% of the annual heat requirements. The overhang for the direct gain windows needs to be properly sized that allows winter sun to openly penetrate into the house while blocking the higher angled summer sun. To determine the length of the overhang projection, the following formula is used:

L (length of projection) = H (height of the window opening / F (f factor depending on the latitude)

* For Ulaanbaatar the F Factor is 2.0-2.2

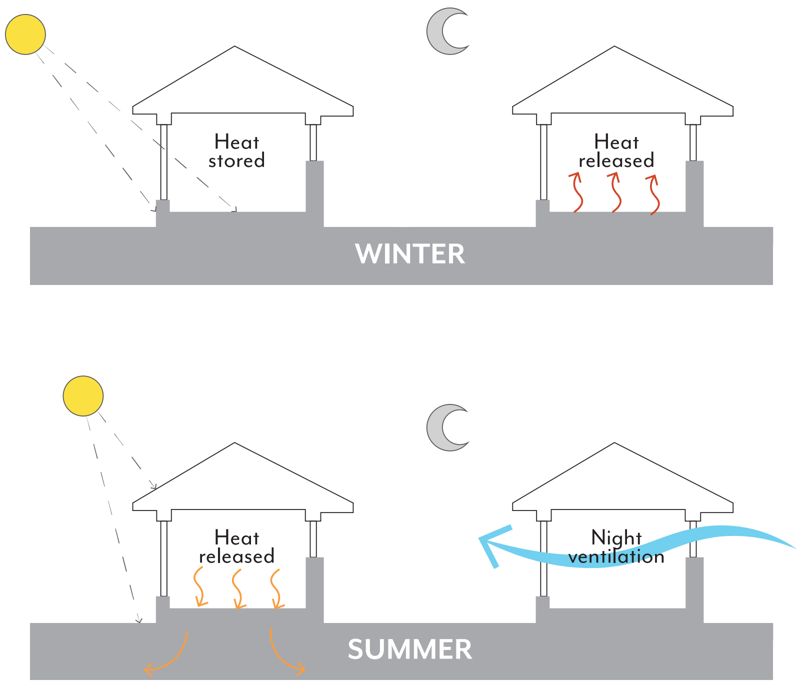


Figure 2.6: Passive Solar Principles Diagram

Thermal Mass

Simply put, thermal mass in a passive solar house is considered to be any dense material that absorbs and stores heat. According to Daniel D. Chiras' Fundamentals of Integrated Passive Design chapter, there are two main types of thermal mass that can be found in homes including free mass and intentional mass.

The first type is the structural components that were not intentionally placed or designed but still absorbs heat and functions as a thermal mass anyway. The second type is intentionally incorporated into the design that strategically absorbs heat from the sun. Brick, concrete, and concrete blocks are majorly used as a thermal mass, but earth materials can also perform as an adequate variation. For many years, thermal mass' color was optimally darker colors to maximize the heat absorption, however, designers and architects have started to rethink this concept and have been introducing light colored walls and ceiling to reflect sunlight and distribute it evenly throughout the space.

PASSIVE HOUSE

Passive House (Passivhaus) is a standard and a certain design technique that could be applied for various housing types, sizes, and climate zones. The central focus of the passive house is to deliver a thermal comfort to the indoor space majorly by means of insulation and building envelope.

Design concept of the passive house originated from the Icelandic people where they used very thick turf walls and turf roofs to insulate their homes to face the Icelandic winter temperatures. From the 1960's and onwards designers and engineers actively researched on the possibilities to replicate this passive performance in different climates and cultures. In his book An Introduction to Passive House, Justin Bere extensively explains the beginnings of passive houses in the architectural industry and mentions the "Pilot Passive House Building". He further introduces the project in Darmstadt Kranichstein, Germany where Dr.Feist brought together a group of architects to develop a building that has "efficient heat-recovery ventilation unit, specially insulated window frames and blinds, integrated connection of building components, and solar heating technologies" (Bere, 2019).

According to the study and the pilot program that was conducted in 1991, with the efficient heat-recovery ventilation and air tight insulation, the building's energy consumption was measured below 10W/m2 which is 90% lower than the German Building

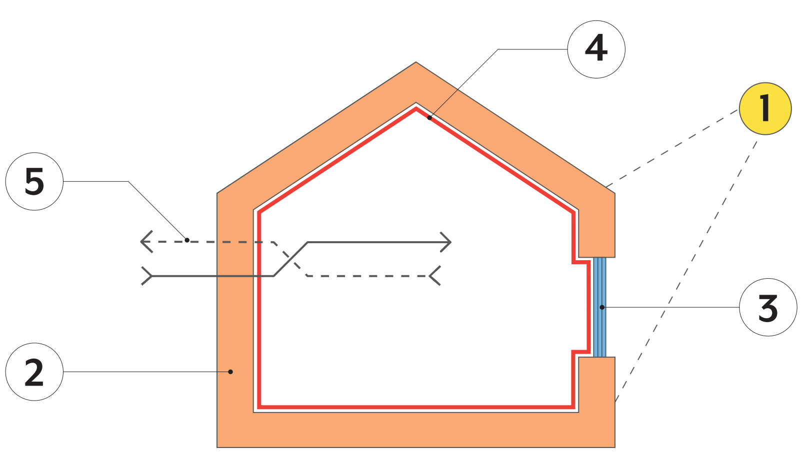


Figure 2.7: Passivhaus Diagram

1. Solar Exposure
2. High Insulation
3. High Insulated Windows
4. Airtight Enclosure
5. Balanced Ventilation

Code of 1995 and almost required no heating instrument at all (Bere, 2019). While a passive house is not a building standard or a certification criteria, it is primarily a technical design method to maximize the building performance.

Justin Bere then listed the Key elements of the passive house in his book:

Insulation

External insulation is a critical component of a passive house as well as the typical wall insulation. The thickness of the insulation panels are quite thicker than the normal building insulation where external insulation ranges from 200-400mm thick and interior insulation needs at least 100mm of insulation. The breathable insulation made out of wood or mineral fiber with weather membranes can be considered as appropriate insulation in an extreme climate with both hot summer and cold winter.

Draught-free construction

Draughts can significantly impact indoor comfort and waste a great amount of the interior heat that was generated. Especially in the passive house, any amount of draught, even a slight leak can be regarded as potential risk to the building performance. It is the responsibility of both architects as well as contractors to carefully check the "airtightness" of the building during construction. The first air test is required right after the windows and doors are installed in order to avoid further complications, and delay of the construction due to air-seal repair.

High-performance windows and doors

The high performance windows in passive houses are usually triple glazed windows that need to be installed correctly and draught-free in order to eliminate any risks of condensation, heat-loss, and mold growth. Windows in passive houses are also designed to maximize the solar heat gain to help interior space to warm up naturally in colder seasons. Thus triple layered glass windows play an essential part to collect solar heat even during the overcast winter days. Summer shading is also necessary in the design that protects the building from overheating during the summer heat as well as the warmer winter days' afternoon sun.

Heat-recovery ventilation

Heat recovery ventilation system provides the essential fresh air into the domestic space without causing condensation and draughts risks by limiting the needs of opening the window for fresh air. Well installed heat recovery system could potentially save approximately 90% of the heat in the stale air extracted from the bathrooms and kitchen by putting it back to the air supplier and avoid releasing "precious" heated air back to the outside. There are also potential improvements of indoor air quality in an urban polluted environment by limiting direct air circulation from the outside where air is already polluted by PM 2.5 particles.

URBAN ECOLOGY

In order to explore urban ecology and surrounding ecosystems, it is crucial to understand the ever-growing migration to the city - in other words the urbanization. In the last 300 years of world's history, the concentration in urban settlement has dramatically increased. The population living in the urban environment jumped from 12% to 89% in the last few hundred years.

Marzluff further explains the motives of urbanization and the urban ecological systems in his book "Urban Ecology: An International Perspective on the Interaction Between Humans and Nature". Industrialization and technological advance has significantly impacted the movement from farmland to the urban city, and the economical advantages of living in the city has also increased tremendously. Ernest Burgess then explains in his chapter "Urban Ecology: An International Perspective on the Interaction Between Humans and Nature" that the expansion of the urban area will continue with the urbanization trend which further develops the urgent need of "re-creating" or "re-imagining" the tissues of natural elements within the city.

Figure 2.7: Urban Farming Concept

"The Loop" the land use zoning concept that radially expands from the central business district to further into the suburban residential area was widely used for many western cities (Marzluff, 2008). Advantages of such planning was that depending on the location there are clear distinctions between the different land uses and their ecologies. In the city center, there usually are large public parks while in the residential districts there are smaller parks and diverse green areas that accommodate the population.

Local Urban Environment in Ulaanbaatar, Mongolia

The global rural to urban migration trend indeed has not gone around Ulaanbaatar as the city has tripled its population from 500,000 to 1.5 million in less than two decades. In his book "Managing Urban Expansion in Mongolia: Best Practices in Scenario-Based Urban Planning" Takuya Kamata details that along with the global trend, the harsh winter of Mongolia resulted in large scale migration of low-income herder families into the ger district of Ulaanbaatar.

The sudden yet dramatic increase in the population has critically affected not only Ulaanbaatar's infrastructure but also the urban ecosystem. According to Kamata the basic services are quite limited and nearly non-existent in the ger district that 85% of the population use wood and coal burning stoves for the heating and drinking waters are only accessible at the public water kiosks that are located scarcely throughout the ger district (Kamata, 2008). Poor urban services have also led to environmental degradation, including the severe air and soil pollution that directly affects the urban well-being and poses health risks for the population.

Cold Climate Ecology

In cold climates, the unique challenges of urban ecology include dealing with harsh winter conditions, managing limited resources, and balancing the needs of both human and non-

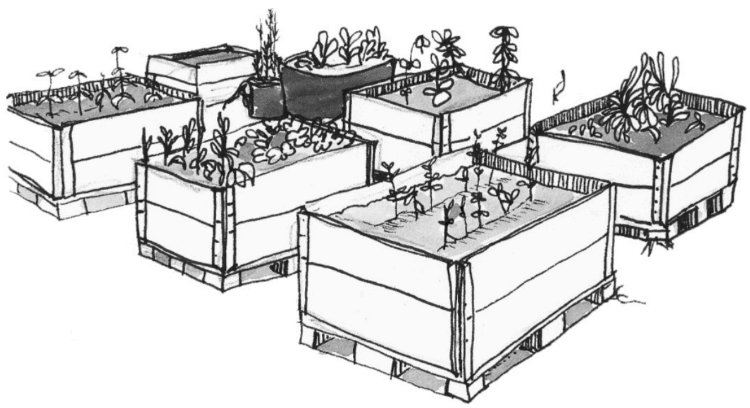


Figure 2.7: Farming Bed Concept Sketch

human residents. One of the key challenges of cold climate ecology is the limited ability of plant survival that majority of the species that are well-suited to warmer climates may not be able to survive in cold climates, and urban planners are faced with the challenge when designing green spaces. In his book "Dryland East Asia Land Dynamics Amid Social and Climate Change" Jiquan Chen highlighted the short growing season in the extreme climate of Mongolia that makes the urban landscape process even harder to establish the greenery and maintain it throughout the year. Indeed the long and cold winter of Mongolia can make it difficult for plants and animals to find food, and urban areas may not have enough resources to support large populations of wildlife. However, despite the challenges, it is important to maintain the primary focus on the benefits of green spaces in the urban area that provide habitat for wildlife, regenerate the ecological balance, and improve well-being of the city population.

Water Systems

It is certain that water "runs through" the core of urban ecology that its flow shapes the urban landscape and the major water infrastructure directly influences the health and well-being of the urban ecosystem. Continuous flow of the drinking water usually gets piped into the urban area while urban residents "transform" the fresh water into the wastewater down into drains. In "Urban Ecology:Science of Cities" especially in the chapter Urban Water Systems, Richard T. T. Forman explains the urban water cycle. Specifically the relation between surface and groundwater in the urban areas and how this water cycle directly affects the ecology with over-pumping the groundwater while not recycling the potential water resources (Forman, 2014).

Worldwide most cities get their fresh water supply from reservoirs and some get from a lake, river, stream or a deep groundwater. Surface water supply almost comes from upslope or upriver of the city by avoiding the risk of contamination from the city activities. In "Urban Ecology" by Kevin J. Gaston, he looks into the global practices of fresh water supplies into the urban areas and suggests a new perspective of fresh water "treatment".

The aquatic ecosystems of the city deeply depend on the water tanks and pipes and generally prefers to have an underground infrastructure system that accommodates the continuous flow of fresh water. Unfortunately, having pressure pumped pipes that contain filtered and sanitized drinking water is not always the case for people in developing countries' urban areas.

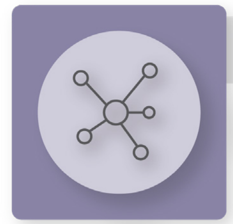
Wastewater Management

In many developing countries and their cities and even some outer urban areas of the western world the wastewater usually passes through the septic systems and later lets out directly into the ground. These specific urban actions can heavily impact the urban groundwater quality and even cause serious contaminations if not treated properly. High density areas are usually served by a treatment facility, however a lower density area or an isolated neighborhood could be served by either a small government-maintained sewage treatment system or handle the wastewater on-site (Forman, 2014).

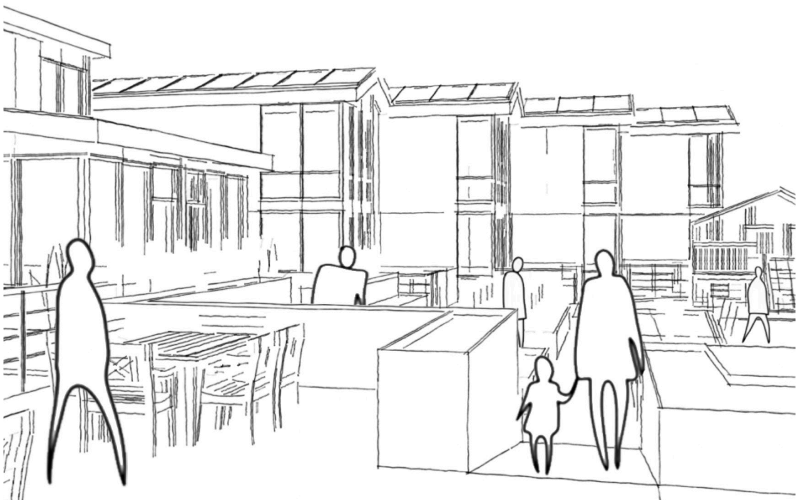
The septic system is designed to provide on-site waste treatment that convert wastewater from toilets, basins, and sinks into the simple stable end product that contains inorganic compounds after eliminating the bacteria and breaking down the organic matter (Gaston, 2010). Although the septic system significantly reduces the environmental impacts of human waste, it is crucial to make sure the existing site is appropriate for septic tanks and does not have ongoing or potential environmental activity that interrupts the surface and shallow ground water level. Ger Districts' sewage flow and its water and soil contamination alarms the majority of the Ulaanbaatar city and its population. Most of the ger districts are located on sloped hills north of the city which also means in the upwind location of the urban area. Currently there are estimated 250-300 households per square miles in the ger district which suggests that there are 150-200 "privy" or wood latrines with roof and wall (Kamata, 2008).

CHAPTER 03: PATTERNS

This thesis project was inspired by the book "Pattern Language" by Christopher Alexander where he presents 235 different design entities called patterns. And each of his patterns describes a problem which occurs over and over again in our environment, and then he describes the core of the solution to that problem, in such a way that people can use this solution multiple times over, without doing it the same way twice. My thesis project presents 9 design patterns that can be applied to different projects in the future to solve certain problems in the built environment; and these 9 patterns are not comprehensive.



01. GER CONNECTION

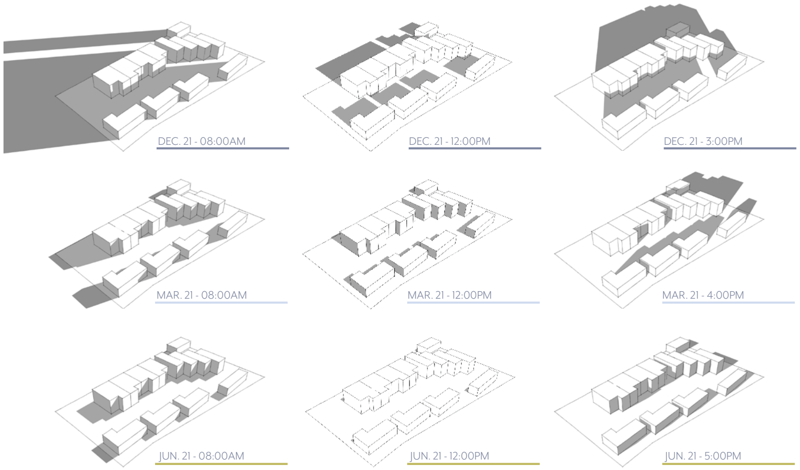


1. Ger Connection

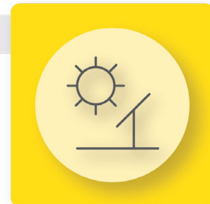
Isolated, individual, free standing buildings possibly give the owner emotional traits where there is more self-sufficiency and freedom. However, among the small individual houses there are "useless" dark spaces that both of the adjacent houses share. It is neither a pleasant view nor a nice space to walk around.

A positive connection between the individual buildings could be achieved if the connecting point of both houses are adjacent to more public areas of the home such as living or dining space. When there are multiple small dwellings on the site, instead of creating small chopped spaces in-between the buildings only to give the "standalone" notion, simply continuing the building form by connecting the buildings is both environmentally and socially beneficial.

To support this specific pattern, reflecting the Mongolian heritage is crucial. Traditionally, Mongolians are known to set up their yurts side by side with each other forming a unique cluster called "khot ail" where family members are within reachable distance to help out each other, but distant enough to have their own privacy. This specific social heritage stayed within the social culture for hundreds of years - thus bringing these aspects out in the modern society as a living typology is advantageous.



02. SOLAR ACCESS



2. South Facing Window

South facing windows are essential yet crucially important design elements when considering energy efficient / passive solar housing typology. The size of the windows significantly matters, but the orientation of the windows is equally important. The environmental benefits of the large window facing directly to the south will allow passive solar heating effect during the cold winter months that would further reduce the need for electrical or coal burning heating.

South windows could also create the positive natural ventilation circulation within the building as the warmer indoor air could ventilate through the upper portions of the windows. Compared to the northern, western, or even eastern windows in the building, the south facing windows are the most important yet the most utilized glazings in the entire building.

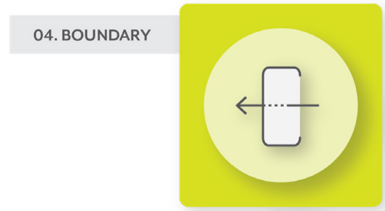
Moreover, besides the environmental benefits, the indoor living quality could also benefit from the south windows. The interior space receives natural daylight almost throughout the year in Ulaanbaatar, Mongolia. The central living space in the building with large southern windows is potentially a more pleasant space to be in for the residents as it naturally creates warmth, brightness, and comfort. It also faces the open space in front of the building as those are the pleasant and nicer views to capture within the community.

3. Sense of Community

The current residents of the Ger District might not be fully familiar with the concept of living together as a community, however there are a greater number of people who currently live with the extended family or share their properties with the leasing tenants. By creating a more unified community atmosphere, designers could re-create the sense of community within the society.

People feel more connected and comfortable towards the people who live nearby, who have similar social backgrounds, and even who they can identify, meaning they know enough about that person's daily lives, family, and their whereabouts. Indeed, living together with a total stranger and having to share the communal space within their neighborhood might be unfamiliar and uncommon in some situations, but after getting to know each other people tend to warm up to the idea of having a community for themselves.

Having a mixture of both adequate amounts of private space and shared space in the community is necessary to achieve a successful housing community. Shared spaces need to be accessible when people want to socialize as they're encouraged to. However, people must have their complete privacy without having to bump into their neighbors when it's needed.



4. Boundary

Transitioning from the street to the houses needs to be designed carefully so that people prefer having a clear indicative "entry" from the street that stands out but not too grand that attracts extensive attention. The point of entry and the experience attached to it directly impacts how people would feel about the interior space, thus consider designing a small garden or open space at the entry that smoothes the transition from public to semi-private and then to private home.

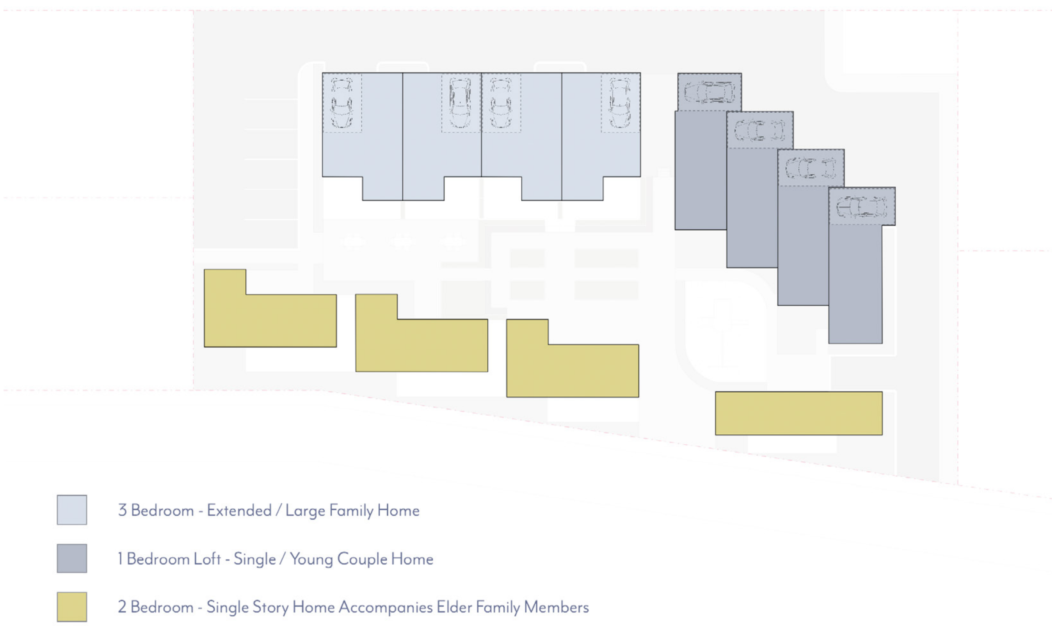
Smooth transition in this case could be a change of noise, texture, or dynamics that signals people that they have escaped the public extravaganza and now they are changing the gear and transitioning into the calmness of home. Although residents might reach their garage first before getting into their homes, still the appropriate amount of buffer that differentiates the public streets from private homes is considered essential.

5. Privacy Hierarchy

People's need for privacy and personal space is quite dependent on the individual's preferences, thus may vary. However, accommodating different levels of privacy within the housing community will benefit residents on numerous levels. Depending on the household need, units need to have various choices of public, open to public, semi-private, fully private spaces within their community as well as within their parts of the home.

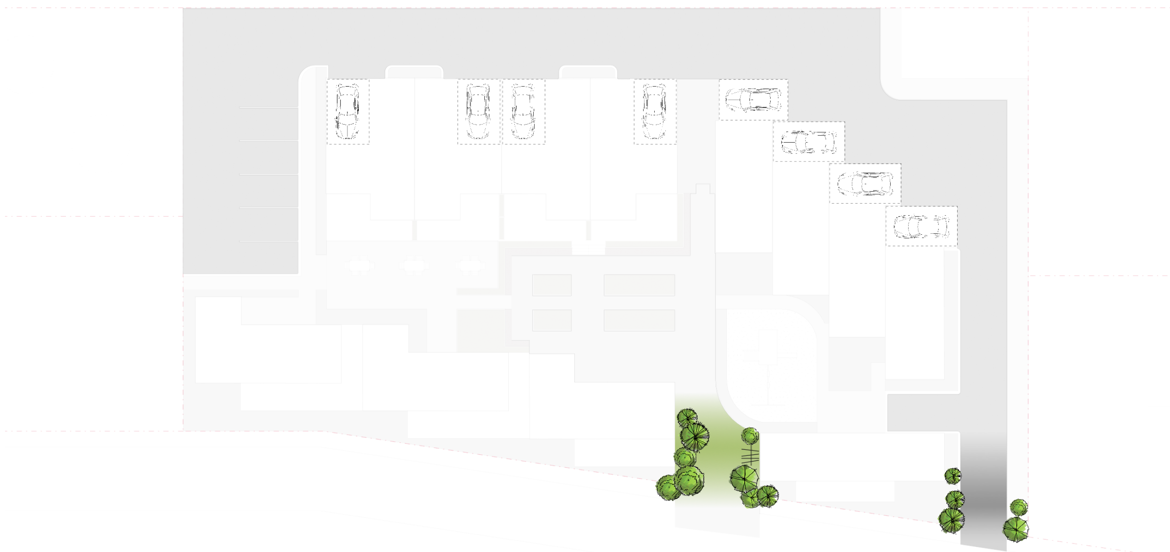
Currently, ger district residents feel somewhat insecure within their compound that they need to constantly lock up their spaces and belongings. Locking may work in the moments, however feeling secure in their community and being able to rely on their neighborhood security would benefit residents' emotional and experiential wellbeing for the longer period of time.

Overall, a privacy hierarchy can provide many benefits for a housing community. By creating different levels of privacy, residents can feel more comfortable, safe, and secure in their homes. This can lead to improved mental and physical health, as well as reduced stress and anxiety.



6. Multi-Generational Home

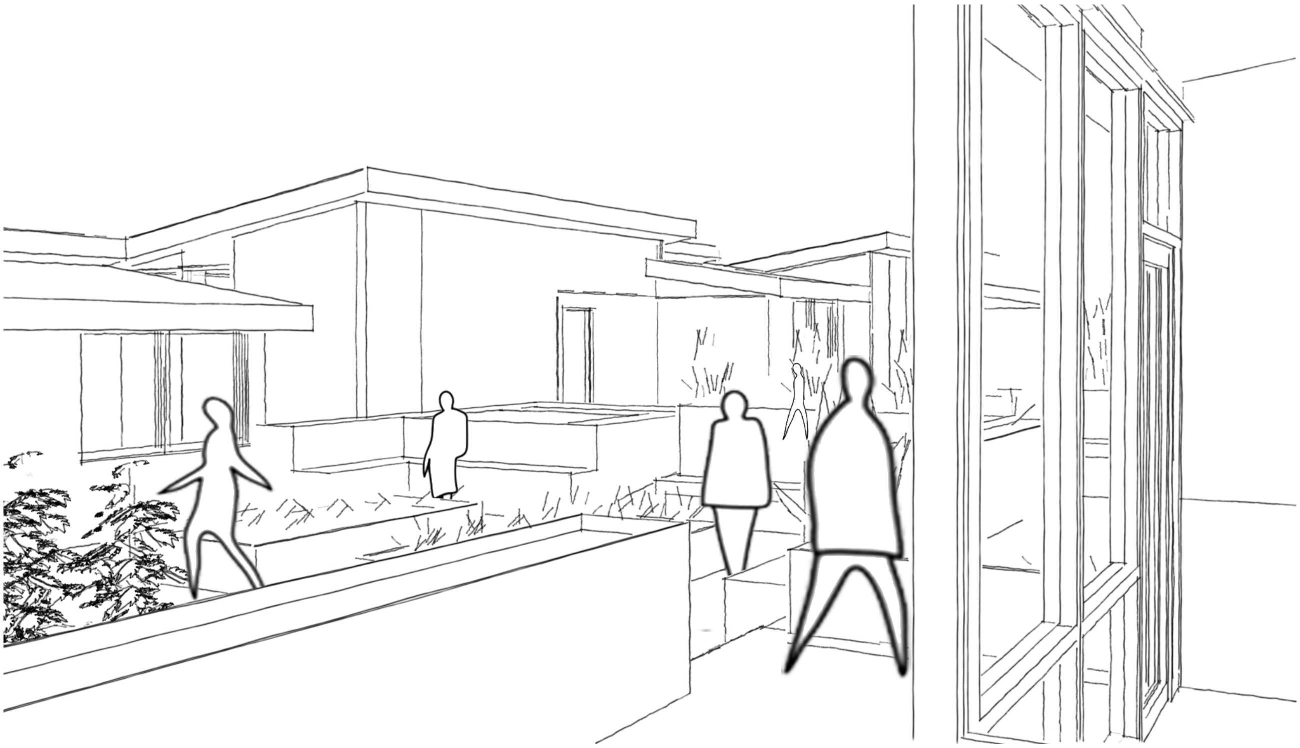
Multi-generational homes, also known as extended family homes, are dwelling units that are purposely designed to accommodate multiple generations of a family under a single roof. Although this housing type was less popular in the modern urban environment because of the lack of full-privacy and independence, after the pandemic there are many families that are considering multi-generational homes. This specific type of housing arrangement provides a number of benefits for families, including financial savings, caregiving, stronger relationships, and cultural continuity. For Mongolian families, especially in the ger district's larger families the multi-generational home type potentially could offer numerous benefits along with an opportunity for the younger generation to inherit their traditions and cultures.



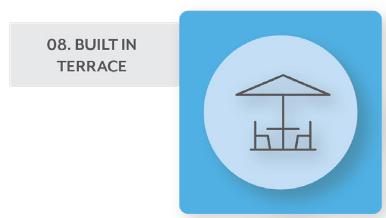
7. Vehicle Access / Private Garages

While thinking about the vehicular access into the home, practical design approaches can be most appropriate while considering the local social norms. With that said, while the western approach to the garage is sometimes referred to as a space for workshops, some social space where you can open up the door and socialize with passing neighbors, and including garage sale events. However, in the ger district people use their garage as both storage and garage where people would store their seasonal belongings, thus needing more private entries.

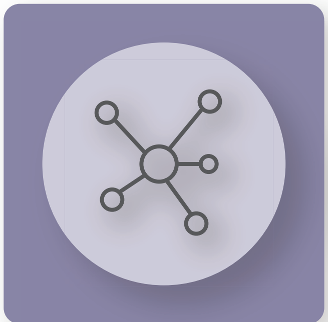
Moreover, with the local's current needs and dependency on the motor vehicle in mind, and even considering the much mobile cultural background - it is essential to keep the vehicle accessible regardless of the western trend of limiting the vehicle.



8. Built-in Terrace and Green Commons



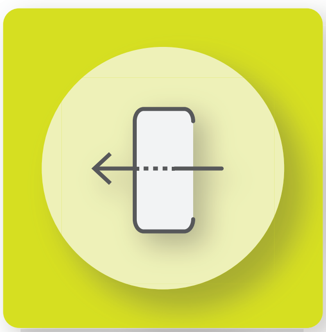
It is clear that planting vegetation and generating abundant green space is significantly challenging in cold climates. However, seasonal gardening and choosing climate appropriate trees have tremendous amounts of social and environmental benefits in the ger district. Regarding the socio-economic condition and current social behaviors of the ger residents, the built-in terrace is a better option to start with. Considering the currently lacking green space and open public gathering space within the whole neighborhood, in order to encourage people to come outdoors during the warmer months and socialize openly with their neighbors it is essential to design an open, green, and pleasant environment within the small community.



01. GER CONNECTION

02. SOLAR ACCESS

03. SENSE OF COMMUNITY



04. BOUNDARY

05. PRIVACY HIERARCHY

06. MULTI GENERATION

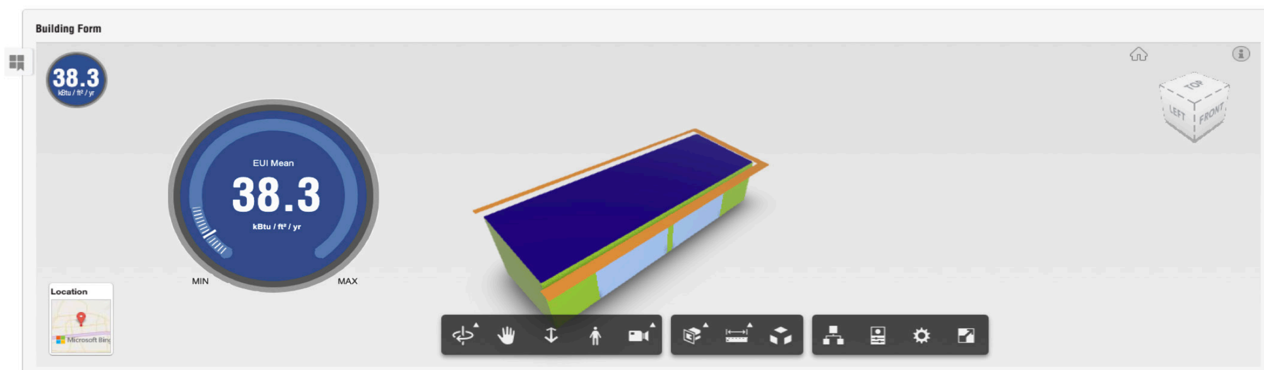
07. PRIVATE GARAGE

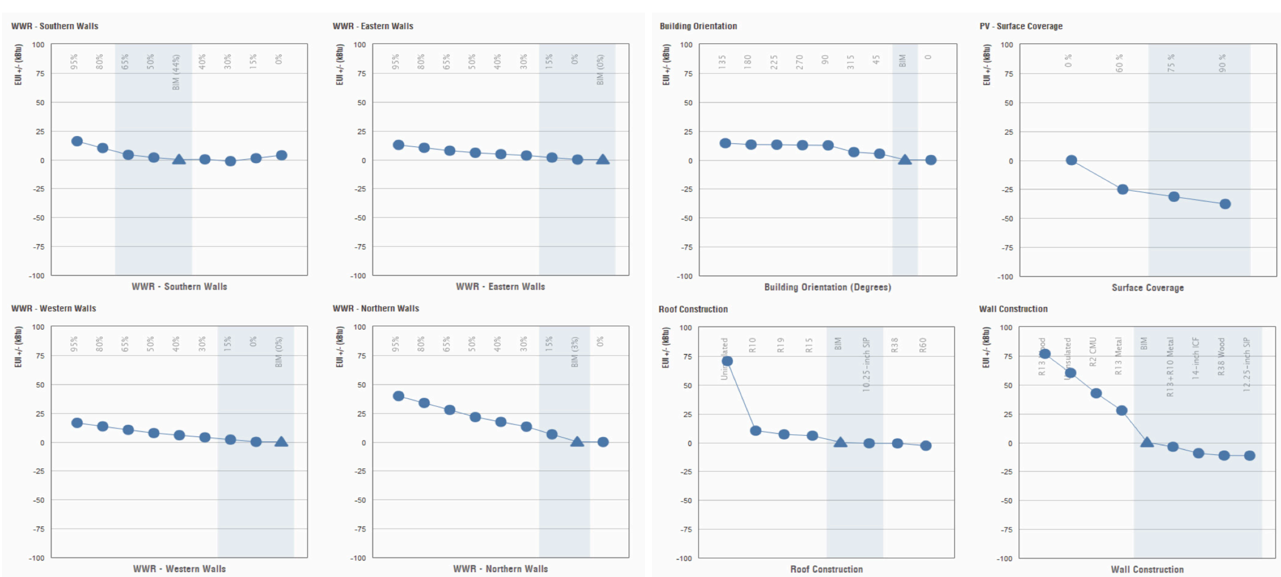
08. BUILTIN TERRACE

09. GREEN COMMONS

COMPUTATIONAL ANALYSIS RESULTS

This thesis project has used Revit Energy Analysis Model and Rhino Climate Studio. Computational Analysis has started from the shoebox model in Revit Energy Analysis Tool in order to determine the optimal window to wall ratio, wall thickness, roof structure, and window shadings. As suggested by the result of the shoebox energy analysis in the local climate, the design would further develop into a larger scale community. The target Energy Usage Intensity in this project was less than 50 EUI.





Informed by the initial analysis, this project will use an 8 ½" SIP wall panel with R value of 31 and U value of 0.032 at 40 degrees Fahrenheit. SIP wall panels will be manufactured locally in Ulaanbaatar (Mazaalai SIP Panels) and dimensioned 4'-0" x 10'-0". Respectively, 12 ½" SIP roof panel with R value of 47 and U value of 0.021 at 40 degrees Fahrenheit. As for the glazing structure, triple glazed insulated windows will be used for the project. According to the analysis report, south window to wall ratio can be optimized at 44%-65% to maximize the solar heat penetration as well as prevent heat loss through the glazing.

1 Bedroom Loft (613 sq.ft) - 55% South Glazing

2 Bedroom House (764 sq.ft) - 52% South Glazing

3 Bedroom Home (1434 sq.ft) - 48% South Glazing

PV ANALYSIS RESULTS

Latitude (DD)	47.93
Longitude (DD)	106.9
Elevation (m)	1313
DC System Size (kW) - South	98.325
DC System Size (kW) - West	13.8
Module Type	Premium
Array Type	Fixed (open rack)
Array Tilt (deg)	10
Array Azimuth (deg)	180
System Losses (%)	14.08

Total of 5700 sq.ft of rooftop space will be used for solar panels of size (17.54 sq.ft). 88% of the PV system will be placed on the sloped rooftops that directly faces the south while the rest of the system will be placed on the gable roof of loft units' west facing slope. Although the difference between west and south facing solar panels is 12-15%, west facing slope in Ulaanbaatar still receives abundant amount of solar exposure.

South: 285 panels x 345 W/panel = 98.325 kW

West: 40 panels x 345 W/panel = 13.800 kW

TOTAL: 325 panels = 112.125 kW system

Total Energy Production of the system:

156,063 kWhr = 532,799 kBTU

ENERGY PRODUCTION INDEX = 41

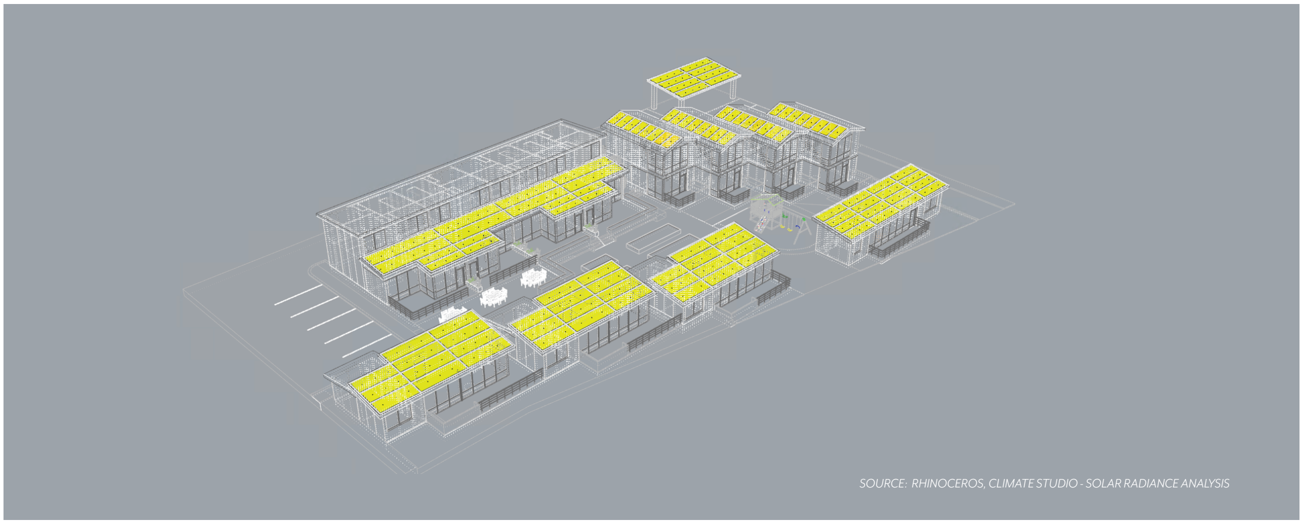


Figure 3.1: PV panel diagram

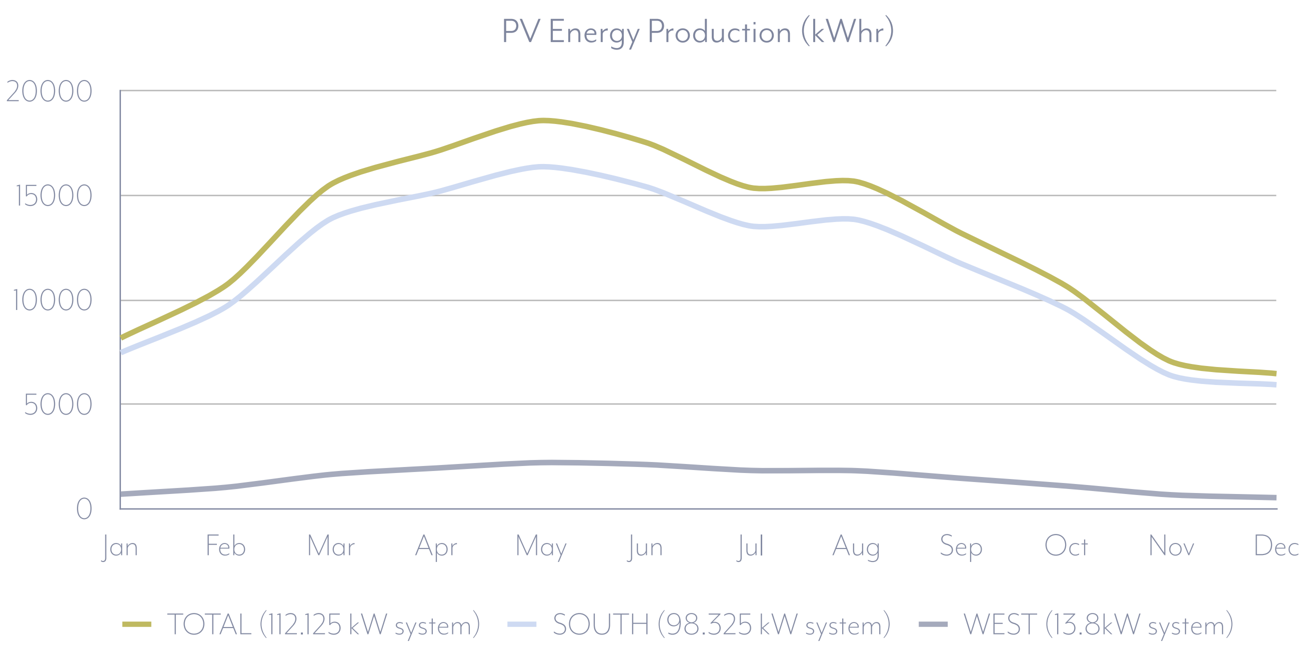


Figure 3.2: PV ENERGY PRODUCTION. Data Source: PVwatts.com

CONCEPTUAL INFRASTRUCTURE DESIGN

In order to provide the essential heating into the housing units, this thesis project uses a horizontally lined ground-source heat pump system which takes the water from the well located in the mechanic unit that's shared within the community. These horizontal heat pipes will be buried in a shallow ground underneath the central green common space. Advantages of this system include cost efficiency, self-sufficiency, and significant energy efficiency that fits well in the site climate conditions. Moreover, the shallow ground hole contains both a heating water pipe and a perforated drainage pipe that filters the used water throughout the drain field. This specific design decision will benefit both independent sewage system to filter the waste water on site and heat pump system to work more efficient during the cold heating season.

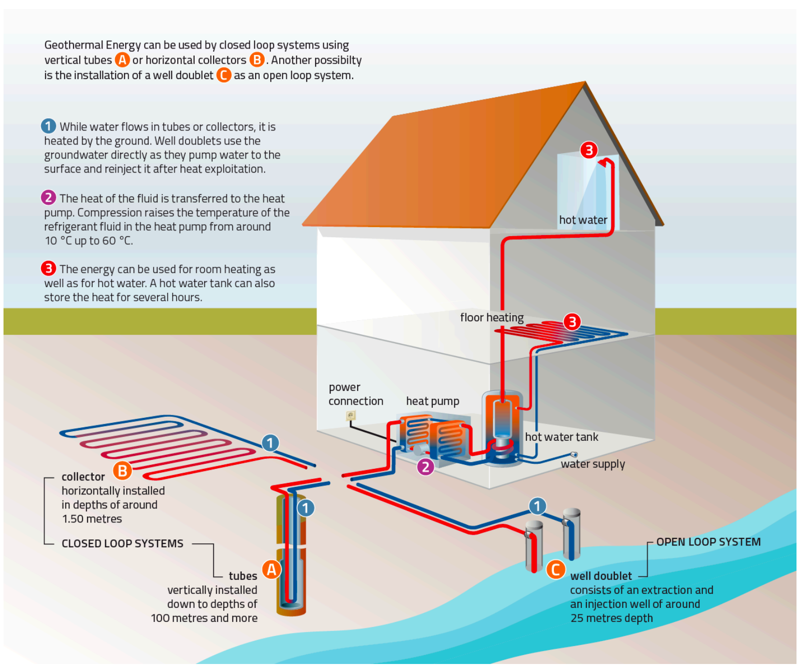


Figure 3.3: Geothermal heatpump diagram

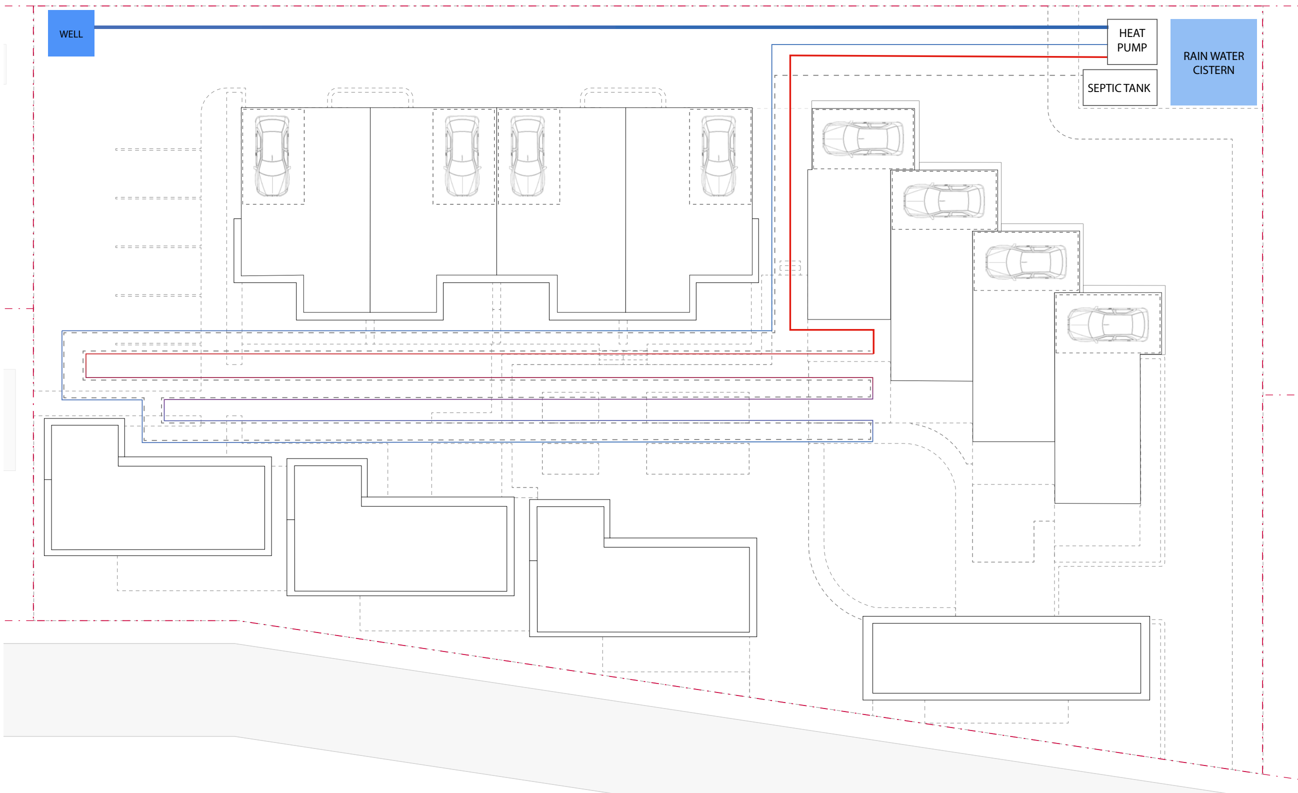


Figure 3.4: Site Geothermal Diagram

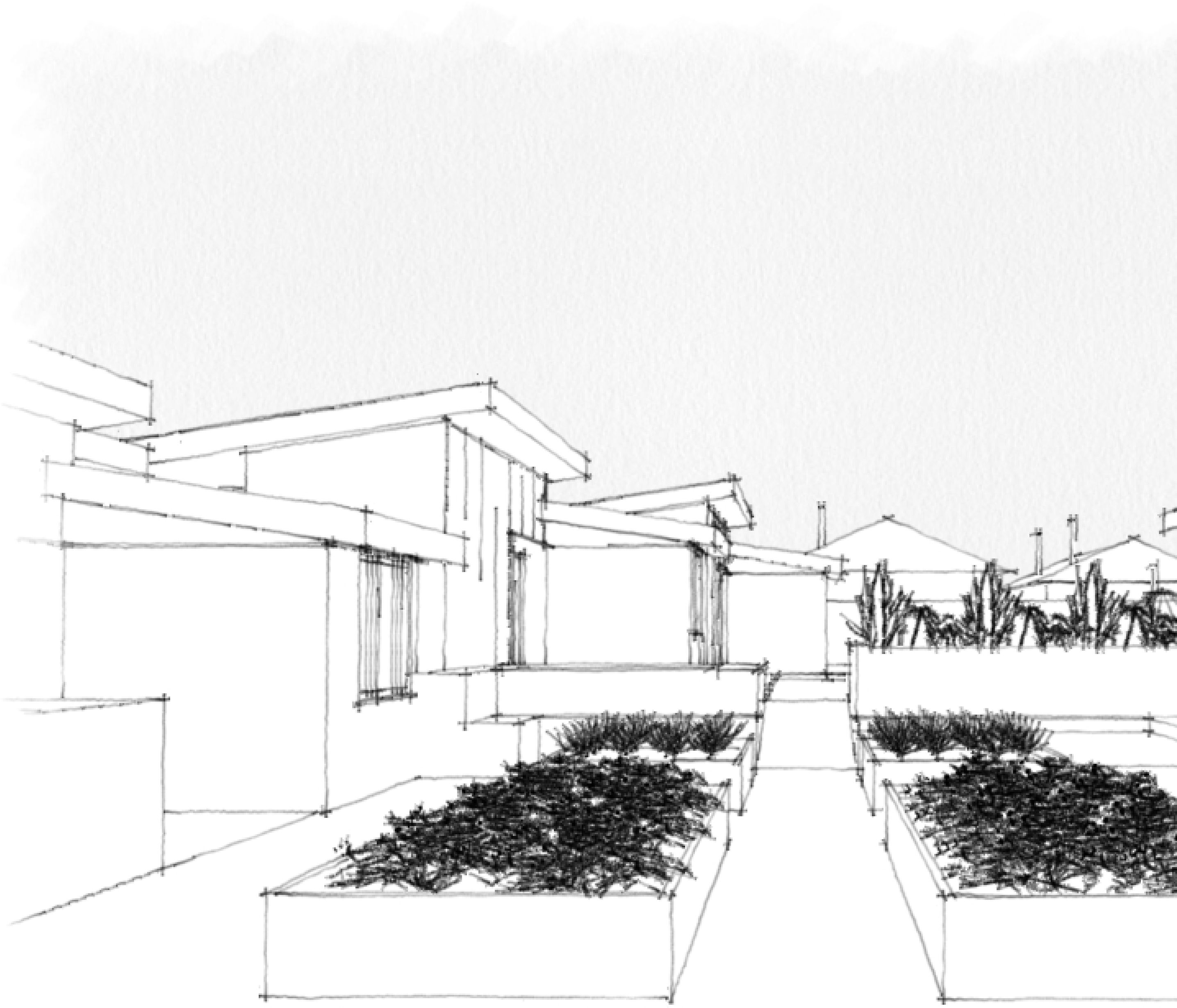


Figure 4.1 : Concept Sketch

CHAPTER 04 : DESIGN

Design approach for this project was to create culturally adaptive and climate responsive architectural strategies that would potentially solve the ongoing environmental issues in a practical manner. Although Mongolian heritage and cultural backgrounds are important ingredients for this project, this thesis will not mimic Mongolian architecture in terms of design concept. Traditional Mongolian concept of housing is the round felt yurt which nomadic people have used as a dwelling for hundreds of years while built structures mostly are monasteries, palaces or public buildings. Thus considering the fact the traditional housing design cannot be directly applied to the modern urban housing scenario, this project proposes a design concept that applies western influenced, advanced technologies into the housing community concept that emphasizes and enhances the local cultural heritage

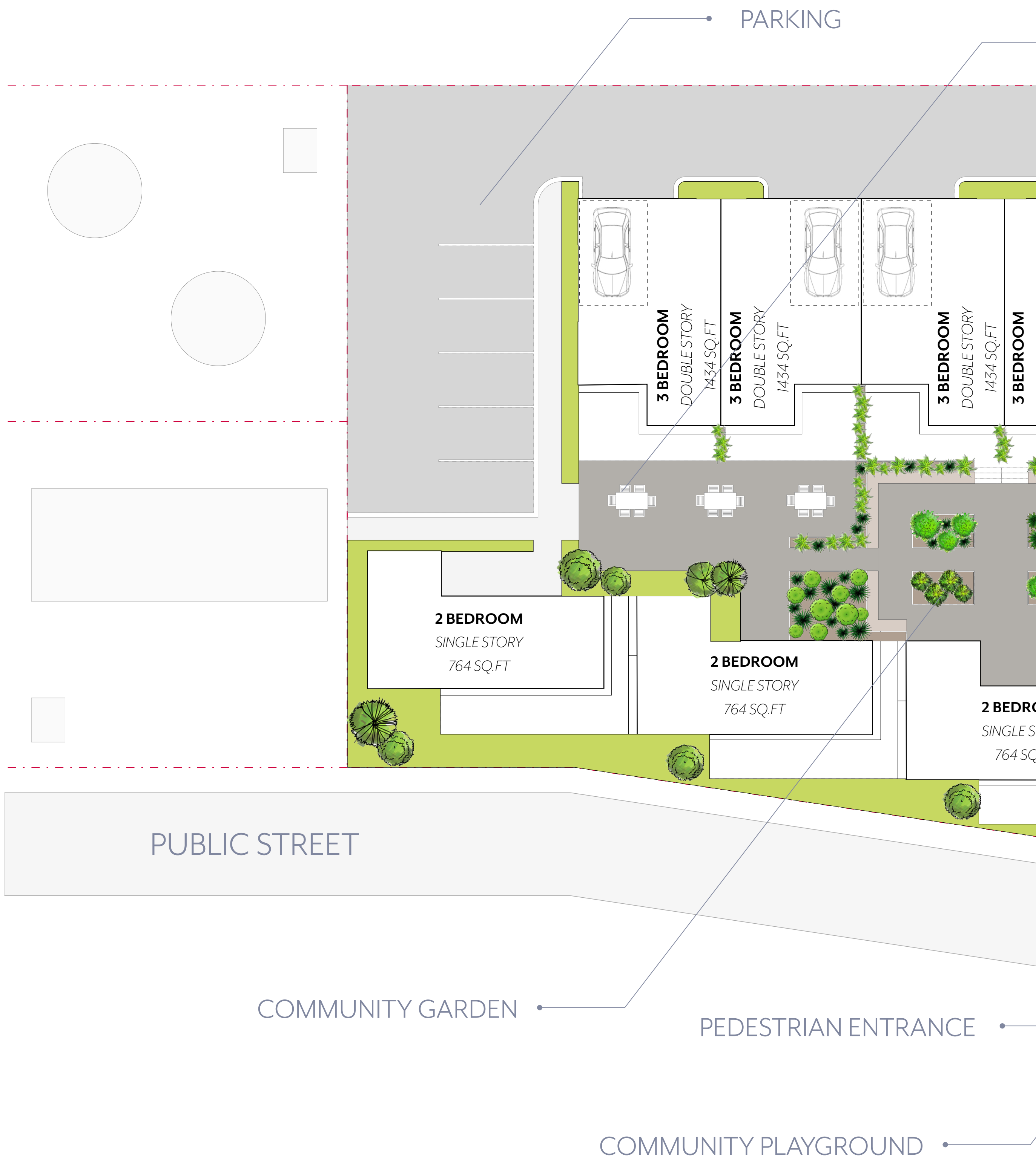


Figure 4.2: Site Plan


OPEN SEATING AREA
MECH.
DOUBLE STORY
1434 SQ.FT
1 BEDROOM
LOFT (613 SQ.FT)
1 BEDROOM
LOFT (613 SQ.FT)
1 BEDROOM
LOFT (613 SQ.FT)
1 BEDROOM
LOFT (613 SQ.FT)
OOM
TORY
).FT
2 BEDROOM
SINGLE STORY
690 SQ.FT
VEHICLE ACCESS

Figure 4.3: Ground Floor Plan

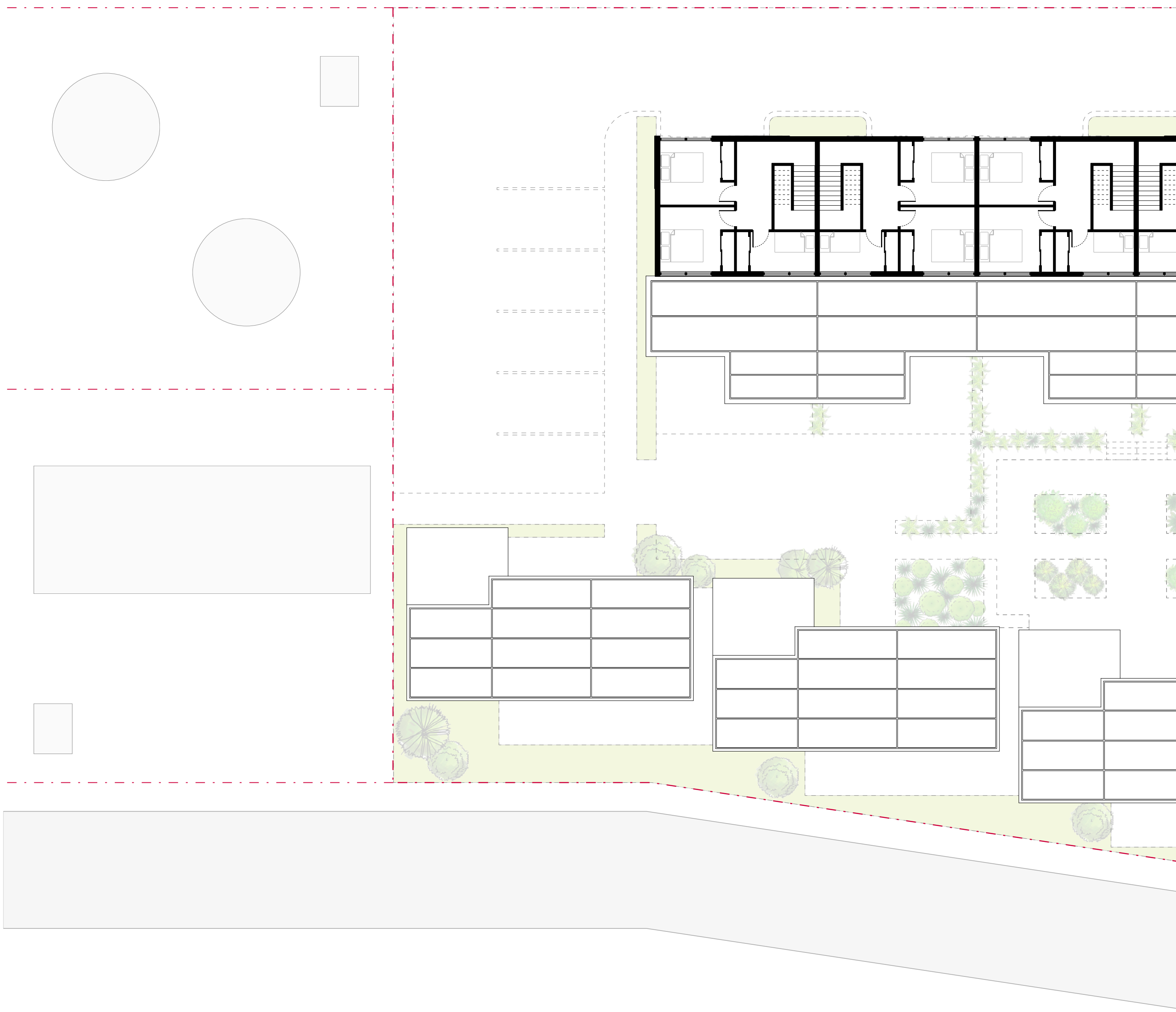


Figure 4.4: Second Floor Plan

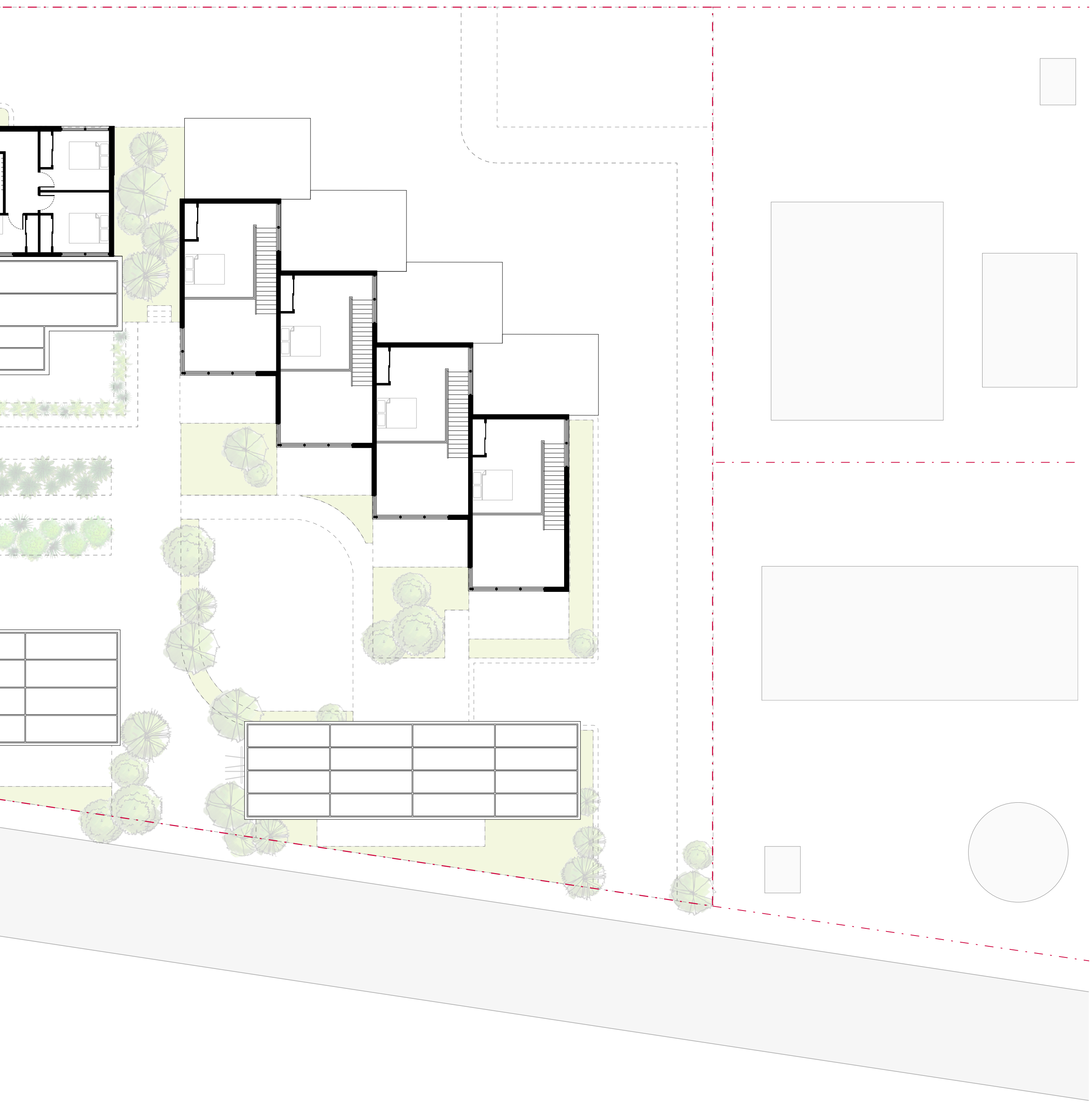


Figure 4.5: Street View Perspective Render

Figure 4.6: Vehicle Entrance Render

Figure 4.7: Common Space Perspective View

Figure 4.8: Pederstrian Entrance Perspective View

Figure 4.9: Green Commons View

Figure 4.10: Aerial View

LOOKING FORWARD

With the deep understanding of the existing culture, and environmental condition, this thesis suggests the potential design patterns that are applicable in the future projects with similar climate or cultural backgrounds. Architectural strategies that are studied in this design are strongly informed by the existing climate - thus not only limited by the housing of ger district, other future design projects of Ulaanbaatar could potentially benefit from this thesis that suggests an integrated, sustainable, and climate friendly housing method that addresses and fulfills the socio-cultural needs of the local residents.

Figure 4.11: Interior View Sketch

LIST OF FIGURES

REFERENCES

- Yang, Jingling, et al. Cohousing Communities: Designing for High-Functioning Neighborhoods. John Wiley & Sons, Incorporated, 2022.
- McCamant, Kathryn, and Charles Durrett. Creating Cohousing : Building Sustainable Communities. New Society, 2011.
- Guity Zapata, Nestor Agustin, and Wendy M. Stone. "Home Motivations and Lived Experiences in Housing Cooperatives and Cohousing Communities: a Two-Contexts Scoping Review." Housing Studies, vol. ahead-of-print, no. ahead-of-print, 2022, pp. 1–24
- Gaston, Kevin J. Urban Ecology. Cambridge University Press, 2010.
- Forman, Richard T. T. "Urban Ecology Principles: Are Urban Ecology and Natural Area Ecology Really Different?" Landscape Ecology, vol. 31, no. 8, 2016, pp. 1653–62
- Forman, Richard T. T. Urban Ecology: Science of Cities. Cambridge University Press, 2014
- Marzluff, John M., et al. Urban Ecology: An International Perspective on the Interaction Between Humans and Nature. 1. Aufl., Springer-Verlag, 2008, pp. xxv–xxv
- Kamata, Takuya. Managing Urban Expansion in Mongolia: Best Practices in Scenario-Based Urban Planning. World Bank, 2010.
- Litfin, Karen T. Ecovillages: Lessons for Sustainable Community. Polity Press, 2013.
- Morris, Olea. "How Ecovillages Work: More-Than-Human Understandings of Rentabilidad in Mexican Ecovillages." Sustainability Science, vol. 17, no. 4, 2022, pp. 1235–46,
- Justin Bere. An Introduction to Passive House. RIBA Publishing, 2019,
- Friedman, Avi. Innovative Houses;Concepts for Sustainable Living. Laurence King Publishing, 2013.
- Kachadorian, James. The Passive Solar House. Rev. and expanded ed., Chelsea Green, 2006.
- Chiras, Daniel D. The Solar House : Passive Heating and Cooling. Chelsea Green Pub., 2002.
- Bainbridge, David A., and Kenneth L. Haggard. Passive Solar Architecture : Heating, Cooling,

Ventilation, Daylighting, and More Using Natural Flows. Chelsea Green Pub., 2011.

- Sabloff, Paula L. W. Mapping Mongolia : Situating Mongolia in the World from Geologic Time to the Present. Edited by Paula L. W. Sabloff, University of Pennsylvania Museum of Archaeology and Anthropology, 2011.
- Chen, Jiquan. Dryland East Asia Land Dynamics Amid Social and Climate Change. Higher Education Press and Walter de Gruyter GmbH, 2014,
- Enkhbat, Enkhjargal, et al. "Driving Forces of Air Pollution in Ulaanbaatar City Between 2005 and 2015: An Index Decomposition Analysis." Sustainability (Basel, Switzerland), vol. 12, no. 8, 2020, p. 3185–,
- Guttikunda, Sarath K., et al. "Particulate Pollution in Ulaanbaatar, Mongolia." Air Quality, Atmosphere and Health, vol. 6, no. 3, 2013, pp. 589–601
- Plueckhahn, Rebekah. "Accessing Heat: Environmental Stigma and 'porous' Infrastructural Configurations in Ulaanbaatar." Urban Studies (Edinburgh, Scotland), vol. 59, no. 3, 2022, pp. 608–23,
- Campi, Alicia. "The rise of cities in nomadic Mongolia." Mongols from country to city: Floating boundaries, pastoralism and city life in the Mongol lands (2006): 21-59.
- Tsovoodavaa, Gantumur, et al. "A REVIEW AND SYSTEMIZATION OF THE TRADITIONAL MONGOLIAN YURT (GER)." Pollack Periodica: An International Journal for Engineering and Information Sciences, vol. 13, no. 3, Dec. 2018, pp. 19+. Gale Academic OneFile, link.gale.com/apps/doc/A563082416/AONE?u=wash_main&sid=bookmark-AONE&xid=bc9f9471. Accessed 13 Jan. 2023.
- Air Quality Analysis of Ulaanbaatar: Improving air quality to reduce health impacts. (2011). World Bank.