Mongolian Green Finance Corporation: Passive Ger - Project Report
by Kim Dupont-Madinier, October. 2018

1. Introduction

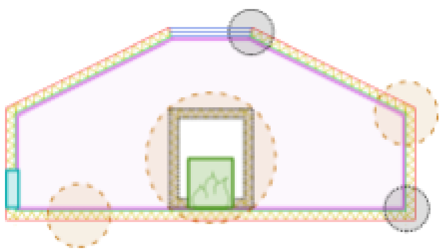

Figure 1: Energy Efficient Ger Diagram

In winter Ulaanbaatar is the most polluted city in the world. With winters as cold as -40 celsius, families are burning tons of coal per household to heat their homes, creating deadly air pollution. The deadly air pollution has become one of Mongolia's biggest problems - contributing to 1 in 10 deaths annually[1]. The scope of the Fulbright Research Fellowship was to adapt the Mongolian *ger,* a local vernacular housing typology also known in the west as a Yurt, using energy efficient construction guidelines of the Passive House Standard for *gers* in Ulaanbaatar's Ger Districts in order to reduce the *ger*'s heating load by 90%, while using alternative energy sources to coal. The project ultimately aimed to create a low-income housing prototype that simultaneously preserved the key elements of the Mongolian *ger*, while adapting it to reduce air pollution in Ulaanbaatar Mongolia.

This sustainable housing solution was developed in collaboration with Mongolian NGOs such as GerHub and EcoTown, as well as local and international partners including: the Institute of Engineering and Technology, the Mongolian University of Science and Technology, Saint-Gobain, Stanford, Arig Bank, UBGC, Render, Zag Construction, and many other Mongolian partners.

2. Project Team

A. Core Members

The project was a collaboration between three primary partners; a Fulbright Research Fellow and two Mongolian NGOs, GerHub and EcoTown. Each party brought a critical set of skills for the successful execution of the project.

i. Kim Dupont-Madinier: Kim was a Fulbright Research Fellowship. For Kim's Fulbright Research Fellowship, her proposal was to reduce air pollution in Ulaanbaatar through the design of low cost, energy efficient Gers by using the Passive House Standard. Kim has a background in Architecture and Fine Arts, with two Bachelor'sDegrees from the Rhode Island School of Design. Her expertise lied in research and development, creating new system and assembly designs for the built environment.. Kim created the pilot program, was the primary research, designer, and project manager.

ii. GerHub: GerHub was a nonprofit social enterprise that sought to find innovative and creative solutions to some of the most pressing issues facing the Ger Areas of Ulaanbaatar. They partner with top universities and institutions globally in the fields of architecture, design, and

[1] Arc Finance. "XacBank's Eco-Banking Department." *AFFORDABILITY MECHANISMS AND ENERGY ACCESS*, Arc Finance, July 2012, arcfinance.org/pdfs/pubs/Arc%20Finance_Case%20Study_XacBank_2012.pdf.

engineering. Their objective was, and still is, to research and develop new ways to affordably modify and modernize the Mongolian *ger* to meet the housing needs of Ger Area residents.[2]

iii. Eco Nogoolin Citizen's development association (also known as EcoTown) was, and still is, a grassroots community collaborative NGO that came together to transform its local Ger District community into a model sustainable Mongolian community. EcoTown's goal is to bring about change through grassroots initiatives, combining forces with concerned community members - working together through small projects and initiatives to steadily create progressive solutions for the Ger Districts.

iv. Nomadic Synergetic Partner (NSP) was, and still is, an architecture firm based in Ulaanbaatar. NSP architectural focus is on sustainable design and energy efficiency. NSP's goal is to build "A Green Home for Every Family".

B. Supporting Partners

i. Building Science
   1. Saint-Gobain : Energy and Moisture assessment of Passive Ger
   2. Building's Technology : Plumbing and Energy assessment
   3. Stanford : Air quality assessment of existing 5 *khana gers*

ii. Construction & Architecture
   1. Zag: Construction and plumbing consultation
   2. QLScale: Architectural consultation
   3. Render: Architectural consultation and rendering support
   4. Shinest Construction: Development of final architectural drawing set

iii. University Facilities & Expertise
   1. The Institute of Engineering and Technology: Student exploration of Passive Ger Concepts
   2. Mongolian University of Science and Technology: Construction materials and plumbing consultation

iv. Financial Package
   1. Arig Bank: Financial package development and alternative heating system support

v. Alternative Energy Solutions
   1. UBGC: Solar panel system consultation
   2. Mongolian University of Science and Technology: Gas heating system consultation

3. Urban Development & Target Market

a. Urban Development in Ulaanbaatar Mongolia

To address Ulaanbaatar's air pollution problem, it was essential to tap into multiple market segments for energy efficient and renewable energy housing solutions to reduce air pollution. As a result, the target market for the energy efficient *ger* took into consideration existing and previous initiatives that sought to reduce air pollution - strategically positioning the energy efficient *ger* in order to tap into a housing segment that has not yet been addressed.

a. Target Market

According to the Mongolian Green Finance Corporation, as of 2016, there were 216,021 households in the Ger Areas where over 88% of the families living in *gers* (104,500 households) wished

[2] Welcome." *GerHub*, gerhub.org/.

to have proper modern housing amenities (such as running water, plumbing, stable electricity, separate rooms, etc.) connected with infrastructure. And these families were willing to take on a mortgage loan to do so. As a result, developing an energy efficient *ger* was deemed to be a measured and pragmatic solution that would significantly reduce greenhouse emissions in Ulaanbaatar in the near future through avenues that had not yet been explored.

The first objective was to ensure the sustainable housing solution met the financial limitations of Ger District families. The Passive Ger project therefore aimed to fit within one of the Mongolian Green Finance Corporation's activities - the Green Affordable Housing Mortgage (GAHM) initiative. The GAHM initiative established a variety of criteria to provide a holistic package of affordable energy efficient housing for the Ger Areas of Ulaanbaatar. In order for the housing proposal to be eligible for this initiative, the Passive Ger design needed to fulfill the following requirements:

1. Built according to the Mongolian building code
2. Have an energy consumption of maximum 38.9 kWh/m^2 per day or maximum 252 kWh/m^2 per year
3. The housing solution should cost less than 900,000 MNT per m^2
4. Profit costs should be less than 30% of the housing cost
5. Designs should be audited by an official organization
6. Maximize the use of natural lighting and ventilation conditions
7. Electricity should be used from the central grid
8. Water supply and sanitation should be individual
9. Environmentally friendly construction materials should be considered
10. Support of domestic manufacturing of construction materials
11. Construction should be simple and for a short period[3]

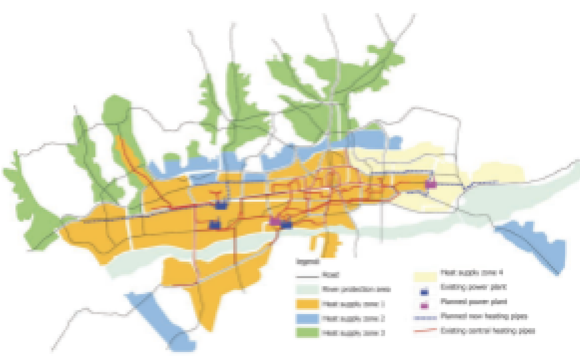
Figure 2: Urban Master Plan for Ulaanbaatar in 2030, from the Asia Development Foundation.

As a result, designing the Passive Ger to fit within this package would be beneficial because it would not only fit within an established energy efficient range - but it would also meet an affordable housing market. As families took on mortgage loans for housing products which were approved by the Mongolian Green Finance Corporation's GAHM Initiative - the interests rate families would pay on these loans would be capped at 8%, a considerable incentive for homeowners as they would traditionally paying interest rates as high as 25%[4].

Furthermore, from a long-term development perspective, it was paramount to develop an independent clean energy housing solution for fringe *ger* Areas in the immediate future. According to the Asian Development Foundation by 2030, zones two and

[3] "Тогтвортой Санхүүжилт (ТоС) Монгол Улсад." *Монголын Банкны Холбоо*, mba.mn/sustainable-finance-in-mongolia-mn/.

[4] XacBank. "Mongolia: Ulaanbaatar Green Affordable Housing and Resilient Urban Renewal Sector Project ." *Safeguards and Social Dimensions Summary*, Asian Development Bank, May 2018, www.adb.org/sites/default/files/project-documents/49169/49169-002--en.pdf.

three (the green and blue zones) of Ulaanbaatar would continue to be separate from Ulaanbaatar's centrally supplied heating infrastructure system[5]. These zones would therefore require self-sustaining utility systems for current and future Ger District families to reduce C02 emissions.

Moreover, as migration to Ulaanbaatar continued, the natural pattern of migration would most likely consist of families moving to the Ger Areas with their traditional *ger*, until they could eventually afford to move into more permanent structures (like apartments or homes). An intermediate sustainable response could therefore include retrofitting a *ger* with pre-engineered low-cost energy efficient system and assembly designs.

In addition, at the time *Baishins* (*Baishin* is the Mongolian word for hard surfaced Western styled home) in the Ger Districts were producing significantly more air pollution due to their in-efficient material applications. As a result, creating an energy efficient housing system that applied sustainable building science practices to a standardized housing typology, like a *ger*, would be easier and faster to deploy on a large industrial scale. It is important to also note that families who built *Baishins* themselves on their own *Hasha* (*Hasha* is the Mongolian word for family's fenced in yards) would move back into their traditional *gers* in the winter season because their *gers* were relatively warmer and easier to heat. As a result, rather than individually attempting to retrofit D.I.Y. *Baishins* families built independently - varying in size, shape, material selection, material application, and so on - addressing the traditional and standardized local housing typology was identified as a more impactful building science problem to address.

Lastly, the final objective was to have an energy efficient *ger* which could be clearly measured, by conducting comparative energy assessments between a traditional 5 *Khana Ger* (the most common standard *ger* size - approximately 5.8 meters in diameter) into an energy efficient Passive Ger's performance. Having a measured comparison of the two different housing systems will provide better data for the overall benefits of a more energy efficient housing assembly. The measured comparison would more effectively outline to future families the benefits of investing in the Passive Ger, and how such a solution would; outweigh traditional energy costs (such as coal consumption), reduce soft costs (such as health care costs related to air pollution), outweigh traditional *ger* maintenance and component replacement costs, and ultimately fulfill their greater aspiration, a stable housing solution that offers the comfort and modern amenities they have been seeking.

4. Project Objectives & Implementation Schemes

a. Project Objectives

The Fulbright Research Fellowship project was based off of the non-for-profit efforts of the core Passive Ger Team. As an interdisciplinary team, each party brought critical skill sets to the development of the prototype. The culmination of these efforts was to develop a solution that was best adapted to meet target market needs - while developing a standardized energy efficient housing system that could be locally available and feasible to build.

The project objective was therefore to develop a 21st century *ger* that was adapted to the urban development needs of Ulaanbaatar. The housing product's goal was to simultaneously address many Ger Area issues, including; the air pollution, water sanitation problems, and income issues of the Ger Areas.

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[5] ULAANBAATAR 2020 MASTER PLAN AND DEVELOPMENT APPROACHES FOR 2030 ." *ULAANBAATAR 2020 MASTER PLAN AND DEVELOPMENT APPROACHES FOR 2030* , Asia Foundation, 2014, asiafoundation.org/resources/pdfs/UBMasterPlan.pdf.

In response, the housing package encompassed: an energy efficient and modernized building assembly, an alternative energy efficient heating system to coal burning stoves, and an adapted septic system that treats human waste such that all remaining water can be reused for the *Hasha's* plants. The culmination of these systems were best adapted to meet target market needs by developing an energy efficient housing system that could be locally available and feasible to build. Because of the added costs in the new housing product in comparison to a traditional *ger*, the target clients for the Passive Ger were middle income families in the Ger Areas, receiving an average income of approximately 1 million MNT per month.

b. Implementation Schemes: Design Thinking & Project Phases

Over the past 15 years there was a growing trend of families living in *gers* in the Ger Districts undertaking the construction of their own homes. Families sought the comfort, practicality, and modern amenities of fixed conventional western style single family homes.

As a result, in order to better understand why this phenomenon occurred and what the living conditions of a traditional *ger* in non-formal urban areas were like, the project utilized a Design Thinking approach to develop the Passive Ger. The Design Thinking method provided an in-depth understanding of the current Ger District inhabitant's needs and preferences to create the most well adapted design.

As a result, the project was broken up into 5 critical design development phases within the 2 year timeline of the project:

I. Phase 1: Evaluating and Defining the Scope and Needs (Sep. 2017 - Nov. 2017)
- Baseline understanding of existing initiatives trying to address air pollution
- Baseline energy assessment of 5 *khana ger*

II. Phase 2: Insights, Ideation, and Iteration (Dec. 2017 - Feb. 2018)
III. Phase 3: Professional Consolation and Prototyping (Mar. - Aug. 2018)
IV. Phase 4: Pilot Project Construction (Sep. - Oct. 2018)
V. Phase 5: Testing, Feedback, Pilot Product Refinement & Business Plan Development (Nov. 2018 - April. 2019)
VI. Phase 6: Passive Ger: Adapting the Passive Ger design (May. - June 2019)

1. Phase 1: Evaluating and Defining the Scope and Needs (Sep. 2017 - Nov. 2017)

The first phase of the project was initiated by researching and evaluating the previous and current initiatives aiming to reduce air pollution in Ulaanbaatar. This phase offered an in depth understanding of the different players addressing the air pollution issue, enabling the Fulbright Research Fellow to learn from past project's strengths and weaknesses, in addition to understanding of a variety of different institutions' activities including; large to small scale NGO projects, large banking to small banking green finance and green idea generation competitions, to a variety of government policies and grassroots initiatives. Understanding the culmination of these endeavors provided a map of the previous and existing efforts aiming to improve Ulaanbaatar's built environment - providing a general framework and criteria for the Passive Ger's project scope and needs.

2. Phase 2: Insights, Ideation, and Iteration *(December 2017 - February 2018)*

To develop a more intimate and personal understanding of the widely known issues in the Ger Areas, the Fulbright Research Fellow furthered the project research by living in the Ger Areas for three weeks in early December to have a better understanding of the challenges and incentives behind living in a Mongolian *ger* in Ger Areas.

Throughout this period, Kim Dupont-Madinier also interviewed 18 different families living in the neighborhood off of Altair road in the Songino Khairkhan District, in the 31st Khoroo. Most interviewed parties included a majority of families living in *gers* and a few in *Baishin*.

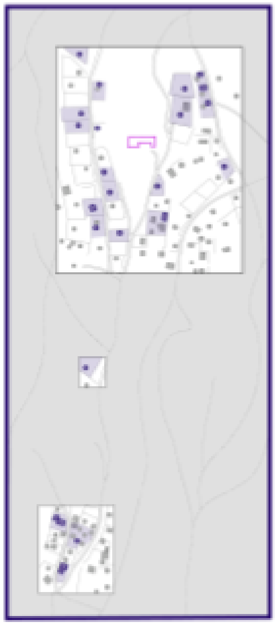

Figure 3: Map of UB, zooming in on EcoTown Ger District Community where insights were collected from 18 families. Pink building is EcoTown's head quarters, and 18 families interviewed are represented in Blue

While living in a *ger* provided personal insight into what the daily challenges one faced living in a *ger* in the Ger Districts of Ulaanbaatar, interviewing the families provided a better understanding of how individuals perceived living in a *Baishin* versus a *ger* in these non-formal urban areas. More importantly, these interviews provided insight into families' fundamental living aspirations. This period provided an in-depth understanding to kick start the design development.

Post the initial insights collection phase in December, a variety of Passive Ger and Passive Baishin designs were developed, creating four critical iteration phases:

1) Concept Development: 3 passive *ger* & 4 passive *baishin* designs

2) Concept Refinement: 1 passive *ger* & 1 passive *baishin* designs

3) Design Development: 1 passive *ger* & 1 passive *baishin* designs with a general material application and cost estimate

4) Design Refinement: 1 passive *ger* with locally consulted material application and cost estimate

3. Phase 3: Professional Consolation and Component Prototyping (Mar. - Aug. 2018)

The Passive Ger was a hybrid between known traditional Ger construction practices in Mongolia and modern western construction techniques. The combination of both methods was a new approach that was heavily documented and optimized to ensure an ease of construction feasibility.

After having conceptually developed the design, the different systems embedded in the design were sought out and tested, including the most cost effective building materials, construction methods, heating, plumbing, and structural systems. These technologies selected gave preference to locally produced materials in addition to consultations with local building material manufacturers and engineering firms to ensure the final solution was best suited for average income families in the Ger Area.

4. Phase 4: Pilot Project Construction (Sep. - Nov. 2018)

In order to ensure the housing prototype follows the estimated project cost, energy and moisture calculations, construction timeline, and aesthetic goals, a first pilot project was built from September and October.

5. Phase 5: Testing, Feedback, Pilot Product Refinement & Business Plan Development (Nov. 2018 - April. 2019)

Once the construction of the housing prototype was completed, a sensor package was installed in the Passive Ger to monitor its energy performance throughout the heating season from Nov. 2018 - April.

2019. The objective was for the Passive Ger project partners to collect data monthly, including: data collected from the sensors installed in the Passive Ger, the monthly utilities bill, and other energy and moisture performance measurements, to eventually optimize the design and bring down costs.

In addition, throughout this period new customer insights were to be collected from the family living in the Passive Ger as well as visitors visiting the Passive Ger. The objective was to identify what functional and aesthetic aspects of the design could be improved to best meet market needs.

Once the second optimized version of the Passive Ger had been built, the objective was to create a final business plan to refine the housing product's implementation scheme on the local market - ensuring the larger public could execute the assembly with little construction expertise.

b. Insights

i. Summary

In seeking to empathize with the families living in the Ger Areas, from November 27 to December 15 2017, the Fulbright Research Fellow lived with 3 different families living in 5 *khana gers* for 3 weeks in the Songino Khairkhan District within EcoTown's community in the 31st Khoroo to have a better understanding of the day to day challenges and advantages of living in a traditional *ger*.

Figure 4: Graph of Income of 18 different families. Graph demonstrate Husband, wife, and total household income.

While living with these different families, a broader pool of 15 additional families were interviewed to have a more extensive understanding of what families' current living situations were like in addition to understanding their future housing aspirations (see figure 4 for map of families interviewed in Songino Khairkhan). The questions asked sought to understand each family's: reason behind moving to Ulaanbaatar, current employment status, expenditures, loans, financial situation, health, current living practices in a *ger* and/or *baishin*, preferences surrounding their future home as well as current laws and regulations surrounding housing in the Ger Districts. Some of the key information collected during this time includes:

ii. Average Household Income

Based on the interviews conducted, salaries in general varied depending on the season. 16 out of 18 families interviewed had incomes that rely on seasonal jobs, where work was scarce in the winter time due to the lack of construction projects, for example, which is when heating load and energy consumption was the highest for the *ger*. The salary ranges from a minimum salary of 216, 000 MNT (an elderly person living alone off of welfare) to a maximum salary of 1, 950, 000 MNT (a household where both parents worked full-time jobs).

iii. Monthly Electric Bill

Based on the interviews conducted, the average for the monthly electric bill was 20,620 MNT per month - excluding 3 out of 18 families who used an electrical floor mat for additional heating (families 4,5, and 13). These three families were an anomaly because they utilized two heating systems - including an electric floor mat and a coal burning stove. Interestingly, all families split an electrical line and measured individual usage based on an electricity meter. For payment, the family to whom the main electrical line belonged would receive a text message from the billing company at the end of the month. Families who were splitting from the mainline would assess how much they used based on their electrical meter and pay the main family, who would then pay the full sum for the monthly bill through text message.

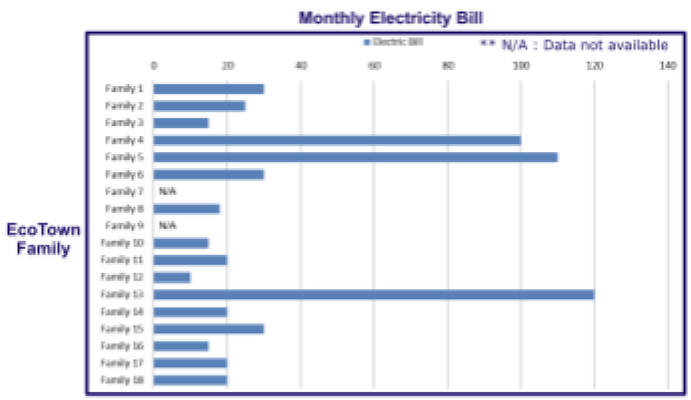

Figure 5: Graph of monthly electrical bill of 18 different families.

The range of electrical bill included a minimum of 10, 000 MNT (a 4 *khana ger*, with a single elderly person living alone), the mean electrical bill of 37,375 MNT (on average a 5 *khana ger*, with household of 4 to 5 family members), and a maximum electrical bill of 120,000 MNT. Often families who were using two heating systems would not be able to afford the heating costs long term - only keeping the electrical floor mat for two to four years. Unless the combined salary of the household was significantly higher than average, most families found it hard to maintain the long term use of an electrical heating system.

Lastly, the grid in the Ger Areas was strained and overused because there were not enough power stations in Ulaanbaatar to support the number of households in the Ger Areas, this caused extremely low flows of electricity during peak hours. Peak hours were between 7-9am and 5-8pm when families were preparing to leave their homes and returning home after work or school.

We conducted additional research to identify whether it was possible to find alternative ways to enable families in the Ger Areas to access better electrical currents - such as a shared photovoltaic system between multiple *Hashas* (plots of land) to share the costs and maintenance of the photovoltaic system. The thesis was that the photovoltaic system would provide a better electrical source and reduce the current stress on the electrical grid. After proposing this possibility to families in the Ger Areas however, families stated that they would be willing to share a photovoltaic system to reduce costs and help maintenance of the system - which was a positive and important note to keep in mind for future infrastructure and housing development in the Ger Areas.

iv. Coal Usage in Winter

The amount of coal families consumed was documented in detail. The goal was to develop a better understanding of the current baseline consumption of households to be able to understand how much cost savings and pollution reduction the Passive Ger could provide.

Families counted coal consumption through two different methods. One approach was their daily consumption of coal in kilos, the other was their seasonal consumption in tons of coal. On average, most families purchased anywhere from .5 to 2 trucks (the size of the truck varied - therefore exact figures on how many tons per truck is difficult to determine) worth of coal throughout October to early November before the extreme heating season in December. Depending on whether or not the family had purchased enough coal for the extreme heating season (Dec. - Feb.) they would potentially purchase another truck of coal or bags of coal through various informal vendors.

Once the truck would deliver and drop off the coal directly in the household's *Hasha* the family would proceed by bagging the coal into individual plastic bags, which would then be burned on the stove an average 3-4 times a day. Typically, the coal was burned once in the morning when families wake up, a second time in the middle of the day depending on whether anyone in the family was home, a third time in the afternoon after kids return from school, and one last time in the late evening before the family goes to sleep.

Based on families' estimate of their daily consumption, the range of daily usage of coal included a minimum of 8 kg, a mean of 19.9 kg, and the maximum of 30 kg. Families' estimated the range of coal consumed in tons throughout the winter to be within a minimum of 3 tons, a mean of 4.5 tons, and the maximum of 8 tons.

It is important to note that there were many variables that influenced the families coal usage including: the number of family members in the *ger*, occupancy during the day time, if the family had additional layers of felt (better insulating the *ger*), and the total volume of the *ger* (ranging from 4 *Khana* to 6 *Khana*, although traditionally 5 *Khana Ger* are the most common. *Khana*, refers to the number of walls that make up the *ger*'s diameter and increase the circumference of the *ger*. A 5 *Khana Ger* is approximately 5.8 meters in diameter, which is an area of approximately 36.32 m^2).

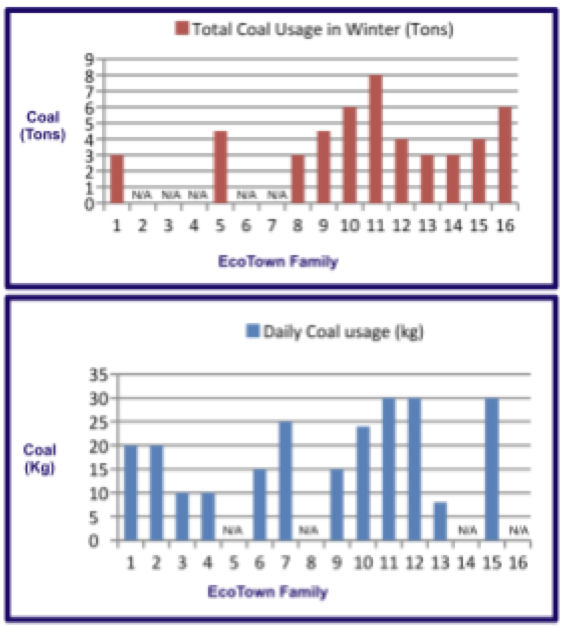

Figure 6: Graph of daily coal usage of families from Dec. - Feb.
Figure 7: Graph of total coal usage of families from Dec. - Feb. in Tons.

To conclude, these figures did not measure perfectly how much coal families were consuming as there were too many variables that influenced the families' estimate of how much coal they were consuming in the winter. However these figures did enable us to understand the scale at which families were consuming coal to heat their homes. For example, if we took the total average tons of coal consumed in the winter time by the families interviewed, approximately 4.5 tons of coal, and multiplied this figure by the current number of *ger* households in the Ger Districts, approximately 104,500 households according to the Mongolian Green Credit Fund, an average of 470,250 tons of coal would be burning from *ger* households alone in Ulaanbaatar. As a result, we can assume at least 48% of the Ger Area residents are burning 470,250 tons of coal. This approximate understanding enabled us to better understand the impact we could have in mitigating the air pollution crisis by creating an energy efficient *ger*.

v. Grocery and Medical Costs

Cataloging other aspects of family household expenses was also important, such as monthly grocery and medical costs. By better understanding standard grocery and medical costs, we identified how much excess cash families could potentially have on a monthly basis after their standard living costs. Our assumption was that the estimate behind these excess funds could potentially allow us to understand how to position the pricing of the energy efficient *ger*, while identifying additional opportunities for cost savings.

The range of monthly grocery costs included a minimum of 70, 000 MNT, a mean of 244,000 MNT, and a maximum of 1, 700, 000 MNT. Families had relatively low grocery costs. Common practices regarding meal preparation for the winter included families purchasing an entire cow, skinning it and chopping it up into smaller pieces in order to fit the cow into the freezers in the household. This enabled families to live off of a staple diet of flour, meat, rice, and milk, with the occasional root vegetables added.


Figure 8: Portait of Dulguun putting on his Air Pollution Mask

The range of monthly health costs included a minimum of 40, 000 MNT, a mean of 198,000 MNT, and a maximum of 400, 000 MNT. It was difficult for families to identify whether or not the health issues in the household were specifically related to air, water, or soil pollution. We recommend further research to be conducted in this area by a medical professional in order to properly document and assess whether living in a healthier built environment could significantly improve members of the household's health due to proper plumbing, clean heating sources, and more stable internal temperatures.


Figure 9: Tuya and Davka's Ger in Songino Khairkhan, and a neighboring Baishin behind their Hasha

vi. Perceptions on Living in *Gers* and *Baishins* in the Ger Districts

In order to better understand how families perceive living in the Ger Districts, we asked a wide variety of questions about the pros and cons of living in the Ger District, as well as what they believed were the pros and cons of living in a *ger* as well as a *baishin*. With this information, we hoped to develop a design that could meet the families ideal needs and preferences.

A. Perceptions living in *gers*;

Some perceived positive aspects of living in a *ger* in the Ger Areas vs. living in a *baishin*:

- "The Ger Areas can be a lot freer… because you aren't living with your neighbors on top of you"
- "Kids can run around outside"
- "The land could be valuable someday"
- "Soil could be good for planting vegetables"
- "The location is easier to park car"

Some perceived negative aspects of living in a *ger* in the Ger Areas vs. living in a *baishin*:

- "A ger is dirtier"
- "A ger is harder to maintain, changing the skin (the felt and canvas) to let it breadth two times a year is difficult"
- "Managing Coal is a pain"
- "The ger is small and uncomfortable when there are visitors"
- "The ger can be more dangerous because kids often burn themselves on the stove"
- "Getting water is really difficult"
- "The ger can smell bad"

B. Perceptions living in *Baishins;*

Some perceived positive aspects of living in a *baishin* in the Ger Areas vs. living in a *ger*:

- A baishin is easier to maintain (because you do not have to air out the felt walls twice a year to prevent mold growth, as you would in a traditional ger)
- A baishin is believed to be cleaner (because you don't have to clean the home as much)
- A baishin is more spacious (as the baishin can be built larger, with a non-fixed shape - compared to a ger)
- A baishin is more private (families can build separate rooms for privacy)
- A baishin is warmer (because of the hard walls and the removal of the "toono" - which is an open air skylight/oculos at the center of a ger)
- A baishin has more daylight (with the ability to have windows inserted in hard walls, instead of simply relying on the toono). And if families can save enough money, they look forward to having plumbing indoors (with an indoor toilet, shower, and sink system, instead of relying on an outhouse that requires one to walk outdoors, which can be a quite cold walk on a cold winter night).

Some perceived negative aspects of living in a *baishin* in the Ger Areas vs. living in a *ger*:

- Perception that a Baishin is a four walled box
- Mold growth is bad
- No ventilation - smells stay and door has to be opened for air circulation
- No bathroom, (families who build baishin themselves often don't install plumbing to cut construction cost and smells can come from toilet if bathroom is self made)
- Foundation often has no reinforcement to reduce construction costs
- Most families aren't aware that Ulaanbaatar is in a Seismic Zone, which is dangerous because the DIY buildings aren't engineered to handle earthquakes

vii. Key Takeaways

As a result of these interviews, critical information was selected to create an ideal energy efficient *ger*, adapted to the living aspirations of current *ger* household families living in the Ger Areas. The characteristics included:

- Building an energy efficient *ger*, using the Passive House Standard to reduce energy load on homes as much as possible
- Proper ventilation and air filtration
- An efficient and cost effective plumbing system that is adapted to the waterfall system of the Ger Areas
- A foundation and structural system that is built to Ulaanbaatar's seismic zone
- Fast and easy build of the *ger* was very important, families are willing to build themselves - DIY (Do It Yourself)
- No longer using stoves as a heat source, using instead an alternative cost effective heating system that does not pollute
- Making the *ger* easier to maintain, and a permanent structure. I.E. removing the need to take down the *ger* two times a year to air out the felt
- Option for separate rooms for privacy, while maintaining the shared space of the *ger*

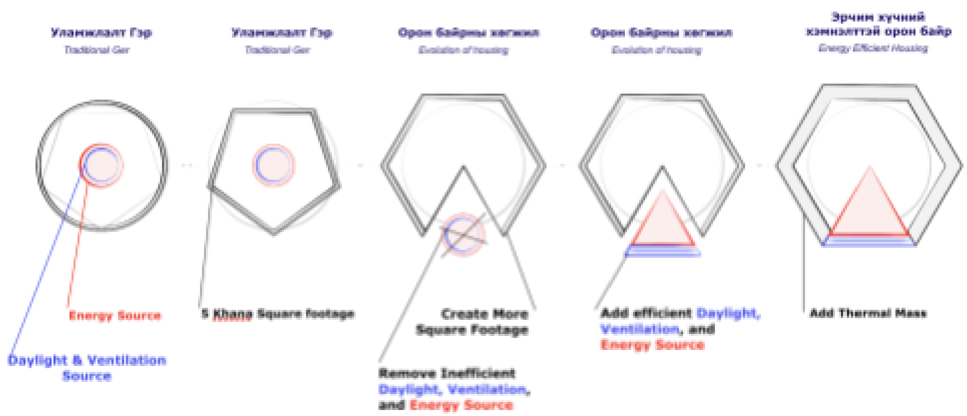

Figure 10: Diagram of Energy Efficient Ger Concept

In Figure 10 you will find a concept diagram of how this transformation was made from a traditional 5 Khana Ger to an improved energy efficient 6 Khana Ger. The evolution of the concept diagram illustrates the removal of the inefficient energy (the coal burning stove), daylight, and ventilation source (the Toono); combined with an increase of square footage to a 6 Khana Ger. As the square footage was increased, space was made for an efficient daylight and ventilation source (triple pane windows), and an alternative clean energy source. In addition, a strategically designed insulation system reduced heat loss, making the *ger* more energy efficient.

6. Architectural Design

c. Architectural Concept

Contrary to popular belief, the *ger* has experienced many stages of evolution from the simple wigwag to modern Mongol *ger*. Evolving over time to be the most suitable mobile home for nomadic herding life, from 3000s BC to the 20th century, the *ger* underwent critical transformation to adapt to new human and technological advances and social changes at each stage*([6])*. Currently, the urban settlement

[6] *Robinson, Carl. Mongolia: Nomad Empire of Eternal Blue Sky. Odyssey Books, 2010.*

trend for Mongolian families is to move from the countryside or smaller cities to the capital in Ulaanbaatar, seeking better job and educational opportunities. With families settling along the periphery of the planned urban areas with their *gers* - the trend created congested *ger* areas along the perimeter of the city, creating in turn intensive pollution in the heating season as families used coal burning stoves to heat their homes. This phenomenon contributed to approximately 80% of Ulaanbaatar's air pollution([7]).

As a result, because families are planning to stay permanently in Ulaanbaatar, there is once again a need for the *ger* to adapt to the sedentary urban context of the city in order to reduce air pollution while also adjusting the housing typology to have the necessary modern housing amenities - such as proper sanitation and alternative affordable heating solutions.

The architectural concept therefore is to develop a 21st century urban-adapted *ger*, where essential cultural practices surrounding the housing typology are conserved while the technologies of the building envelope used the Passive House Standard as a design and construction guideline to produce and consume significantly less energy to reduce the amount of air pollution in Ulaanbaatar. The Passive House Standard traditionally enables western style homes to consume 90% less energy, consuming a total of 15 KWh per Square meter per year [8]. Using the standard as a guideline therefore helped adapt the *ger* to modern building science practices and refine the housing typology to be energy efficient, airtight, manage moisture in the building envelope, and require less maintenance.

Figure 11: Diagram of internal ger symbolism from Kochevnik

i. Cultural Evolution of Symbolic Traditions Surrounding the Mongolian Ger: From Tradition to Current Practices in the Ger Areas

In Mongolian tradition, the *ger* and its interior is believed to symbolize a microscopic universe within the vast galaxy. The organization of the *ger* is connected with beliefs that simultaneously protect and provide fortune for the families within a *ger* from internal and external conflicts or spiritual harm[9]. The *ger*'s interior was broken up into 12 regions, each section representing a symbolic animal that corresponds to a household function. Each region acted as a double clock - where each animal had 2 hours; "the hour of the mouse (24-2), bull (2-4), tiger (4-6), hare (6-8), dragon (8-10), snake (10-12), horse (12-14), sheep (14-16), monkey (16-18), chicken (18-20), dog (20-22), and the pig (22-24). The mouse symbolized wealth and its accumulation, so the northern part of the *ger* was reserved for the most valuable possessions and guests of honor. Dog was a symbol for hunting, marking the space for storing weapons. Dragons and snakes symbolized water in all its manifestations; the women's (eastern) side was used for water containers. Under the sign of the sheep (south-west) were kept newborn lambs, and under the bull (north-east) were placed food

Figure 12: Diagram of internal ger symbolism from Kochevnik

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[7] "Зориг Сан - Би Монгол Хүний Саруул Ухаанд Итгэдэг." *Зориг Сан - Zorig Foundation*, zorigsan.mn/en/.

[8] Institute, Passive House. "Passive House Institute." *Passivhaus Institute*, 2015, www.passiv.de/en/02_informations/02_passive-house-requirements/02_passive-house-requirements.htm.

[9] Kochevnik. "Yurt - Nomaads Personal Universe - Ger, Mongol, 2014-2015. Yurthttp://www.kochevnik.ca/yurt-nomads-personal-universe.html

crates. Horse, a nomad's main possession, guarded the entrance and wellbeing of the owners."[10]

Today these traditions are still observed in *gers* in the Ger Areas - varying depending on the household's preferences and age. In the mouse's region, people usually placed pictures of their family and gods, placing figurines of religion in order to protect them from harm. The bull's angle was still used for storage, often using contemporary closets or drawers to hold clothes - instead of following the tradition of storing alcoholic beverages from animal milk because this area does not get any direct sunshine until the coldest months of the year.[11] Mostly, today men and women in the Ger Areas are no longer too concerned about which sex sit on which side of the *ger* - although visitors can often be invited to sit on the monkey and chicken's angle where a bed sits and visitors can often sleep. Traditionally men sit on the East side, and Women on the West. Families all slept on the North End of the *ger* between the dog and the bull, shifting from the tiger and the hare. The modern *ger* had been adapted to make room for other kitchen supplies such as an electric stove, a microwave, and freezer to store the meat - expanding the dragon's angle which was traditionally where families' utensils and foods could be found. Families traditionally continued to store their barrels of water, collecting from the well at the snake's angle. The horse angle and entrance was still required to face south. At the angle of the sheep, because families are no longer herding livestock in Ulaanbaatar, this area was often used for storage and a washing machine.

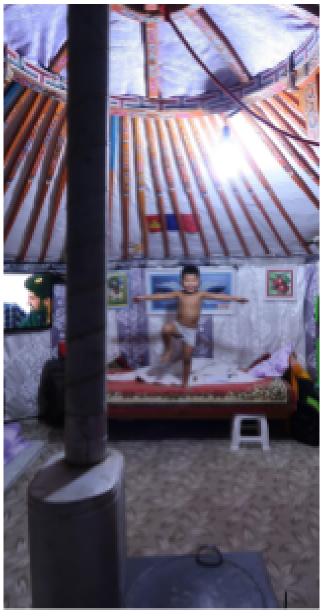

Figure 13: Interior of contemporary Ger in the Ger Areas of Ulaanbaatar.

ii. Passive Ger Design: 21st Century adaptations to the Mongolian ger and the introduction of modern amenities and contemporary building technologies

With the *ger* already having been slightly modified with the introduction of modern household technologies, the Passive Ger Design took into consideration existing cultural norms surrounding the *ger* while integrating modern housing amenities and contemporary building materials according to the Passive House Standard.

First, the south facing entrance was slightly moved to the right hand side to make way for a triple glazed south facing window, allowing for passive solar heat gain. Upon entering into the Passive Ger, there was a small vestibule space, reducing heat loss inside the *ger*, before entering into a bathroom with a traditional sink, shower, toilet, and 1 ton water tank system that will provide water to the shower, sinks and toilet. The position of the bathroom systems in this area enabled the new design to respect traditional practices - while practically locating the water tank for refills and enabling the bathroom to share a water wall with the kitchen to reduce

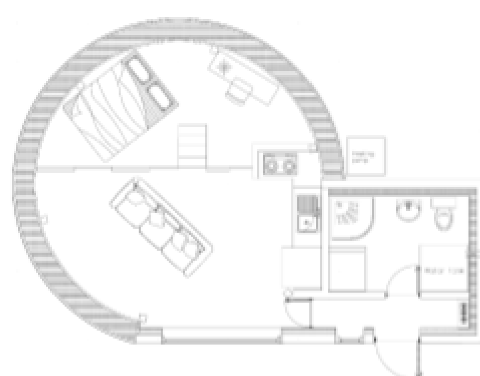

Figure 14: Passive Ger Floor Plan

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[10] Kochevnik. "Yurt - Nomaads Personal Universe - Ger, Mongol, 2014-2015. Yurthttp://www.kochevnik.ca/yurt-nomads-personal-universe.html

[11] Kochevnik. "Yurt - Nomaads Personal Universe - Ger, Mongol, 2014-2015. Yurthttp://www.kochevnik.ca/yurt-nomads-personal-universe.html

construction cost and allow for efficient plumbing. The living room and kitchen area continued to be combined. The elevated bedroom area left room for storage space below, removing clutter from the Passive ger walls. From the elevated bedroom area, there was a loft space on top of the mechanical core - acting as a second sleeping area for children.

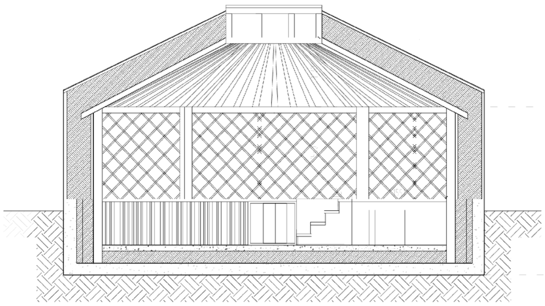

Figure 15: Interior Elevation of Passive Ger

Meanwhile, the building envelope was adjusted to use modern construction materials to make the Mongolian *ger* more energy efficient and reduce the maintenance of the building assembly. Looking at a wall section of the Passive Ger assembly, moving from the inside out, there is a primary structural wooden frame that took the majority of the compressive load of the wall and roof assembly, removing the *Bagana* (the traditional central pillars of the *ger*). Connecting behind this structural frame, wallpaper was laminate to a thin curved piece of wood - replacing the interior curtains that families usually hung in front of the *khana* of the ger, as many families in the Ger Areas feel the *khana* are hard to clean and prefer hard walls. Next is the interior *Khana* and *Uni* of the *ger*, on which sits a vapor barrier (to extract condensed water from inside the wall assembly), 4 layers of earthwool insulation, and an air barrier layer. The Passive Ger no longer used Mongolian felt as the manufacturing processes of the product often did not undergo strict washing protocols resulting in the material to have strong odors - especially when wet. After the air barrier was a *Khana* and *Uni* between the final outer PVC membrane layer, to allow for airflow below the PVC membrane and prevent condensation of the surface of the air barrier layer. PVC membrane is traditionally installed on rooftops on contemporary buildings, lasts for 50 to 100 years, is UV and water resistant. As a result, the performative qualities of PVC were more advantageous for this application; reducing maintenance of the Passive Ger, in comparison to a traditional *ger*'s cotton fabric which only lasts 3 years and is not water tight, causing water damage to the felt insulation.

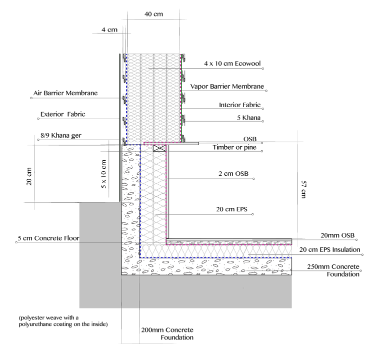

Figure 16: Interior rendering of Passive Ger

The layered application of these building materials used five basic principles of the Passive House standard as a guideline. Looking at the project in section elevation view, in comparison to the Passive House Standard the design demonstrates[12];

[12] Institute, Passive House. "Passive House Institute." *Passivhaus Institute*, 2015, www.passiv.de/en/02_informations/02_passive-house-requirements/02_passive-house-requirements.htm.

Passive House Standard	**Passive Ger**
Airtight envelope: Uncontrolled leakage through gaps must be smaller than 0.6 of the total house volume per hour during a pressure test at 50 Pascal (both pressurized and depressurised)	A continuous airtight envelope (dotted blue line + triple glazing windows). * *No air pressure test took place during the construction of the prototype, therefore final Pascal results are unknown.*
All opaque building components of the exterior envelope of the house must be very well-insulated. For most cool-temperate climates, this means a heat transfer coefficient (U-value) of 0.15 W at the most, i.e. a maximum of 0.15 watts per degree of temperature difference and per square meter of exterior surface are lost.	A continuous layer of thermal insulation. **According to Saint-Gobain's calculation, the Passive Ger currently consumes an average net energy of approximately 159 kWh/M2/year - ultimately 91 kWh/M2/Year than the Mongolian Green Finance corporation's requirements.*
Absence of Thermal bridges. All edges, corners, connections and penetrations must be planned and executed with great care, so that thermal bridges can be avoided. Thermal bridges which cannot be avoided must be minimized as far as possible.	No thermal bridges, reducing the amount of uncontrolled heat transfer from the interior to the exterior. **Connection details of the building were designed to best reduce the amount of thermal bridging.*
The window frames must be well insulated and fitted with low-e glazings filled with argon or krypton to prevent heat transfer. For most cool - temperate climates, this means a U-value of 0.80 W/(m²K) or less, with g-values around 50% (g-value= total solar transmittance, proportion of the solar energy available for the room).	Triple pane windows. **Windows were triple glazing and low-e glazing. However no argon or krypton was injected into the windows as the current workforce in the construction market often confuses the proper orientation of windows for correct energy efficiency application - wasting the gasses that already have a short life span.*
Efficient heat recovery ventilation is key, allowing for a good indoor air quality and saving energy. In Passive House, at least 75% of the heat from the exhaust air is transferred to the fresh air again by means of a heat exchanger.	Ventilation system. * The ventilation system was a small standardized ventilation system that could be found on the Mongolian market.

As the Passive Ger design was developed for middle income families in the Ger Areas of Ulaanbaatar, more cost effective variations of the Passive House Standard building strategies were implemented to reduce construction costs. The final design therefore did not consume an average of 15 Kwh/M2/year, however, it significantly improved the energy efficiency of the *ger* and while enabling the enclosure to be more durable and longer lasting.

b. Project Drawings

See Appendix: F_Passive Ger.pdf for FULL DRAWINGS SET

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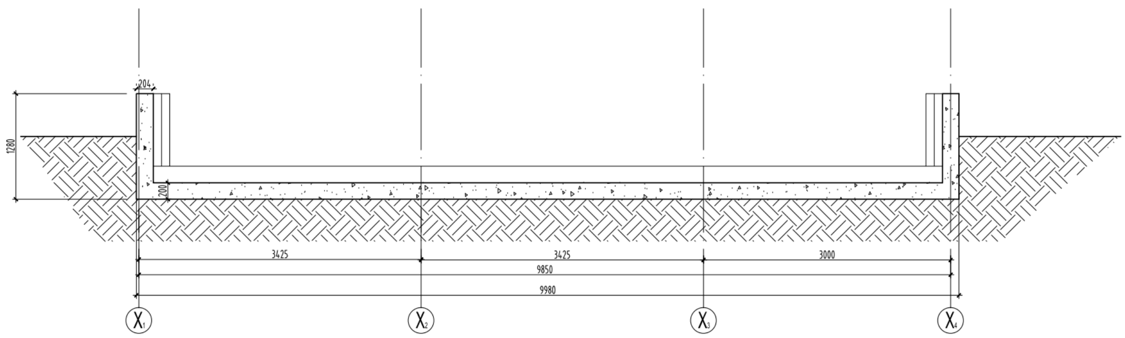

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Гүйцэтгэсэн	Б.Балжмаа			А3
Шалгасан	Э.Болор			2018 он

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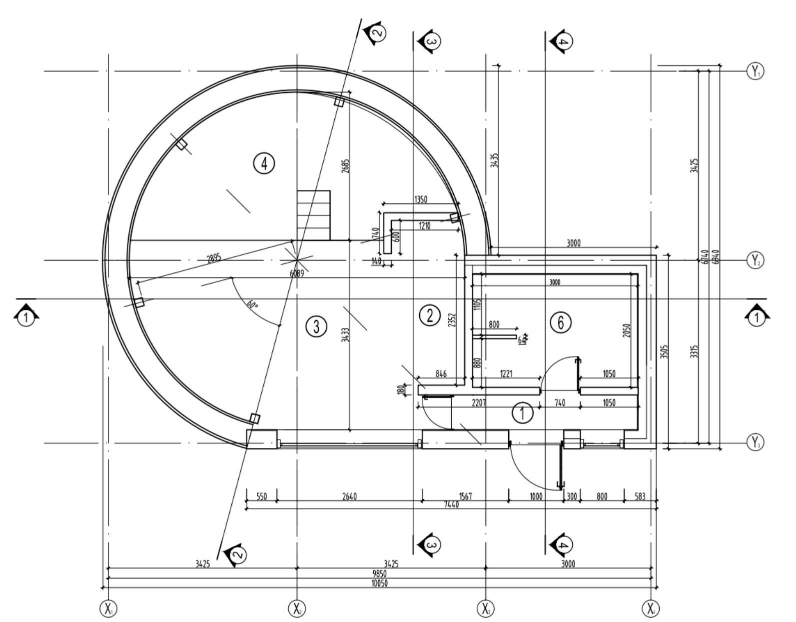

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3	Зочны өрөө	15.07
4	Унтлагын өрөө	11.02
5	LOFT	4.18
6	Угаалгын өрөө	6.16
7	Шат	0.54
	НИЙТ ТАЛБАЙ	43.06

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Архитектор	KIM Dupont-Madinier			Үе шат / Хуудас / Бүх хуудас
Гүйцэтгэсэн	Б.Балжмаа			А3
Шалгасан	Э.Болор			2018 он

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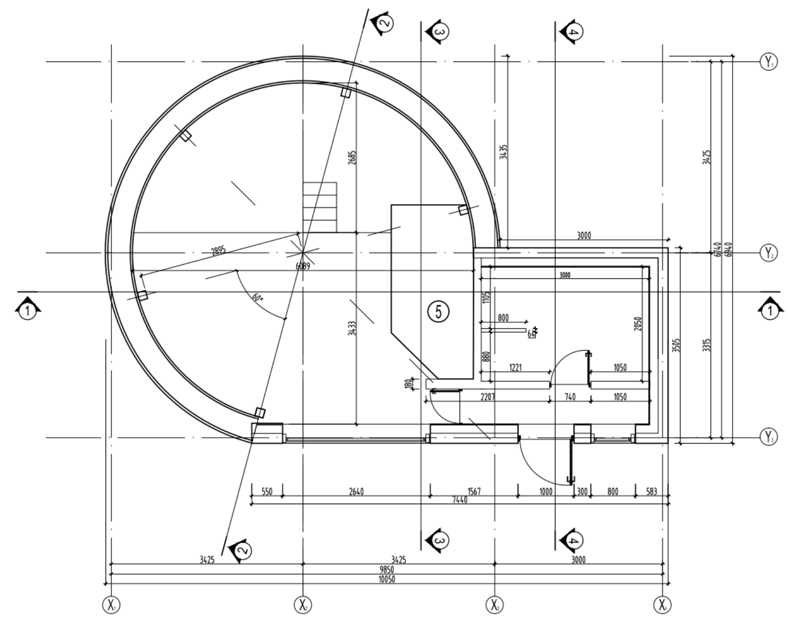

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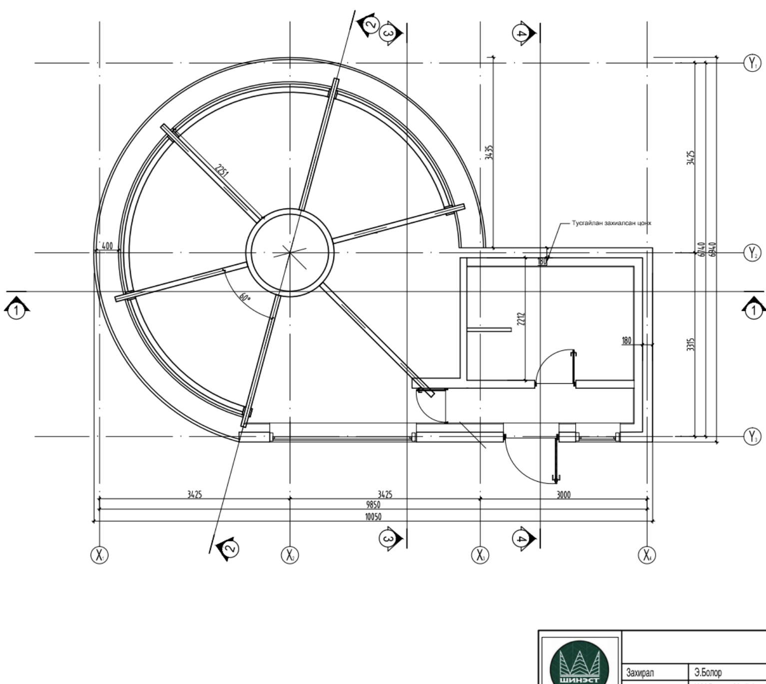

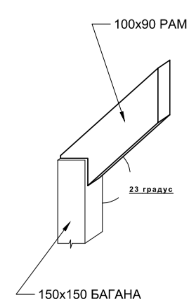

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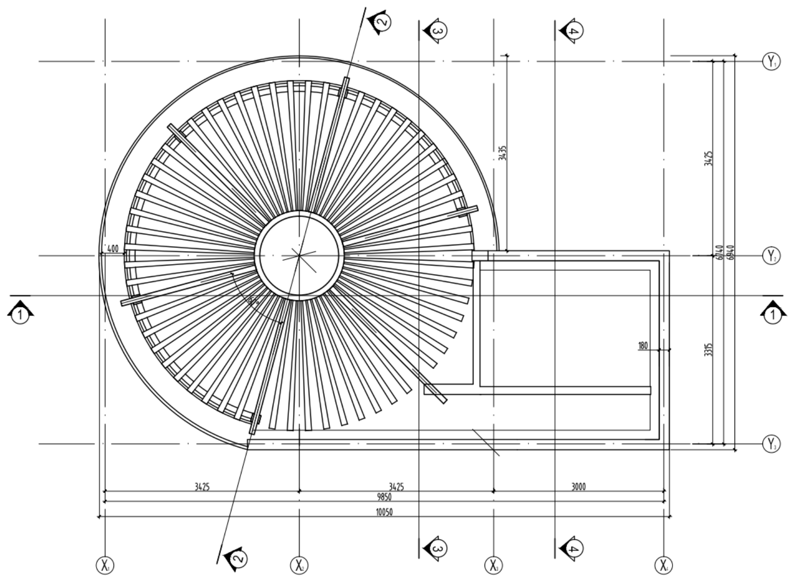

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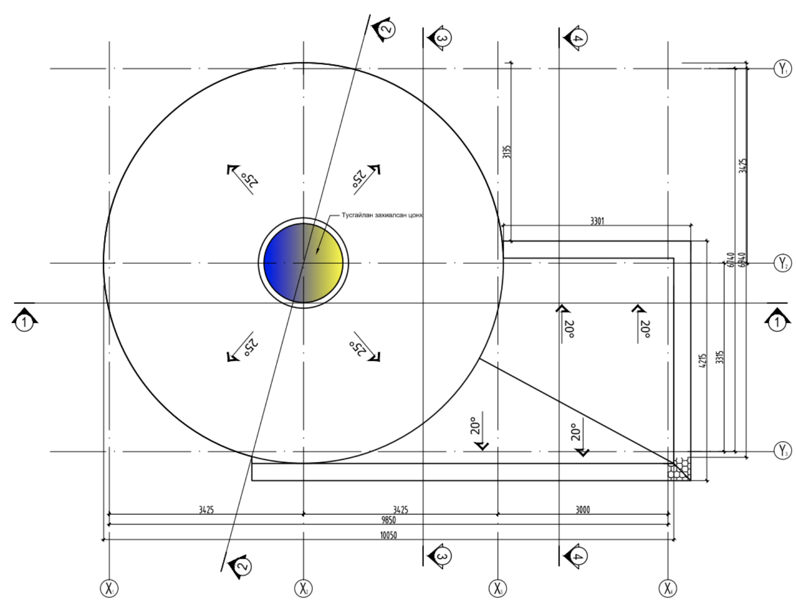

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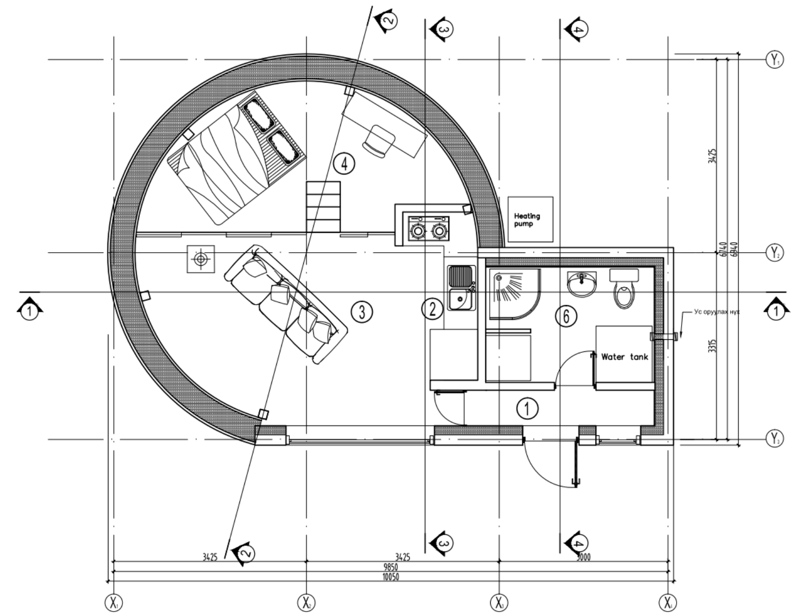

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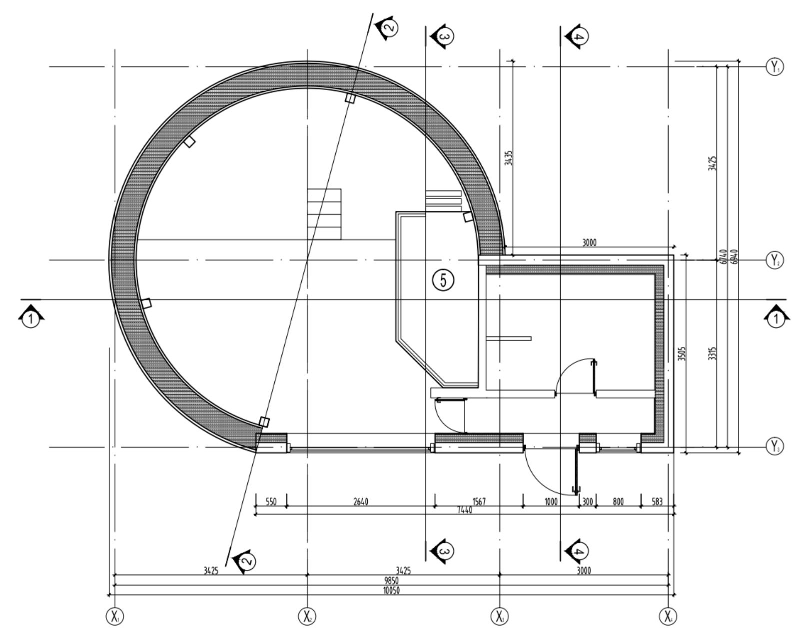

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Архитектор	KIM Dupont-Madinier		Үе шат / Хуудас / Бүх хуудас	
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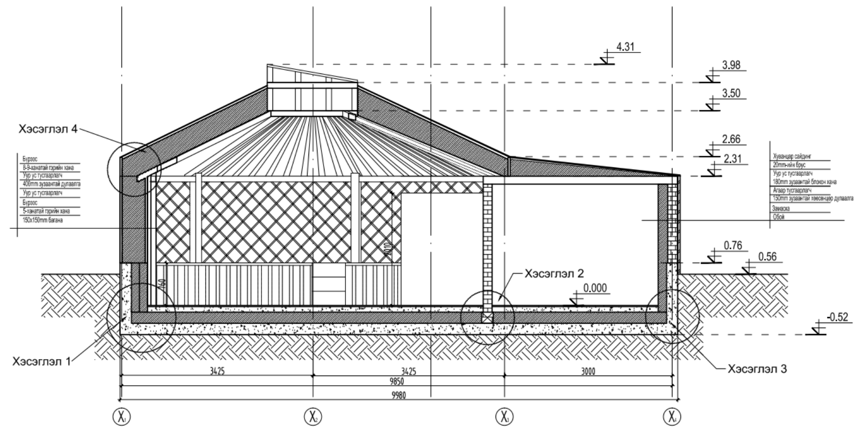

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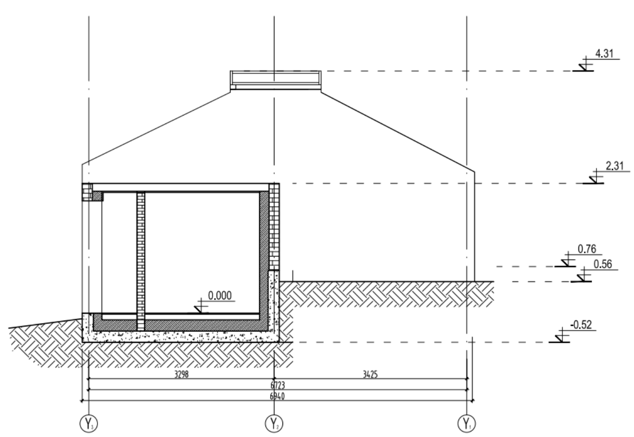

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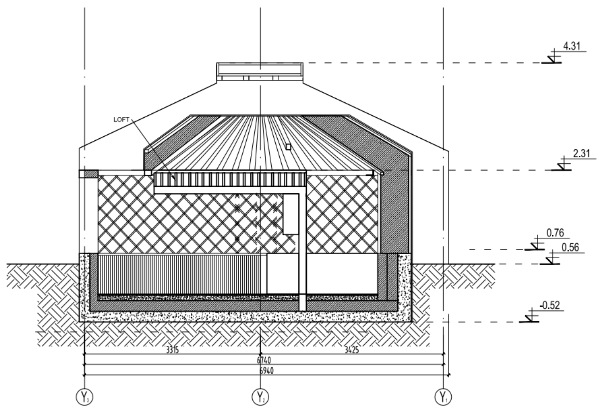

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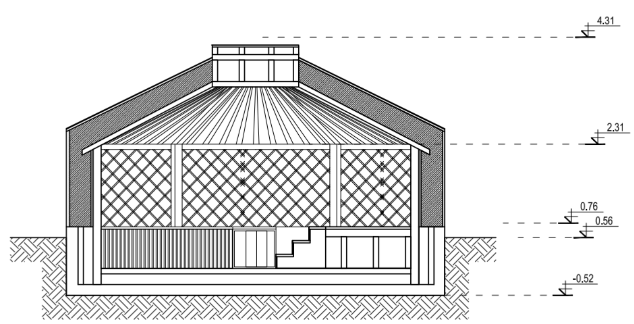

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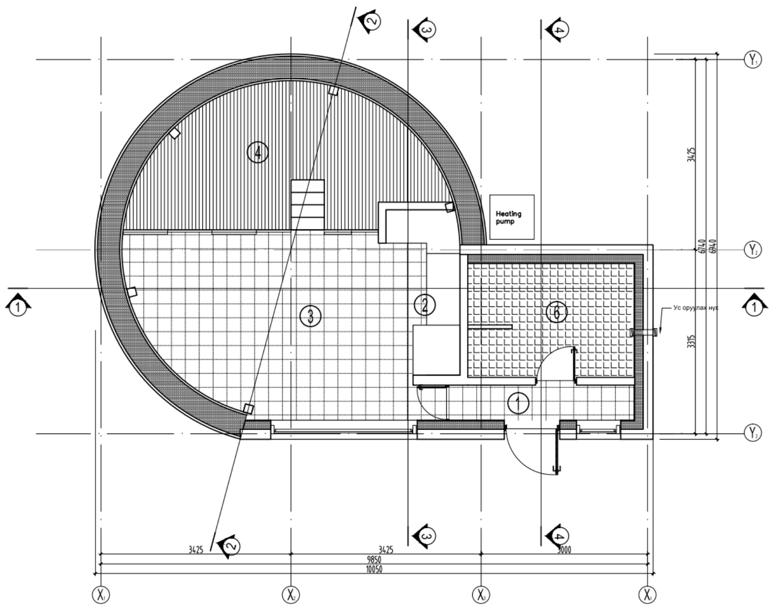

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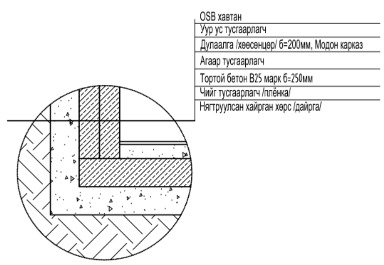

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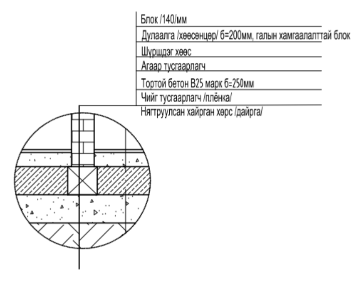

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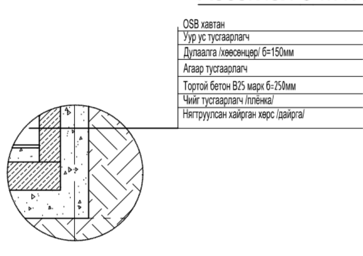

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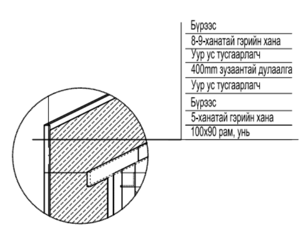
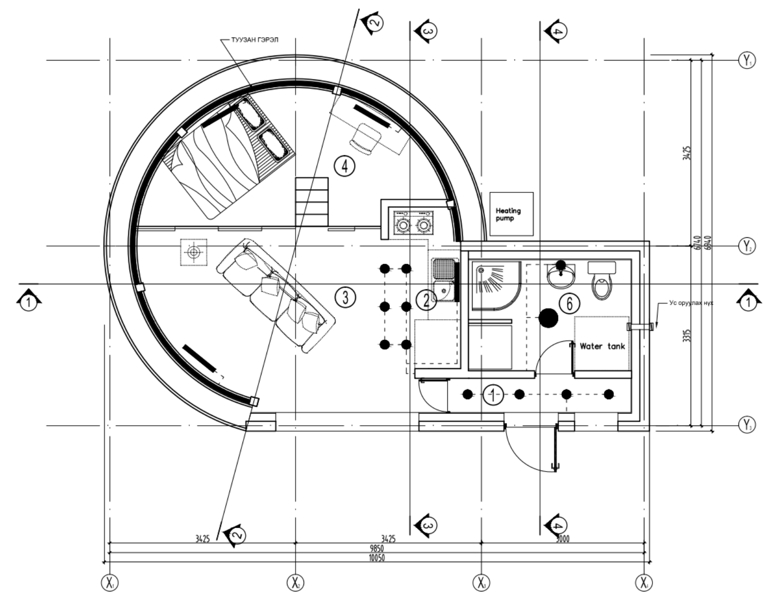


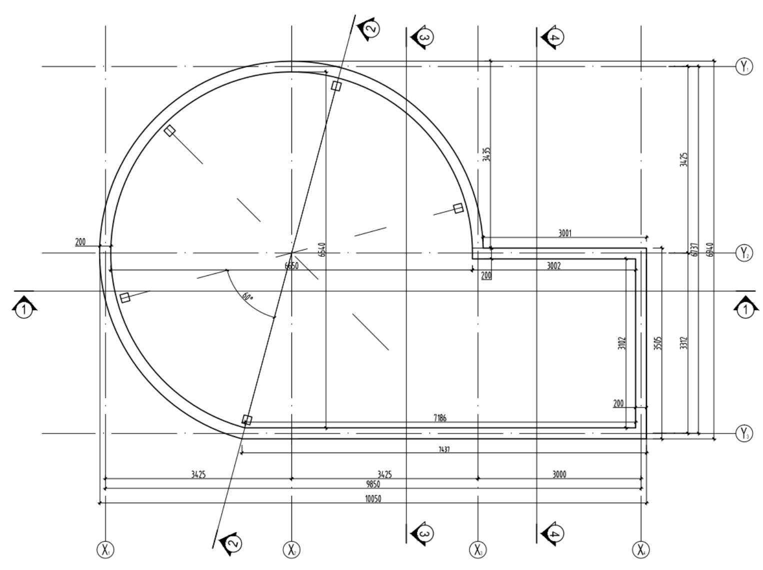
	PASSIVE GER			БА		
Захирал	Э.Болор		Хэсэглэл	Масштаб:		
Архитектор	KIM Dupont-Madinier			Үе шат	Хуудас	Бүх хуудас
Гүйцэтгэсэн	Б.Балжмаа			А3		
Шалгасан	Э.Болор			2018 он		

1-р давхрын гэрэлтүүлгийн байгуулалт М1:100



	PASSIVE GER				БА		
	Захирал	Э.Болор		1-р давхрын гэрэлтүүлэг	Масштаб:		
	Архитектор	KIM Dupont-Madinier			Үе шат	Хуудас	Бүх хуудас
	Гүйцэтгэсэн	Б.Балжмаа			А3		
	Шалгасан	Э.Болор			2018 он		

Суурийн байгуулалт М1:100



	PASSIVE GER				БА		
	Захирал	Э.Болор		Суурийн байгуулалт	Масштаб:		
	Архитектор	KIM Dupont-Madinier			Үе шат	Хуудас	Бүх хуудас
	Гүйцэтгэсэн	Б.Балжмаа			А3		
	Шалгасан	Э.Болор			2018 он		

d. **Standards and norms**

i. **Mongolian Construction Standard: BNbD 23_02_01**

The Passive Ger design followed Mongolian BNbD 23_02_01 standards for construction to ensure the design met the local building envelope requirements. According to building code, these were "set requirements for thermal performance of buildings to save energy while ensuring sanitary and optimal parameters of indoor climate and the durability of enclosing structures of buildings and structures."

1. Tabel 1 : Levels of Energy Efficiency

The Levels	Classification vs. Energy Efficiency	Deviation of design (actual) values of specific thermal energy consumption of for building heating, q_h^{des} from normative, %	Recommended Actions by Authorities
For new and reconstructed buildings			
A	Very good	Less than minus 51	Economic incentives
B	Good	Minus 10 to minus 50	Economic incentives
C	Normal	Plus 5 to minus 9	Increase the efficiency level
For existing buildings			
D	Poor	Plus 6 to plus 75	Preferred reconstruction of the building
E	Very poor	More than 76	Insulate the building in the near future

2. Table 2 : Standard values of resistance of building envelopes to heat transfer

Buildings and facilities, coefficients a, b.	Degree-days for heating period D_d, °C • day	Standard value of resistance of building envelopes to heat transfer, R_{req} m² • °C/W				
		Walls	Coverings above the passages	Coverings of attic floor & unheated basements	Windows & balcony doors	Roof lights with vertical glazing
1	2	3	4	5	6	7
1. Housing, medical and child care facilities, schools, boarding schools, hotels and hostels	2000	2.1	3.2	2.8	0.3	0.3
	4000	2.8	4.2	3.7	0.45	0.35
	6000	3.5	5.2	4.6	0.6	0.4
	8000	4.2	6.2	5.5	0.7	0.45
	10000	4.9	7.2	6.4	0.75	0.5
	12000	5.6	8.2	7.3	0.8	0.55
a	-	0.00035	0.0005	0.00045	-	0.000025
b	-	1.4	2.2	1.9	-	0.25
2. Public, except as outlined above; administrative, domestic, industrial and other with humid or wet conditions	2000	1.8	2.4	2.0	0.3	0.3
	4000	2.4	3.2	2.7	0.4	0.35
	6000	3.0	4.0	3.4	0.5	0.4
	8000	3.6	4.8	4.1	0.6	0.45
	10000	4.2	5.6	4.8	0.7	0.5
	12000	4.8	6.4	5.5	0.8	0.55
a	-	0.0003	0.0004	0.00035	0.00005	0.000025
b	-	1.2	1.6	1.3	0.2	0.25
3. Industrial with dry and normal conditions	2000	1.4	2.0	1.4	0.25	0.2
	4000	1.8	2.5	1.8	0.3	0.25
	6000	2.2	3.0	2.2	0.35	0.3
	8000	2.6	3.5	2.6	0.4	0.35
	10000	3.0	4.0	3.0	0.45	0.4
	12000	3.4	4.5	3.4	0.5	0.45
a	-	0.002	0.00025	0.0002	0.000025	0.000025
b	-	1.0	1.5	1.0	0.2	0.15

3. Heat transfer coefficients of inner surface of enclosing structures

The inner surface of envelopes	Heat transfer coefficient α_{int} W/(m^2 • °C)
1. Walls, floors, smooth ceilings and ceilings with protruding ribs with relation of the height ***h*** of ribs to the distance ***a*** between the edges of neighboring ribs is $h/a \leq 0.3$	8.7
2. Ceilings with protruding ribs with relation $h/a > 0.3$	7.6
3. Windows	8.0
4. Roof lights	9.9

4. Normalized Specific Consumption of thermal energy for heating of flat residential buildings (detached and blocked)

Heated floor area of houses, m2	No. of floors			
	1	2	3	4
60 and less	38.9	-	-	-
100	34.7	37.5	-	-
150	30.6	33.3	36.1	-
250	27.8	29.2	30.6	31.9
400	-	25.0	26.4	27.8
600	-	22.2	23.6	25.0
1000 and more	-	19.4	20.8	22.2

5. Standardized air permeability of building envelopes

Enveloping structures	Air permeability G_n, kg /(m2 • h), max
1. Exterior walls, coverings & ceilings of residential, public, administrative and utility buildings and premises	0.5
2. Exterior walls, coverings & ceilings of industrial buildings and premises	1.0
3. Joints between panels of exterior walls of: a) residential buildings b) industrial buildings	 0.5* 1.0*
4. Entrance doors to apartments	1.5
5 Entrance doors to residential, public and utility buildings	7.0
6. Windows and balcony doors of residential, public and utility buildings and premises, in wooden frames; windows & roof lights of industrial buildings with air conditioning	6.0
7. Windows and balcony doors of residential, public and utility buildings and premises, in plastic or aluminum frames	5.0
8. Windows, doors and gates of industrial buildings	8.0
9. Roof lights of industrial buildings	10.0

In kg /(m • h).

6. Maximum allowable values of the coefficient Δwav (Protection of Building envelopes against over-moistness

"*Resistance to steam infiltration, Rvp , m2 • h • Pa /mg, of enclosing structures (ranging from the inner surface to the flat surface with potential condensation) should be not less than the greatest of the following values of normalized steam infiltration resistance:*

a) normalized resistance to steam infiltration, Rreq m2 • h • Pa /mg (the condition of non-accumulation vp1 of moisture in building envelopes for the annual period of operation), defined by the formula: Rreq =(e −E)R*e* (E−e)

b) normalized resistance to steam infiltration, Rreq m2 • h • Pa /mg (the condition limiting moisture in vp2 the enclosing structures for the period with negative average monthly temperature of outside air), determined by the formula: Rreq = 0.0024z0 (eint − E*0)*"[13]

Please consult the Appendix to review the Mongolian construction standards in further detail.

ii. Passive Ger Standard

In using the Passive House Standard as a guideline to develop an energy efficient *ger*, the goal was to significantly reduce the energy load of the *ger* by developing a building envelope design to minimize the amount of heat loss through thermal bridging and uncontrolled air filtration.

According to The Passive House Institute, in order to meet the Passive House Standard[14], the design of the *ger* had to apply five basic principles for the construction:

Traditional Passive House Standard Components and Metrics	**Passive Ger Design**
Thermal insulation: All opaque building components of the exterior envelope of the house must be very well-insulated. For most cool-temperate climates, this means a heat transfer coefficient (U-value) of 0.15 W/(m²K) at the most, i.e. a maximum of 0.15 watts per degree of temperature difference and per square meter of exterior surface are lost.	- Wall to Roof system of the ger was comprised of 40cm of Rockwool Insulation; Lower Wall= 5.2 (m2K/W), Upper Wall and Roof System = 4.8 (m2K/W) - Wall to Roof system of the technical core was 20cm of Rockwool insulation and 20cm of concrete and 18cm of mudbrick finish = 4.6 (m2K/W) - Floor to Wall System was comprised of 20cm of EPS Insulation and 20cm of reinforced concrete = 4.4 (m2K/W)

[13] LIST OF NORMATIVE REFERENCES USED IN THESE STANDARDS - See Appendix
[14] Institute, Passive House. "Passive House Institute." *Passivhaus Institute*, 2015, www.passiv.de/en/02_informations/02_passive-house-requirements/02_passive-house-requirements.htm.

Passive House windows : The window frames must be well insulated and fitted with low-e glazings filled with argon or krypton to prevent heat transfer. For most cool-temperate climates, this means a U-value of 0.80 W/(m²K) or less, with g-values around 50% (g-value= total solar transmittance, proportion of the solar energy available for the room).	Triple glazed windows on the South side and on the Toono with low-e glazing, yet no argon or krypton embedded injected into the windows as the current workforce in the construction market often confuses the proper orientation of windows for correct energy efficiency application. = 7.6 (m2K/W).
Ventilation heat recovery: Efficient heat recovery ventilation is key, allowing for a good indoor air quality and saving energy. In Passive House, at least 75% of the heat from the exhaust air is transferred to the fresh air again by means of a heat exchanger.	No ventilation heat recovery system was installed to reduce excess electrical consumption of the Passive Ger and keep construction costs low. However an air to air heat pump system will allow for controlled airflow between exterior and interior in the heating season.
Airtightness of the building: Uncontrolled leakage through gaps must be smaller than 0.6 of the total house volume per hour during a pressure test at 50 Pascal (both pressurized and depressurised).	A continuous air barrier and vapor barrier lines the outer *ger* and inner *ger* in order to control air and moisture flow.
Absence of thermal bridges: All edges, corners, connections and penetrations must be planned and executed with great care, so that thermal bridges can be avoided. Thermal bridges which cannot be avoided must be minimized as far as possible.	Passive Ger contained a continuous layer of insulation in order to refrain from any thermal bridging.

All design developments in the Passive Ger are congruent to local construction practices and familiar material applications in high rise construction projects in Ulaanbaatar Mongolia while using the Passive House Standard to design specifically for significant thermal and moisture improvement. As the Passive Ger was intended for middle income families in the Ger Areas - significantly lower cost calculations were taken into consideration when calculating material applications while maintaining high energy and moisture standards in order to reduce costs and meet the project objectives.

7. Engineering and Construction

e. Engineering and Construction Summary

The engineering and construction behind the Passive Ger's was a combination between the *Ger*'s traditional building practices, energy efficient construction techniques, and simplistic engineered systems. The combination of these efforts allowed the Passive Ger to not only adapt to more rigorous building code standards, but also mitigate the production of air and soil pollution in the Ger Districts of Ulaanbaatar.

f. Structural Design

The Passive Ger's structural system was a hybrid structure that preserved some of the traditional structural properties of the *ger* (and some of existing construction practices in the Ger Areas) while adding additional support structures to take into account the supplementary material loads and appropriate assemblies necessary to enable the *ger* to follow Passive House construction practices. The design of the structure was adapted to allow the *ger* to be more spacious, removing the *Bagana* (the traditional central pillars holding up the compressive load of the *Toono*) according to families preferences in the Ger Areas. The structure can be broken down into a three part system; a primary structural frame, an inner 6 *Khana Ger*, and an outer 8 *Khana ger*.

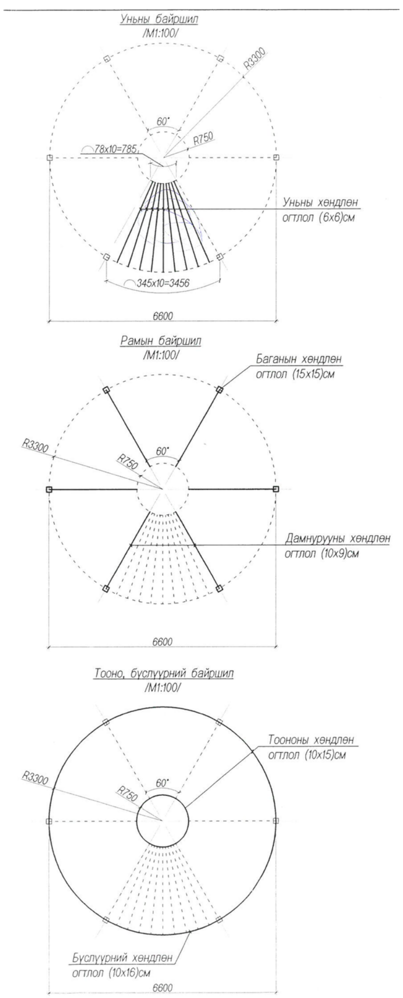


Figure 18: Structural Calculations from BBCMO Firm for the Primary Structure of the Passive Ger

The primary structural frame was developed by the executive engineer b. bat-erdene from the BBCMO firm based in Ulaanbaatar. The structural calculations took into consideration the forces on the building, including the uni, the ribs, the structural ring, and columns in order to be able to endure all loads. The frame is composed of 6 wooden column (15x15cm) to rib (10x9cm) components that line the inner *Khana* and *Uni* of the inner 6 *Khana Ger* and connect to the inner *Toono* (which is sized for a 6 *Khana Ger)*. The columns and ribs were braced by a rolled steel ring (to reduce costs) that connect on the column, where the column and rib connect at a height of approximately 2.280 meters.

The inner 6 *Khana Ger* wass installed behind the 6 columns and ribs of the primary structural frame, using the standard wooden *Khana and Uni* which also connect to the inner *Toono* (which is sized for a 6 *Khana Ger)*. The *Khana* sit elevated by 76 cm on a concrete rim that lines the inner perimeter of the *Ger*. In pairing the inner *Ger* with the primary structure, the *Khana* and *Uni* help hold the compressive load of the vapor barrier, added layers of insulation, air barrier, outer *Uni*, PVC membrane, and *Toono* Window.

The outer 8 *Khana Ger* acted as a tertiary structure. Similar to the 6 *Khana Ger*, the *Khana* sat elevated by 128 cm on a concrete rim that lines the outer perimeter of the *Ger*, enabling for the proper flow of rainwater outside of the *ger*. The outer 8 *Khana Ger*'s structural role was to hold in the many layers of insulation, as well as provide an air gap between the air barrier and PVC membrane to prevent long-term moisture condensation on the air barrier membrane. In turn, proper airflow enabled any moisture condensation to evaporate and maintain a healthy wall assembly.

Lastly, the reinforced concrete foundation of the *ger* was 20 cm thick by 694 cm in diameter and embedded 1 meter deep into the ground to retain heat as well as maintain the standard propositions of the *ger* from the exterior. The perimeter was surrounded by a 10cm thick by 128 cm tall concrete rim, which protruded out of the ground an additional 28cm to help control rain water flow and refrain from any penetration to the interior of the *ger*.

g. Construction Design

i. Construction Design Summary

The construction process was designed to be an enhanced version of how families currently build their *gers* in the Ger Districts. In learning from existing construction practices in the Ger Districts, these findings were internalized and reengineered to apply measured alternative solutions for the structure, foundation, plumbing, heating, electrical, and building envelope performance. The combination of these efforts enabled a systematized approach to upgrading a standardized housing typology, to develop a 21st century *ger* for the Ger Areas of Ulaanbaatar.

ii. Construction Strategy

The construction period was aimed to be as efficient and cost-effective as possible. The objective was to minimize construction time and costs by maintaining the tradition of home owners' contribution to the construction process, while avoiding the participation of large scale construction companies and employing instead the appropriate subcontractors (such as plumbers, carpenters, welders, etc.) from the EcoTown community. In turn, this created opportunities for job creation within the Ger Districts while lowering costs for the construction of the Passive Gert.

iii. Lead times and Subcontractor of construction materials

The Construction of the Passive Ger is estimated to take approximately one month to build. The following gantt chart shows the project schedule and the dependencies that exist between each stage and each of the components of the construction process. The table on the left lists out the task under each critical milestone: the foundation, structure, floor installation, interior to exterior construction, concluding with the final finishes and landscaping. Based on the timeline indicated in the x-axis, the length of the horizontal bars next to the task indicate the amount of days it would take to conduct the indicated task.

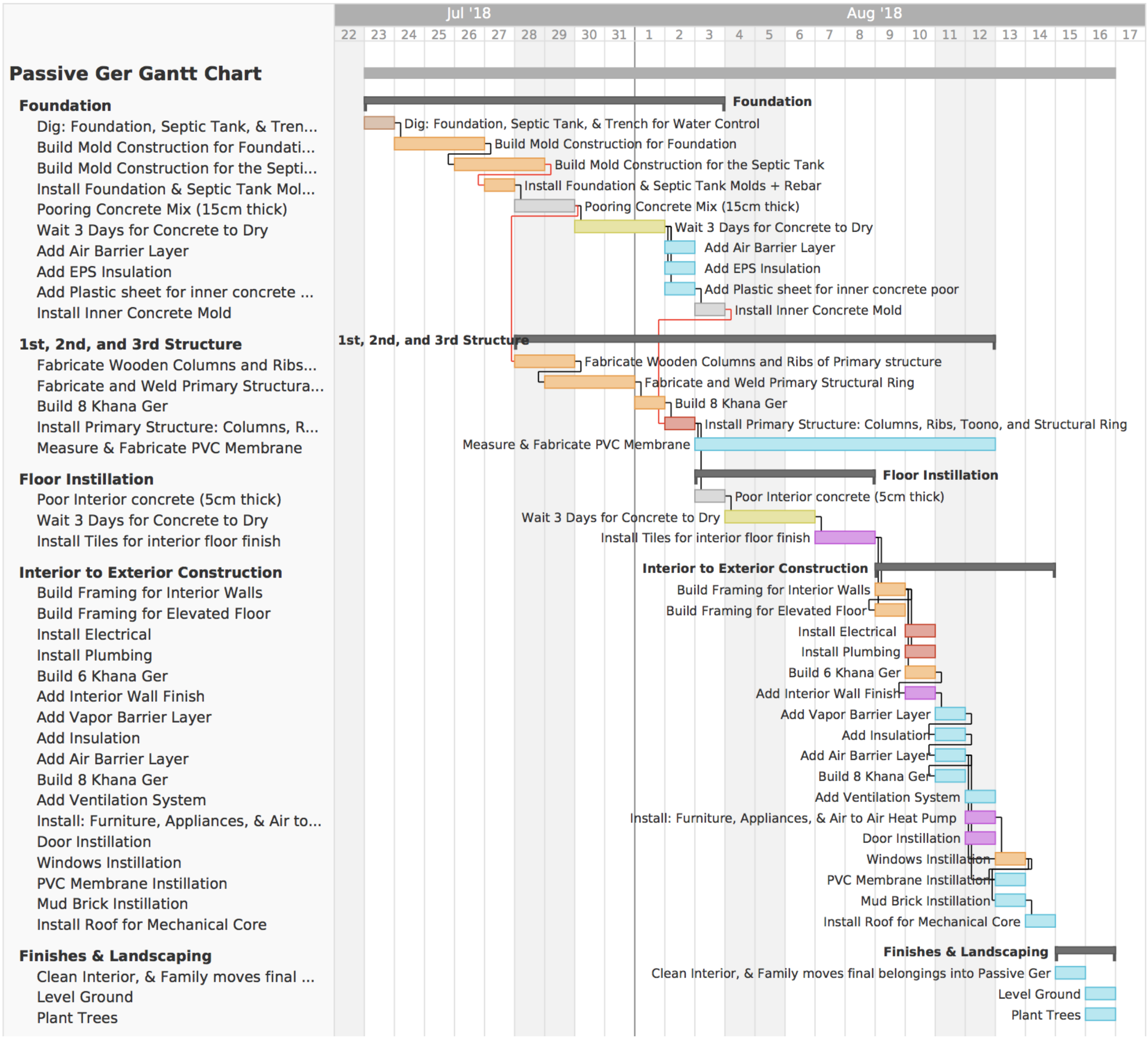


Figure 19: Gantt chart for build

h. Plumbing Design

Taking into account the lack of infrastructure in the Ger Areas and the water well stations that families used to supply cooking and cleaning water to their homes, the housing product included a variety of modern housing amenities that were adapted to work without central infrastructure.

The plumbing design for the Passive Ger used a centralized water system, and a one ton water tank that was installed in the bathroom to meet the totality of the household's water needs (kitchen sink, shower, bathroom sink, toilet and washing machine). Above the one ton tank was a water heater that could pump hot water to each of the appropriate household appliances. The tank could be filled bi-weekly by a water truck that would come to deliver and pump water to the tank through a pipe on the eastern wall. This channel was capped from both sides when not in use to refrain from unnecessary heat loss. This approach was easier for families as the system no longer required families to fill empty barrels and personally wheel the water back to their homes.

Lastly, the toilet system was no longer a latrine. To avoid soil and well water contamination which often resulted in exposure to hazardous bacteria and viruses such as Hepatitis, a proper septic system was installed with a three part tank system to treat solid and liquid waste up to 70%.

i. Electrical/Lighting Design

The electrical and lighting design aimed to maximize daylight and energy efficient LED lighting, while conserving as much energy as possible.

Unlike a traditional *ger*, which only has a natural daylighting source through the *Toono* (with no window), the Passive Ger benefited from two triple glazed south facing windows in the entrance hallway (*w*80 cm x *h*100 cm) and the living room area (*w*260 cm x *h*150 cm), providing both passive solar heat gain and ventilation in parallel with the triple glazed window on the *Toono* (*d*150 cm).

Meanwhile, artificial lighting on the interior of the Passive Ger was divided into two types and six sections. Traditional LED ceiling bulb lighting with the entrance hallway, bathroom, and kitchen; and strip LED lighting, that lines the structural ring of the *ger* and uplights the *Uni* in the living room, bedroom, and loft area.

2. Energy and Moisture Performance

a. Energy and Moisture Summary

The driving force behind the Passive Ger was the challenge of adapting a Mongolian *ger* to meet the passive house criteria in order to reduce the *ger*'s heat loss, energy consumption, and moisture damage. Because the Passive House Standard is one of the highest construction standards for energy efficient buildings - the goal was to use the standard as a guideline for the building performance of *ger* to leapfrog into a significantly more energy efficient assembly, ultimately adapting the *ger* through a simple application of 21st century building technology.

To meet the Passive House Standard, the total energy consumption was not to exceed 120 kWh/M2/year[15]. A large portion of the energy was dedicated to heating water for household appliances and domestic use. What made the energy efficient standard appealing for Ulaanbaatar's climate, was the exceptionally low heating and cooling load on the space - requiring an annual demand to be less than 15kWh/M2/year.

As a result, to reduce the *ger*'s heat loss, it was critical to adapt the *ger*'s assembly for it to be highly insulated and airtight to reduce the thermal conduction of the building materials between the inside and outside temperatures. The new design also needed to redesign the air filtration that escaped the building envelope through poorly designed and installed construction details in a traditional *ger*[16].

Two different kinds of energy assessments of the Passive Ger were conducted by two different organizations.

The first was by a local engineering firm with a focus in building science, Building Technology's Engineering Company (BTEC), a Mongolian building science engineering firm. The engineering firm used German modeling tools to assess the total energy loads on the building, however their assessment did not include a specific vapor and air barrier as the organization believed these materials to not be important when calculating the heat loss and energy load on the building.

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15 Institute, Passive House. "Passive House Institute." *Passivhaus Institute*, 2015, www.passiv.de/en/02_informations/02_passive-house-requirements/02_passive-house-requirements.htm.

16 "Calculating Heat Loss." *Materials - Plastics*, www.sensiblehouse.org/nrg_heatloss.htm.

The second party to conduct a performance assessment of the Passive Ger was the Energy and Moisture Team of the Research and Development group of the CertainTeed Corporation (a wholly owned subsidiary of Saint-Gobain). CertainTeed is a North American manufacturer of building materials for both commercial and residential construction. The R & D's Energy and Moisture group evaluated the heating degree days, energy needs, solar gain, surface and heat losses of the design, as well as the conducting moisture simulations for the passive ger prototype.

b. Heating and Energy Load Assessment : Buildtech

i. Climate Assessment

Buildtech's climate research indicates that the average temperature range in Ulaanbaatar is a typical annual range of -25°C – 18°C[17].

The three graphs demonstrate a 3 part assessment of the Passive Ger Design throughout the year. The first graph determined the external air temperature throughout the year in Ulaanbaatar. The second graph outlined the overall heating load for the Passive Ger throughout the year; measuring how much heat needed to reach comfort temperatures of 19°C - which is a good general approximation of climate. The third graph summarized all other energy and environmental loads on the Passive Ger including the amount or air filtration, the solar, lighting, persons, and devices energy loads on the housing system.

What made Ulaanbaatar's climate especially challenging to design for however was the extreme cold winter temperatures that drop to as low as -40°C. The heating system therefore had to be accurately dimensioned for the heating load of the coldest day of the year, even though these extreme temperatures are outside the average annual demand. For example on February 15, the coldest day of the year, BTEC estimated this heating load would approximately be 2,701kWh - demonstrating the required heating load dimension of the final selected heating system. *(see appendix "Buildtech_Energy Assessment" Page 4 for further detail)*

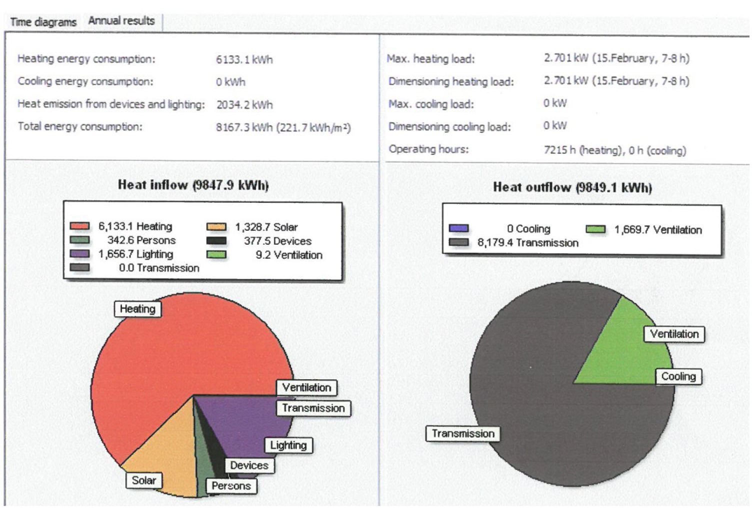

Figure 21: Heat inflow and outflow chart for Passive Ger

ii. Heating Flows and Distribution Summary

To calculate the energy efficiency of a building, the total energy load needed to be accounted for. BTEC used a software to generate a comprehensive study of the total energy gains and losses of the Passive Ger. Their simulations accounted for a total energy consumption of 8167.3 kWh (221.7 kWh/M2/year). When calculating the average yearly heating energy consumption per M2, from the

[17] "Climate & Weather Averages in Ulaanbaatar, Mongolia." *Timeanddate.com*, www.timeanddate.com/weather/mongolia/ulaanbaatar/climate.

total of 6133.1kWh, the final result was 166.66 kWh/M2/year. (*See figure 21)*

The heat inflow chart demonstrates the total amount of added heating loads to the building, including the; heating, passive solar gains, persons, electronic devices, lighting, and ventilation loads. The total heat inflow according to BTEC's calculations amounts to approximately 9,847.9 kWh.

A heat outflow chart was also developed to demonstrate the amount of heat loss throughout the year through the ventilation systems and general passive transmissions. The calculations did not account for a cooling system to reduce the Passive Ger's material, building, and operational costs. The total heat outflow's calculation was therefore 9,849.1 kWh.

Lastly, as the Passive Ger's assembly is an open floor plan a majority of the heat distribution is generally evenly dispersed within the living room, kitchen, bedroom, and loft area. However as the bathroom area is separate from the central heating system, a small additional heater may be required to achieve thermal comfort.

c. Heating and Energy Load Assessment: Saint-Gobain

Due to the project's overarching goal to create an energy efficient ger that was to be permanently adapted for the Ger Areas, Saint-Gobain's calculations primarily focus included; the heating degree days, energy needs, solar gain, surface and heat losses of the design, and to conclude moisture simulations for the Passive Ger Design.

i. Disclaimer

"CertainTeed's Energy and Moisture study provides support for the construction design and is performed on the basis of information provided by the client (the Fulbright Research Fellow).

Due to the nature of the study involving use of hypothetical data, the results arising therefrom may differ from the actual conditions observed inside the construction subject to the study.

Therefore, Saint-Gobain CertainTeed makes no representations or warranties, express or implied, as to exhaustiveness of the possible scenarios and as to the match between the simulation results and the actual conditions observed inside the construction."

ii. Average Heating Degree Days

Heating degree day (HDD) was a measurement designed to quantify the demand for energy needed to heat a building, deriving measurements from the outside air temperature of the local site [18]. In this case, CertainTeed's Energy and Moisture group has calculated the total number of heating degree days in Ulaanbaatar from 1998 to 2016. The heating degree days for each year were the total number of days that had an average temperature that was below 18.3 °C. In order to maintain internal thermal comfort, the Passive Ger therefore needed to be heated - which was calculated in conjunction with the R-values of the Passive Ger's building envelope (See table below for CertainTeed's total R-Values accounted per each component of the Passive Ger Assembly).

	UP. ROOF	DOWN	UN.WIND.	WINDOW1	WINDOW2	Ground	SQUARE	Door	Thermal bri	Air infiltration	
A (m2)	77.5	12.5	1.4	2.6	1.1	40.3	15.8	2.0	-	10.0	
R (m2K/W)	4.8	5.2	7.6	1.6	1.6	4.4	4.4	1.0	-	-	
W/K	16.1	2.4	0.2	1.6	0.7	9.2	3.6	2.1	3.6	16.1	55.6
								35.9		=Ca*Q50/20	

Figure 22: CertainTeed's R-value Calculations for Passive Ger

[18]Staff, Investopedia. "Heating Degree Day - HDD." *Investopedia*, Investopedia, 18 Apr. 2018, www.investopedia.com/terms/h/heatingdegreeday.asp.

Based on the Energy and Moisture's team's results, the team calculated an average net energy required (represented in the graph as a blue dotted line) of 7823 kWh/yr and an average 95% net max energy required (represented in the graph as a orange dotted line) of 8707 kWh/yr in the worst case scenario.

If the total area of the Passive Ger was 48.92 M2, then the average net energy required is approximately 159.9 kWh/M2/year (not including energy gained through Passive Solar heating gains). Based on the 95% confidence band of the net max energy required, the Passive Ger would consume 177.9 kWh/M2/year (not including energy gained through Passive Solar heating gains). As a result, even in the worst case scenario - the Passive Ger was meeting the energy requirements of the Mongolian Green Finance Corporation.

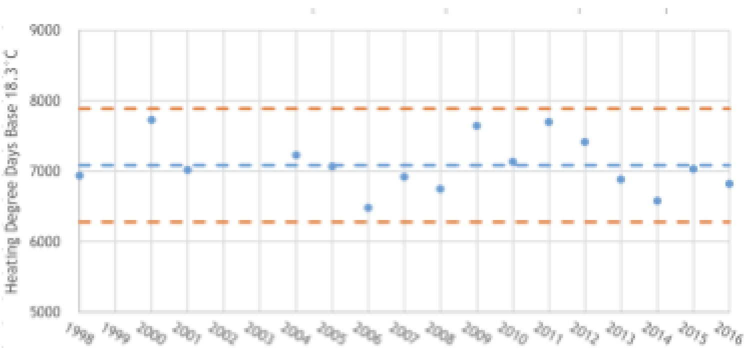

Figure 23: CertainTeed's Heating Degree Days Calculations for Passive Ger

Furthermore, because of the energy efficient changes in the Passive Ger design, families would now only be consuming an average of 939 kg to 1,045 kg of coal each year - assuming that the energy density of coal was 8.33 kWh/kg[19]. In comparison to a traditional 5 *khana ger* therefore, families would be burning an average of 3 and ½ less tons of coal.

iii. Solar Heat Gain

Due to the Passive Ger's South facing triple glazed window a significant amount of passive solar gain was produced. Of the 4,380 hours of possible sunshine in Ulaanbaatar; there was an average 2,791.5 hours of sunshine per year. And if the area of the window was 2.6 M2, including the amount of diffusion of energy that would radiate and transmit through the South Facing window would be 1,465 kWh. (See figure 23).

	MORNING								AFTERNOON										
	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	MONTHLY	
Jan					5.9	16.6	23.2	27	28.2	27	23.2	16.6	5.9					Jan	170
Feb				1.2	8.6	15.9	20.9	24	25	24	20.9	15.9	8.6	1.2				Feb	170
Mar			0.1	2.6	9.1	15.6	20.6	23.7	24.7	23.7	20.6	15.6	9.1	2.6	0.1			Mar	170
Apr			0.5	2	5.7	10.6	15	17.8	18.8	17.8	15	10.6	5.7	2	0.5			Apr	120
May		0.1	1.1	2.2	3.9	7.3	11.1	13.7	14.6	13.7	11.1	7.3	3.9	2.2	1.1	0.1		May	94
Jun		0.3	1.4	2.4	3.4	5.6	8.6	10.9	11.7	10.9	8.6	5.6	3.4	2.4	1.4	0.3		Jun	77
Jul		0.2	1.3	2.4	3.6	6.3	9.7	12.1	13	12.1	9.7	6.3	3.6	2.4	1.3	0.2		Jul	84
Aug			0.8	2.1	4.8	9.1	13.2	16	17	16	13.2	9.1	4.8	2.1	0.8			Aug	110
Sep			0.2	2.3	7.4	13.1	17.7	20.5	21.5	20.5	17.7	13.1	7.4	2.3	0.2			Sep	140
Oct				1.9	9.5	16.7	21.9	25.1	26.2	25.1	21.9	16.7	9.5	1.9				Oct	180
Nov				0.2	6.9	16.3	22.3	25.8	27	25.8	22.3	16.3	6.9	0.2				Nov	170
Dec					4.5	15.8	22.8	26.8	28	26.8	22.8	15.8	4.5					Dec	170
	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	ANNUAL	
	MORNING									AFTERNOON								1,700	

Figure 23: CertainTeed's total Solar heat energy gains for the south facing window of the Passive Ger

d. Moisture Assessment : Saint-Gobain

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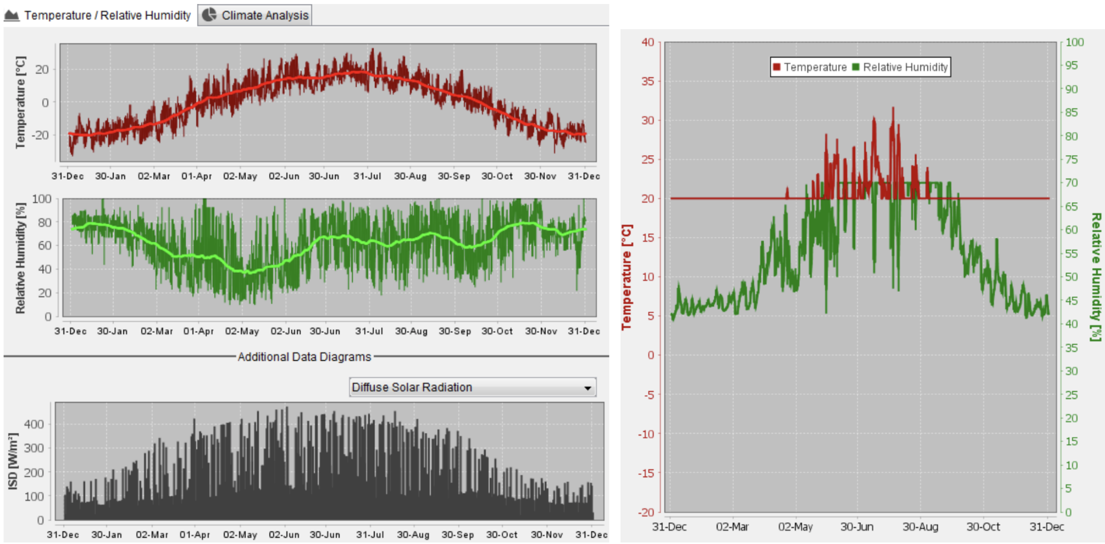
19 See Saint-Gobain Appendix.

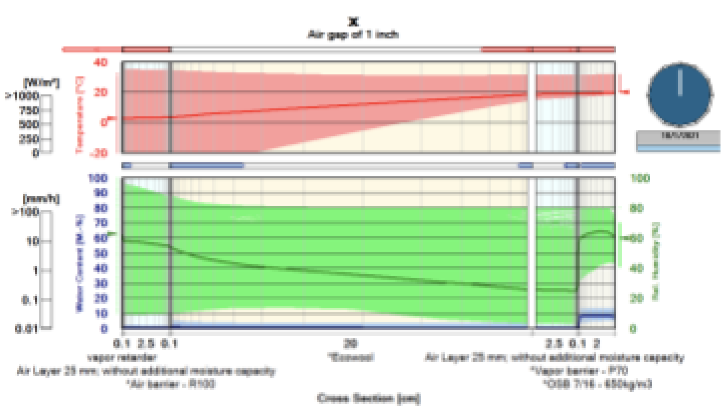
While thermal insulation was critical in order to enable the Ger's building envelope to conserve heat, proper moisture management was critical in order to refrain from condensation and eventually cause mold growth - creating serious long term damage inside the building envelope.



Figures 24: Demonstrates CertainTeed's climate analysis of Temperature and Relative Humidity throughout the year.

In a traditional Mongolian Ger, families take down their Ger a minimum of twice a year - once in the fall and another in the spring - to prevent the felt from mold growth by exposing it to UV rays and airing out the felt below the cotton exterior fabric.

In the Passive Ger design, the enclosure was developed to correctly apply an air barrier and a vapor barrier. In collaboration with CertainTeed's recommendations, moving from inside to out the placement of the building materials were such that; the vapor barrier was between and inner set of *Khana* and *Uni* and the insulation, followed by the air barrier and an outer *Khana* and *Uni* on top - which simultaneously held in the four layers of insulation and air barrier down through compressive strength, as well as creating a three centimeter gap between the air barrier and exterior PVC membrane to allow for proper airflow and reduce the risk of condensation. Base on the condensation analysis in Figure 24, the WUFI model demonstrates that the assembly had a relative humidity less than 90%. The model demonstrated that the envelope passed the criteria because the humidity was less than 95% anywhere in the assembly (which would present itself as condensed liquid water), avoiding a moisture peak greater than 20% which would traditionally create mold growth.



Figures 24: CertainTeed's Moisture Condensation calculations of the wall to roof assembly

e. Conclusion

In conclusion the final heating load calculations of the Passive Ger whether by Buildtech's calculations (166.66 kWh/M2/year) or CertainTeed's calculations (159.9 - 177.9 kWh/M2/year) were within a similar range of 18 kWh - between 159.9 - 177.9 kWh/M2/year. These results varied slightly due to each party's modeling methods. The results met the heating load requirements of the Mongolian Green Finance Corporation. In comparison to a traditional Mongolian g*er*, the Passive Ger was now significantly more energy efficient and moisture resistant.

In the future however, more extensive modeling and testing should be conducted on the physical prototype in order to ensure the airtightness of the assembly, as well as more accurate estimates using passive house design tools such as PHPP and other dynamic energy, thermal bridge analysis tools.

3. Social and Environmental Impact

a. Upgrading a standardized system for Rural to Urban migrants

The Mongolian *ger* is a standardized vernacular housing typology that has been the primary housing system for thousands of years until recent urbanization developments in the 20th and 21th century in Mongolia. The recent urban development trends included the construction of high rise concrete apartment buildings as well as individual homes built out of hard materials (including brick, mortar, etc.).

Fueled by the economy and climate change,[20] a natural urban migration trend emerged, with families moving from rural areas with their *gers* to settle along the city periphery in the Ger Areas. Once families saved enough money, the tendency was for families to move out of their *gers* and into western style homes they built themselves.

However, the challenge with these self-built homes was that families for the majority don't apply the proper layering of building materials either through lack of proper knowledge of building science practices and/or a lack of financial resources. These larger, more energy inefficient buildings ended up burning more tons of coal to heat their homes, creating more air pollution.

As a result, the benefit of adapting the Mongolian *ger* to be more energy efficient as well as have the modern amenities families are seeking, is that the ger is a standardized housing typology that families already own and build themselves. By re-engineering the design to have a 21st Century application of building materials, affordable plumbing and heating systems, as well as contemporary housing improvements; the design had the potential of being easily reproduced at a large scale with greater ease and at a faster speed than other housing development initiatives.

b. Accessible and Diffusible Construction Methods

The Passive Ger was a hybrid between traditional *ger* and contemporary construction techniques. The design was developed such that the construction process required a minimum amount of professional trades and a maximum amount of the homeowner's involvement. This combination allowed for significant cost reductions, avoiding the use of costly construction companies, while utilizing instead experienced builders in EcoTown's Ger District community.

As a result, this approach aimed to provide two main benefits.

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[20] "Steppes and the City: Rural to Urban Migration in Mongolia." *International Migration Institute*, www.imi.ox.ac.uk/blog/steppes-and-the-city-rural-to-urban-migration-in-mongolia.

First, to provide local Ger District community members with employment, generating more income for low and middle income families which have a greater impact on the local economy - especially in areas with high-unemployment rates[21].

Second, to generate momentum around the product application, with local community members leading construction efforts, increasing the likelihood for knowledge sharing throughout the community. Through GerHub's new community center in EcoTown, adult education courses were intended to be held on the Passive Ger's construction strategies to help disseminate knowledge and create a domino effect of good building science practices to reduce air pollution in Ulaanbaatar.

c. Affordability

The Passive Ger project had gone through many design development iterations to ensure the cost of the housing system was as cost efficient as possible while including the necessary contemporary heating and plumbing systems to address the pollution and sanitation issues in the Ger Areas.

The total cost of the Passive Ger was approximately 30,5 million MNT for a 48.92m2 home - meaning the cost was about 623,500 MNT per meter squared. This was critical according to the Mongolian Green Finance Corporation (MGFC). The current average price of apartments in Ulaanbaatar is approximately 1,5 million MNT per meter squared - which was outside of what was considered affordable for most middle income families in the Ger Districts. The MGFC therefore requested housing product be less than 900,000 MNT per meter squared - which the Passive Ger met before the build.

d. Energy Efficiency

A traditional *ger* is a housing system that has an exorbitant amount of heat loss. Building Technology's Engineering Company conducted a study in 2012 to calculate a traditional 5 *Khana* Ger's annual heat loss. In their calculations they accounted for 2 layers of felt on the wall and roof, a floor, skylight, and door in the assembly. According to BTEC calculations, a traditional ger losses approximately 13,028 Q, BT (see Figure 25 below).

Calucaltions of the heat loss of the Mongolian Ger
МОНГОЛ ГЭРИЙН ДУЛААН АЛДАГДАЛЫН ТООЦОО
Energy Loss at the perimeter of the Mongolian Ger

Хашлага хийцийн дулаан алдагдлын тооцоо

1	Room	Хашлага хийцийн (Framework) Name	Square	Дулаан дамжуулах коэф (Heat transmission coefficient)	n	Room temperature	Гадна агаар (outside air)	Δt	Үндсэн дулаан алдагдал Q,Вт (Total Heat Loss)	Нэмэгдэл дулаан алдагдал (Additional Heat Loss)	Хашлага хийцийн дулаан алдагдал (Framework Heat Loss)	**Өрөөний дулаан алдагдал Q,Вт** (Room Heat Loss)
1	Энгийн гэр (2давхар эсгий) Traditional Ger (2 layers of Felt)	Floor Шал	36	0.465	0.9	20	39	59	1156	1.25	1444	13028
		Wall Хана	46	1.32	1	20	39	59	4657	1.25	5822	
		Skylight Тооно	1.6	5.5	1	20	39	59	675	1.25	844	
		Door Хаалга	1.8	2.1	1	20	39	59	290	1.25	362	
		Roof Хучилт	40	1.32	0.9	20	39	59	3645	1.25	4556	

Figure 25: BTEC Energy loss calculations of a traditional 5 Khana Ger

In comparison, the Passive Ger's assembly was adapted to be highly insulated, airtight, and vapor resistant - reducing the thermal conduction of the building materials between the inside and outside

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21 "Social Benefits from Job Creation Much Higher in High-Unemployment Local Economies." *Investinginkids*, 17 July 2015, investinginkids.net/2015/07/17/social-benefits-from-job-creation-much-higher-in-high-unemployment-local-economies/.

temperatures as well as the amount of air filtration that escapes the building envelope through carefully designed and installed construction details. The final heating load calculations of the Passive Ger are between 159.9 - 177.9 kWh/M2/year - which is approximately 8 times more energy efficient than a traditional *ger*.

Although the Passive Ger would not meet the final metrics for the assembly to be a certified Passive House, the significant reduction in energy consumption was a huge improvement in comparison to a traditional *ger*.

e. Clean Energy Source

One of the most important advantages of developing an energy efficient *ger* was its ability to reduce the running cost of an alternative electric heating system, such that the price of the alternative heating system could be as cost efficient as a coal burning stove. This was a major challenge as coal was the most cost effective heating source for families in the Ger Areas; where approximately 1 months worth of coal consumption in the winter (1.3 tons of coal) was approximately 160,000 MNT[22].

Families who had electrical heating mats in their traditional gers spent an average total of 130,000 MNT per month on their electrical bill in comparison to families who only used their electrical supply for household appliances - which was an average approximately 20,000 MNT [23]per month. If an electrical heating system was used, it was often used in addition to a coal burning stove, which made this approach to heating a traditional *ger* costly and often unsustainable for most middle income families. As a result, coupling a clean energy source with an energy efficient building envelope was the optimum approach to significantly bring down the cost of the alternative heating systems while reducing air pollution.

For the Passive Ger, a Chinese made air-to-air heat pump system was selected based on a recent study conducted by Kirk Smith. The model had an “enhanced capacity in cold ambient conditions, COP is up to 2.0+ at the outdoor temperature of -20C, it can run normally at the outdoor temperature of -35C, includes automatic defrost, and has a working fluid of R-32” *(please see Appendix for further information about the study*). Furthermore, what is critical to note is that the running cost of the air-to-air heat pump in a traditional 5 *Khana Ger* was a total of 257 USD in comparison to 335 USD for the total heating season from 2017-2018 for a same sized, same square footage household. *(please see Appendix for further information about the study)*

f. Clean Plumbing System

Soil and water contamination from the pit latrine system in the Ger Areas of Ulaanbaatar was also a major pollution challenge in Ulaanbaatar. These peri-urban communities were approximately one-fourth of the population with “inadequate disposal of human fecal waste, sanitation-related diseases… increasing risks for soil and water contamination”[24]. This created considerable human health challenges, which was why we included an engineered plumbing system to provide an on-site, and decentralized, fecal waste management system. The system was sustainable without adequate urban infrastructure, while composting waste and water treatment independently from local government support.

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22 Photographs, and Text Bryan Denton. “Burning Coal for Survival in the World's Coldest Capital.” *The New York Times*, The New York Times, 15 Mar. 2018, www.nytimes.com/interactive/2018/03/15/world/asia/mongolia-ulan-bator-coal.html.

23 See Ger District Insights Appendix

24 Headhoncho. “49113-001: Managing Soil Pollution in Ger Areas through Improved On-Site Sanitation Project.” *Asian Development Bank*, Asian Development Bank, 3 July 2017, www.adb.org/projects/49113-001/main.

The Passive Ger therefore used a three part septic tank system with Brocadia anammoxidans, or anammox bacteria, which effectively ate human waste.[25] The system filtered 90 percent of the solid waste for approximately 1.5 million MNT, making the sanitation system more affordable in comparison to traditional sanitation products that could cost as much as 7 million MNT. As a result, the application of this plumbing system could have a significant social and environmental impact in reducing the soil and water contamination of the Ger Areas, while also allowing families to begin improving the state of their *hasha* through proper plumbing and water management.

g. The Power of Time Saved and the Reduction of Household Maintenance

In 20th Century Society the invention of the washing machine and other modern appliances profoundly transformed women's lives by reducing the amount of time they dedicated to household chores - ultimately enabling them to enter the workforce[26].

In adapting the *ger* to have the modern amenities families sought, the Passive Ger sought to achieve the same time saving advantages would enable household members to focus more on professional development and child education amongst other activities.

4. Cost Estimate

a. Material and Construction Cost

Cost was one of the major challenges for the project. In comparison to a traditional 5 *Khana Ger* - which was usually around 1.5 million MNT. The estimated cost for the Passive Ger design was valued at approximately 29 million MNT, before the build. While there is a large cost difference between the two the Passive Ger offers long term gains.

When taking into consideration the traditional costs of a 5 *Khana Ger*, the purchase includes few locally made components; *Toono (Oculas), Uni (rafters), Bagana (Pillars), Khana (Walls), Haalga(door), Floor (Shal), Felt Cover of Roof Ring (Urkh), Roof (Deever),* Wall Cover (Tuurga), White Dense (Outer Cover of Ger). Most of these products are locally made ,while some of the materials are sourced from China and Russia, like the Chinese felt or the Russian wood.[27] The initial purchasing cost of the *ger* is low, however there are many long term maintenance costs due with the initially low cost housing system. For example, maintenance is a major challenge and costly, because *gers* need to be taken down twice a year to air out the felt in order to prevent mold growth. Moreover, the interior textile walls collect dust and need to be washed, and the inner and outer contents of the *ger* fabrics need to be replaced, in addition to the floors every 3 years. Another temporary, yet costly element, are 2 meter deep latrines in your *Hasha* where the solid human waste overflows after many years, creating long term air, soil and water pollution problems for families. The long term costs of a traditional *ger* therefore incur larger secondary and tertiary costs.

In response, the Passive Ger is a long term investment for families, rewarding households with a better quality of life and healthier environmental conditions, while potentially being more cost effective in the long term. At an area of 56.12 M2 and a total cost of 29 million MNT, the cost per square meter of the Passive Ger was approximately 516,750 MNT per M2; making the energy efficient housing typology a

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[25] *National Geographic*, National Geographic Society, news.nationalgeographic.com/news/2005/11/1109_051109_rocketfuel.html.
[26] University of Montreal. "Fridges And Washing Machines Liberated Women, Study Suggests." ScienceDaily. ScienceDaily, 13 March 2009. <www.sciencedaily.com/releases/2009/03/090312150735.htm>.
[27] "MONGOLIAN TRADITIONAL DWELLING GER." *Mongolian Ger Camps*, www.mongoliagercamps.net/home/pages/about_mongolia_ger.

competitive housing solution. The Passive Ger was designed to be a more affordable price in comparison to other apartments and homes in Ulaanbaatar with the same square footage and often more amenities.

Work Name	Foundation / Masonry Works/ Structure/ Floorworks	Windows / Glass	Finishes / Built-in Shelves	Insulation	Plumbing works / Septic tank	Electrical Works / HVAC System	Labor	TOTAL COST
Cost (MNT)	2,750,000 / 600,000 / 5,200,000 / 2,100,000	1,500,000	2,750,000	2,500,000	3,100,000 / 6,000,000	2,000,000	3,000,000	TOTAL COST
TOTAL COST (MNT)	10,650,000	1,500,000	2,750,000	2,500,000	9,100,000	2,000,000	3,000,000	29,000,000 MNT

Figure 26: cost break down of Passive Ger

b. Financial package

While energy efficiency was a critical goal for the Passive Ger, affordability was what would enable the project to be a feasible long term solution. Taking into consideration the subsidized interest rate (eight percent) that the MGFC would provide, the general financial package for the housing product was outlined to ensure the owner's ability to pay the mortgage - while bundling in the costs of the alternative heating system to the coal burning stove.

Item	Cost in MNT
Selling price of the ger	MNT 29 mln
Down payment 30%	MNT 9 mln
Price of the air to air heat pump	MNT 3.6 mln
Loan size	MNT 23.6 mln
Loan maturity	10 years
Interest rate of 8%	1.888 mln
Monthly mortgage payment	MNT 212,400

The table to the left outlines key financial components that were taken into consideration to develop a comprehensive financial package, and arrive at an affordable monthly mortgage payment of 212,400 MNT per month for an average household income of 1 million MNT per month. The table includes: the current selling price of the Passive Ger at 29 million MNT, the minimum initial down payment of the future homeowner of 9 million MNT, the price of the air to air heat pump at 3.6 million MNT, the loan size of 23.6 million MNT, a ten year loan period (which is the most commonly preferred period of time to take out a housing loan according to Arig Bank), and the subsidized interest rate of 8%.

In addition, in order to ensure that the Passive Ger was properly insured, homeowners were encouraged to purchase housing insurance from Practical Daatgal or Bodi Daatgal (which are Mongolian insurance agencies that provide comprehensive the financial packages to cover the Passive Ger's housing system) to not only protect the property's value by financial protection against damage due to disasters, theft and accidents.

c. Operating Cost

The energy efficient components of the Passive Ger were carefully value engineered to focus on the most important modern amenities while avoiding excessive operating costs. We focused on standard operating costs of a 5 member family in a 5 *Khana Ger,* and taking into consideration how much the average family currently spends on coal (335 USD for the total heating season), electricity (20,000 MNT per month) and water (2,000 MNT per month at the water well).

In comparison, with the Passive Ger, the estimated heating costs with the air-to-air heat pump system was a total of 257 USD (base on a study conducted by Kirk Smith). According to the ADB, standard electricity consumption for other household appliances was approximately 20,000 MNT per month and water(15,000 MNT per month with the water truck. In comparison to the traditional operating cost of 1,101,500 MNT for a standard 5 *Khana ger*, the Passive Ger's operating costs were estimated at 1,062,500 MNT.

5. Estimate of CO2 Emission

Because the Passive Ger was no longer using a coal burning stove, the CO2 emission produced by the individual building's operation will be close to zero. However, the alternative heating solution would be powered by electricity that stemmed from Ulaanbaatar's local power plants.[28]

6. Appendix

a. Ger District insights of Ulaanbaatar
b. Structural Calculations
c. BEEC Construction Norms
d. Build Tech's Energy Calculations
e. Saint-Gobain's Energy and Moisture Calculations
f. Full Passive Ger Drawing Set

[28] Seman, A. (2017, April). *Mongolia's Energy Sector: Time for a rethink* (Rep.). Retrieved May, 2018, from CEE Bankwatch Network website: https://bankwatch.org/wp-content/uploads/2017/06/Mongolia-energy-sector-web.pdf