Solar Decathlon India™

Single Family Housing

Final Design Report 2021 - 2022

ARNIMA

Team Arnima

Project Partner : **ASEEM Foundation**

ASEEM

PCCOE

Satish Misal Educational Foundation's BRICK™ GROUP OF INSTITUTES

VK:e environmental

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Executive Summary :

Team Arnima from SMEF's Brick school of architecture, Pune, Maharashtra, includes nine 4th year architecture student and two Mech. Engineering students. The team is well-equipped with a balance of designers and technical consultants helping to create a feasible, liveable and workable space. Supporting the fact that development of a sustainable urban living is a necessity and which needs to start from our own space which is our house. Hence, we challenge ourselves by developing a net-zero **single family housing** module for te region of **Leh**. The place has got liberalized recently, which has created a sudden boost ihn housing demand in that region. This has marked a start of new era in history of Leh, hence we aim that the start should be with a positive net-zero approach and so taking a responsibility of proposing a proper way for their lifestyle and living.

We have collaborated with **Aseem foundation** who is our **project partner** from Leh, they have been involved in several society development project for students and people from Leh Ladakh region. With their help we came by a **site in Thiksey village** which is very close from Leh town. So it gives an opportunity to tackle the problems faced by the local people with the project of **Nilaya housing.** The project is well thought of in terms of typical house planning inspired from their vernacular style of living to the site level plan keeping in mind of accommodating 8 housing modules together. Many case studies and research has been taken into consideration to come up with some **innovative passive techniques** to provide thermal insulation and increase heat gain for comfortable living.

Considering the challenges on site such as low wind velocity, cloudy weather in winters, biogas was one of the option during winters to fulfill the basic needs and maintain the thermal comfort in the indoor spaces. Therefore, the usage of **biogas** throughout the year is **85 %** which gives us a total annual energy as **18696.32 KWH per year** and the **solar energy** will be utilized for the electrical equipments which involved **15%** generation of overall energy requirement as **3299.352 KWH per year.** The **total** requirement of energy is, **21995.68 KWH per year** for a single family house.

Studying and analyzing the water availability and its usage, we found that the usability of water is meagre due to its cold climate and prominent use of dry toilets, which helped us to design efficient **water consumption** system for which the daily requirement of water per single family house is **375L**. The **discharged grey water is efficiently treated** with the help of **root zone** system and **chlorination** technology and **2.03KL per day** amount is available for reuse **at community level.** Usage of **ice stupa,** a form or artificial glacier is proposed to meet the water requirements in spring time during April / may which eventually reduces the water demand from thiksey monastery for four months.

Keeping in mind the value of leh people for their cultural and traditional aspects, the local traditional use of material and architecture, the comfort of Local people and to overcome the extreme cold environment, passive heat gain strategies are being used in the design such as solar wall construction on Southern side, Earth berming the structure, designing sun spaces on southern side and insulating floors and roofs are designed to maintain the thermal comfort in the space. All these strategies are achieved by the usage of locally available materials. Usage of local materials, local skilled masons, as well as local market will help in raising local infrastructure and regional development in this region. These local strategies will also help in reducing the cost for the single family house, making it cost-efficient and effective for their living.

Team Introduction :

Team Arnima
SMEF's Brick School of Architecture, Pune
PCET'S Pimpri-Chinchwad College of Engineering, Pune - Mechanical Engineering

Yash Shinde (Leader)
B.Arch 4th year
(Report writing & Calculation)

Tanay Lalwani
B.Arch 4th year
(Report writing & Designing)

Rutuja Daule
B.Arch 4th year
(Calculation & Designing)

Omkar Gund
B.Arch 4th year
(Simulation & Designing)

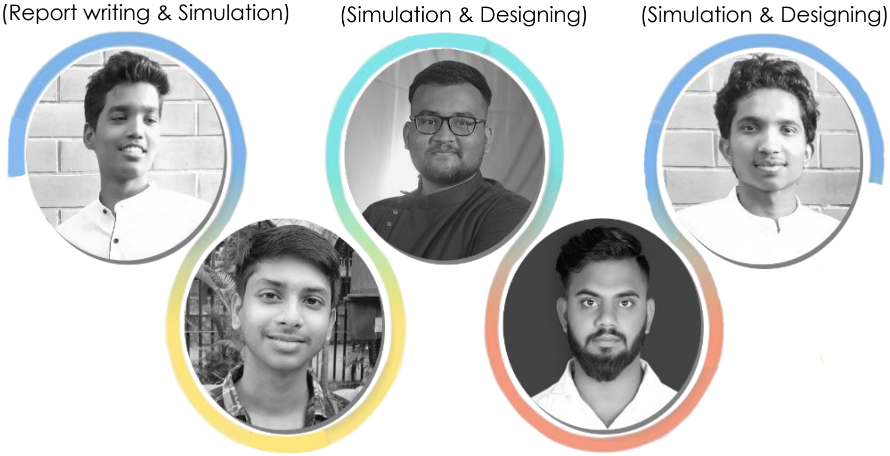
Rucha Kulkarni
B.Arch 4th year
(Calculation & Designing)

Mahesh Vanave
B.Arch 4th year
(Report writing & Simulation)

Pranav Hake
B.Arch 4th year
(Report writing & Simulation)

Hrishikesh Jadhav
B.Arch 4th year
(Simulation & Designing)

Yash Dighe
B.Arch 4th year
(Simulation & Designing)



Vaibhav Bhosale
B.Tech 4th year
(Calculations)

Rajesh Tambe
B.Tech 4th year
(Calculations)

Approach :

- Understanding the typology of net-zero building for the division of Single-family housing
- As a part of the many goals for the union territory, net-zero housing would be a perfect fit in the context and aligning with the proposed government schemes.
- Considering the extreme climate, water scarcity, no consistency in electric supply and habitual living is a great challenge. Hence, Leh Ladakh is the best-suited location for net-zero building.
- Studying the traditional construction techniques and habitual housing, we tried to inculcate these technologies into the single family housing.

Lead Institution Background: At SMEF's Brick Group of Institutes, education isn't confined to classrooms, textbooks, and exams. It goes beyond conventional learning and teaching techniques to encompass a global approach. For us, learning opportunities are endless. Whether it's during an extracurricular activity, a research project, or while working on a social cause, students learn multidimensional academics that make them better designers and creators of the future. We're reinforcing a culture of innovation and experimentation to expand the discipline of design, and change the world. We encourage students to strengthen their knowledge of the past and present and gain insights into the future, to contribute towards a better-built environment. Our undergraduate programs present a unique blend of both, research and lots of collaboration. Together, this fosters an environment of productivity and collective learning. The precise and rigorous design training builds the foundation to push students beyond their comfort zones. As an institute, our goal isn't just to teach the best design practices to our students, but to prepare them to meet the current and future challenges of our industry.

Building of Brick School of Architecture

Ar. Vinita Lulla

Faculty Lead : Ar. Vinita has a flair for sustainable architecture, chases creativity minutely and adds aesthetics in everything she perceives. Having completed her Master's in Environmental Architecture and being a passionate designer, helps her create a niche with a unique combination of art, design, and technical expertise. She is ecstatic at the opportunities to bring more sustainably designed buildings and a built environment, which is the need of the time and a way forward.

Ar. Divya Mallavarapu

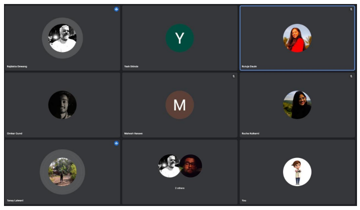
Faculty Advisor : Ar. Divya has a mixed bag of experiences of more than 9 years. Her experience ranges from Environmental Architecture to Project Management. She has worked in US, New Zealand along with India. She loves to interact and shape up young minds towards sensitive, sensible and sustainable designs. Furthermore, she believes that architecture needs to be an essence of the environment and drives this thought through her teaching as well.

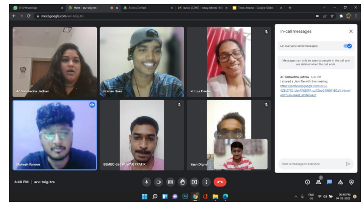
Dr. Poorva Keskar

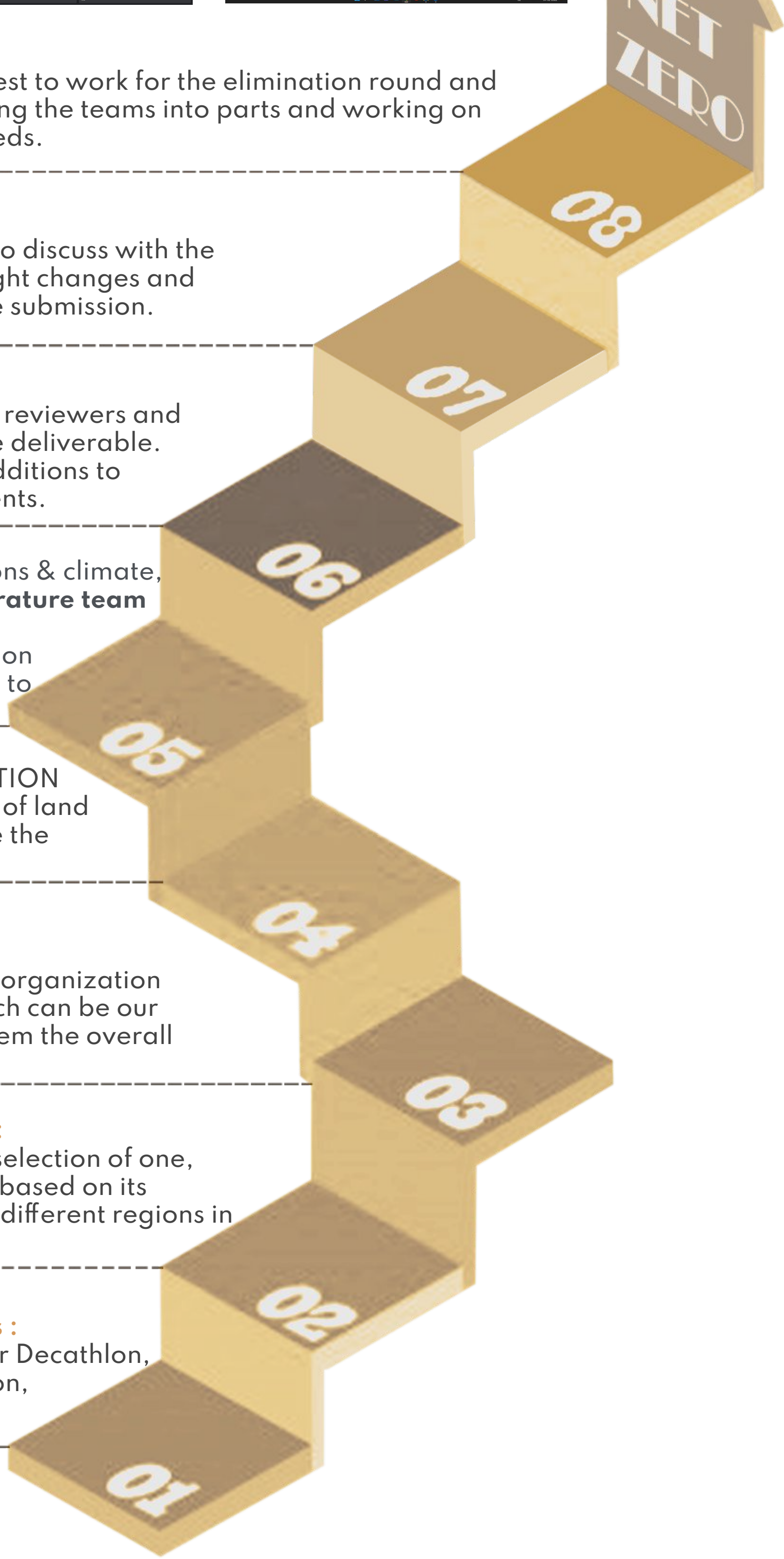
Faculty Advisor : Dr. Poorva Keskar is an architect, environment designer, quality manager, educator and author of numerous articles on the practice of environment design and environment management. She is the Director at VK:e environmental, a consultancy firm. Her practice has won the HUDCO national award for outstanding green rated office building and the AESA award for her LEED project for skf bearings in the year 2015.

Industry Partner : **VK:e Environmental, Pune.** This firm is formed by Ar. Vishwas Kulkarni, which believes in passionately promoting sustainability.

Design Process:







08 **Working On Deliverable 3 :**
Team members are giving their best to work for the elimination round and complete the requirements. Splitting the teams into parts and working on their assigned task to meet the needs.

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07 **Deliverable 2 Submission :**
Compiling all the data and slides to discuss with the mentors and incorporating the slight changes and get the deliverable 2 ready for the submission.

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06 **Post Deliverable 1 Submission :**
Discussion of the reviews from the reviewers and incorporating the comments in the deliverable. Simultaneously working on the additions to meet the deliverable 2 requirements.

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05 **Working On Deliverable 1 :**
Acquiring data about site conditions & climate, team got split into 3 parts - **a) literature team b) graphic team c) design team.**
Each member working cohesively on gathering data & then splitting up to formulate data on sheet.

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04 **Selection Of Site :**
With the help of ASEEM FOUNDATION being the project partner, a piece of land was shown us in Leh region where the project could be established.

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03 **Search For Project Partner :**
Faculty guiding to reach out to an organization named **"ASEEM Foundation"** which can be our project partner & explaining to them the overall project.

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02 **Discussion Within Team Members:**
Study of different typologies and selection of one, working on the selected typology based on its requirements and effectiveness in different regions in India.

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01 **Common Discussion With Mentors :**
Deciding team name, what is solar Decathlon, competition typologies explanation, working on net-zero concept.

Project Introduction :

Sarang Gosavi
Founder and President

Ar. Neha Ghugari
Volunteer

ASEEM Foundation

Project Partner : Aseem foundation, a non-governmental organization committed to developing and establishing connections between the people from disturbed border regions and from the rest of India. The NGO was registered in the year 2010 with a universal theme cutting across economics, social, religious or ideological differences to change the society. The NGO works in the field of education, entrepreneurship and development.

We have Mr. Sarang Gosavi, the Founder and President of Aseem foundation and Ar. Neha Ghugari; the Volunteer at Aseem foundation who will be helping us with the requirements of the project partner.

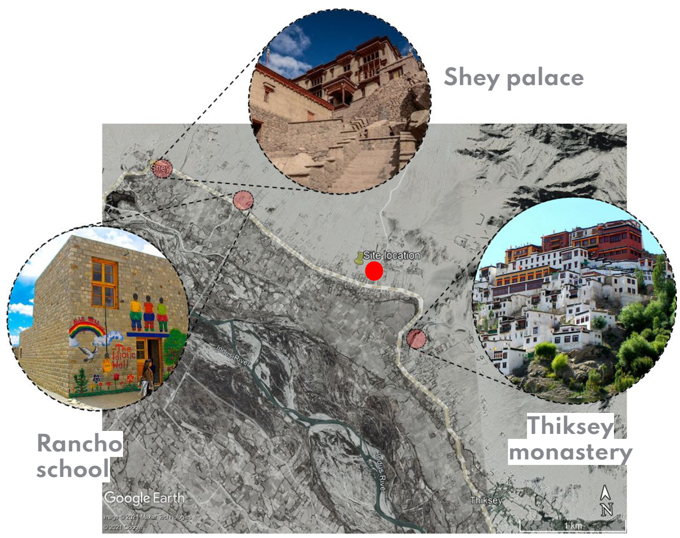
Building type : **Single Family Housing**
No. of occupants : **4-5 peoples per unit**
Climatic condition: **Cold**
Size of the land : **4480 Sq.m.**
(448 sqm Per single family house)

FAR : **1**
Possible replications of house module : **8**
Neighborhood : **Residential and agricultural areas**
Total estimated area: **150-200 sq.m.**

Project Name : Nilaya Housing

- The site is located in Thiksey village. The Leh-Manali Highway divides the terrain where-in the southern part has the Indus River basin which forms good soil for farming hence has major farm lands and the northern part has the huge Himalayan terrain which forms the barrel land including the site.

- Iconic structures are the thiksey monastery that lies towards the southern side at a distance of 1 kms. Shey palace lies towards northeast at distance of 3-4 kms from the site. Some schools toward northwest near Shey village.



Meso Level Plan

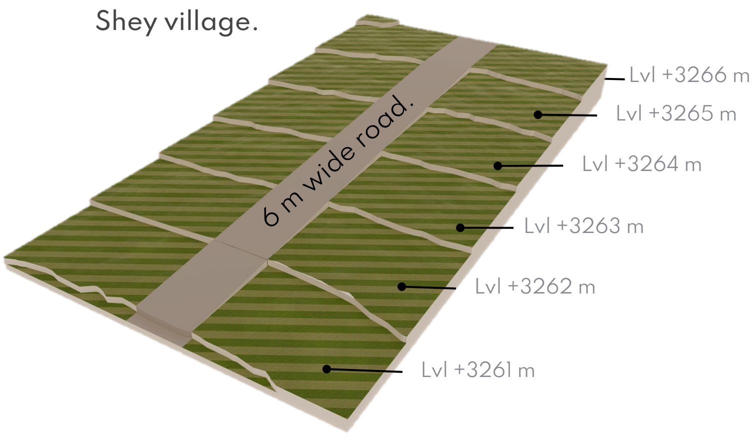


Fig 1; Site level details

Site demarcation

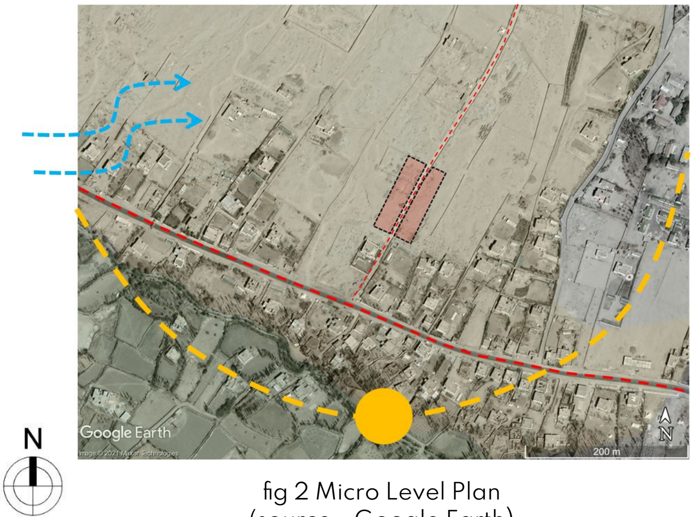


fig 2 Micro Level Plan
(source - Google Earth)

Micro level analysis:

- **Site location :** Thiksey, leh district.
- **Site area :** 4480 sq.m
- **Wind direction :** prominent is from West to east. With avg wind speed of 7 km/ hr during normal days and 15 km/h during month of February.
- A 6 m wide internal road bisecting the site into two halves.
- Site is adjacent to the 9 m wide leh manali highway

Project Brief :

The site for the **Nilaya housing** is located in **Thiksey village**, which is 15 kilometers down to Leh. The region is a dry desert, which falls under the cold climate zone. (Ref - ECBC 2017). In the recent COP26, the Prime Minister of upheld a vision for India to become net-zero by 2070. This proposal will be a model and a step towards that vision. The recent policies proposed by government of India in 2019, has liberalized Leh-Ladakh creating an opportunity for housing development and investments in the region, but currently there are no advancement in housing construction. The local communities use the traditional techniques which are effective, which will be a baseline for our project. We intend to provide some solutions for issues such as water scarcity, sanitation, electric supply, etc. With help of our project partner '**ASEEM Foundation**'. We would be developing an innovative housing module which will be Net-zero, resolving the many challenges faced here.
The main occupation of the people living there is **agriculture**, along with cattle rearing. Their symbiotic way of living along with domestic animals has become a way of life. Almost all families have their own farmlands where vegetable and fruits are grown.

Requirements from Project Partner:

1. Single family housing that we are proposing should include all the people from Leh, especially the larger population of farmers living in that region.
2. The module should show out the character of Leh Architecture and interpret their traditional practice that will showcase the lifestyle of people in the building architecture itself.

Construction Budget :

Cost of construction (per sq.ft.) = 1200 / sq.ft.
Total cost of construction project = Total built-up area x per sq.ft cost
= 332 sq.ft x 1200 / sq.ft
= **4,288,332 Rs/per module of single family housing.**

NO.	PARAMETERS	GOALS	STRATEGIES
1.	**Architecture**	To maintain the architectural character of Leh and develop passively design space to meet the optimum thermal comfort.	Orienting buildings maximum towards South and compact planning will help maintain thermal insulation in spaces
2.	**Energy Performance**	To utilize solar power and waste to generate energy which will not only help the community but also people in thiksey village including grid.	Optimum usage of PV panels for energy generation and biogas for cooking and heating purpose and to propose net metering.
3.	**Water Performance**	To devise water storage at a community level and to use Ice as a source of water in spring times.	To construct insulated OHT and UGT to restore the recycled water and to propose artificial glacier (Ice stupa.) as water source in spring times
4.	**Waste Management**	Redirecting the organic waste and human compost from dry toilet, to generate energy and manure production for farm lands.	Utilization of cow dung for energy generation and human compost for manure production in agricultural fields.
5.	**Resilience**	To design a disaster resilient structure as a measure to overcome the effects of earthquakes.	Tying the building at different level with proportionate planning and application of pier beam system
6.	**Thermal comfort and indoor air quality:**	To mitigate the extreme temperature variations and to achieve indoor comfort both visually and thermally.	Use of passive solar strategies, smaller windows, dark walls on South facade, cavity wall for better thermal insulation to withstand the extreme climatic conditions
7.	**Innovation and Engineering**	To innovate a material palette with reference to indigenous materials for optimum thermal comfort and maintain their cultural heating element (bukhari).	Innovate a carbon free / smoke free bukhari and CSEB blocks with insulation which will maintain the intern thermal environment.
8.	**Scalability and market potential.**	To develop a design that serves the entire occupation of thiksey village with plan for smaller payoff bills for PV cells	Decrease the energy load by usage of LED bulbs and using parabolic solar panel for cooking in summers and also reduce the overall cost.
9.	**Site area for Vegetation**	To be able to cultivate their own fruits and vegetables and also to promote green areas in the region to help maintain the balance at large scale	To cultivate vegetables and fruits by proposing a greenhouse at each building level and also plantation of trees on west side to block the cold breeze as suggested by project partner

Solar Decathlon India

Performance Specification:

Renewable Energy Generation - Solar Panels(module level)	
Total enegy generation per day (module level)	1.89925
Systeam Type	Grid Connected
Brand	Wolt Solar,Ahmedabad
Wattage	380W- 400 w
Model Type	WT 144M380
Dimentions	1000cm*2000cm*40cm
weight	22.5kg
cost	₹ 8,800 / Piece

Wall	
U-Value (W/m2-K)	0.22
Specification	0.450 mm earth CSEB hollow block with wooden reinforcement wall & wool insulation
Window - Dbl Elec Abs Bleached 6mm/13mm Arg	
U-Value (W/m2-K)	1.493
SHGC	0.745
Specification	Dbl Elec Abs Bleached 6mm/13mm Arg

Lighting specification					
Sr no.	Wattage	Lumens	No of luminaries	Spaces used in	Product specifications
1	5	450	5	Passage, Toilet, lobby, buffer space,parking	Wipro Garnet E27 Polycarbonate 5W Cool Day Light LED Bulb
2	10	800	3	Staircase, terrace, bathroom	wipro 10W B22 LED Cool Day White Bulb
3	13	1100	4	Bedroom, strorage room	Havells E27 13-Watt LED Bulb (White)
4	18	1600	4	Prayer room, stable	Syska SSK-SRL-18W-2 B22 18-Watt LED Bulb
5	19	1800	1	Kitchen	Philips LED Bulb 19W
6	20	1900	2	Living room, cattle shade	wipro 20W B22 LED White Bulb (Garnet)

Type	Power	No.s	Total wattage	Brand	Description
Socket 1	12	12	144	Exquisite Export International	Exquisite Export International 3+1 Universal 6/13 amp Multisocket Extension Board Indicator model with 1.5mm 3 Core ISI Copper Wire Cable
Socket 2	12	9	108	Exquisite Export International	Exquisite Export International 3+1 Universal 6/13 amp Multisocket Extension Board Indicator model with 1.5mm 3 Core ISI Copper Wire Cable
Television	80	1	80	samsung	SAMSUNG 80 cm (32 inch) HD Ready LED Smart TV (UA32TE40FAKBXL)
Mixer grinder	400	1	400	Bajaj	BAJAJ 3501 GX 400 W Mixer Grinder
Water filter	35	1	35	Aquagrand	Aquagrand SkyLand 18 Ltr RO + UV + UF + TDS Water Purifier

Design Documentation :

Energy Performance :

The Thiksey village in Leh is supported by electricity from Alchi hydro project. Being a small scale hydro plant, there are problems like electricity cut-offs at frequent phases. To overcome this scenario and also to support the grid, solar energy and biogas systems were implemented on the site for renewable energy generation. The energy generated with help of solar panels will be stored in batteries and the extra amount of energy generated will be transferred to the grid to overcome the electricity cut off problems.

Winters force the locals to stay indoors as much as possible, and the water streams are frozen. During summers, the occupants spend most of their time in the farmlands or work place, while in winters the occupants regularly are inside the house due to the extreme cold weather. The irregular terrain with mountains, hilly and dry regions adds to the existing extreme weather challenges. The Project intends to propose solutions to these challenges which will enhance the living of the occupants. Considering all these factors, we proposed a net-zero module which will resolve the existing issues and A net-zero proposal will help provide an off-grid solution.

Energy consumption calculation : BASE CASE

For deliverable 3 base case EPI of 100 kWh/m2 per year was considered as per GRIHA and accordingly our design case calculated EPI was 71 kWh/m2 per year.

For deliverable 4 considering 71 kWh/m2 per year as our base / conventional case EPI, we further developed our design to achieve our target EPI of 65 kWh/m2 per year as mentioned in 3rd deliverable.

Base case:

	Total Energy [kWh]	Energy Per Total Building Area [kWh/m2]	Energy Per Conditioned Building Area [kWh/m2]
Total Site Energy	9799.85	71.06	137.75
Net Site Energy	9799.85	71.06	137.75
Total Source Energy	12703.57	92.12	178.57
Net Source Energy	12703.57	92.12	178.57

After implication of passive solar heating strategies & active heating strategy as radiant floor heating system, the **EPI** (energy performance index) calculated as **71.06 KWh/sq.m.** Hence, the total energy needed is provided with **70%** with **biogas** and **40%** energy with help of **solar energy.**
In summers, the 70% of biogas which will be generated, out of which 30 % biogas will be use for the module and 40 % of biogas will be given to nearby communities. In winters, from 70 percent of biogas, 40 % of biogas will be utilised for cooking and remaining 30% will be utilised for radiant floor heating system. In summers and winters, 30% of solar energy will be utilised for electrical appliances. In summers, an extra amount of solar energy will be generated with the help of solar disc. This energy will be used for heating water for bathing and cooking also. This helps in reducing the biogas usage for the module, which will be given to the nearby communities.

For deliverable 3, the total amount of **benchmark (GRIHA) EPI** for a residential typology in cold climates is **100 KWH/sq.m per year,** which for our design we calculated the epi as **71 kWh/sq.m per year**, from the energy simulation **design builder** software, which is nearly **28.94%** reduction **in energy consumption.**

Energy requirement calculation through design builder : **DESIGN CASE**

For the design case, the final energy performance index is calculated as 66.28 KWH/sq.m per year through design builder. Hence, the total energy demand for the housing is, 21995.6KWH per year.
In winters, the condition in leh is harsh with low temperature and cloudy weather, during these months, relying on energy generated through solar is difficult to cater to daily needs. For an avg. of 10-15 days, the sunlight does not reach the ground. As a solution to the situation, energy will be stored in the batteries. This time, period will require, total, 15 batteries to last for all 15 days without solar energy. In extreme conditions, when there is no possibility to generate solar energy, the system can be shifted over the grid supply for certain period of time. For the payback of the electricity to the grid, the extra amount of electricity generated on site in summer and monsoon months will be transferred to the grid and to the nearby community. Solar energy will be utilized only for electrical lighting and electrical equipment.

During winter months, biogas generated will be used in greater amount for cooking, heating water for bathing and radiant heating system to maintain thermal comfort for indoors. For this, total 2.4Cu.m of biogas is generated daily, which will cover all the basic necessities during winter. During this month, water for bathing will be heated with the help of a solar disk (used in secmol) on the west side of the site. The extra amount of biogas which will be saved from heating of water will be provided to the nearby neighbouring houses. Biogas in winters is also used for radiant floor heating system to maintain the internal thermal environment. The amount needed for the heating purpose will be catered through the generation of biogas.

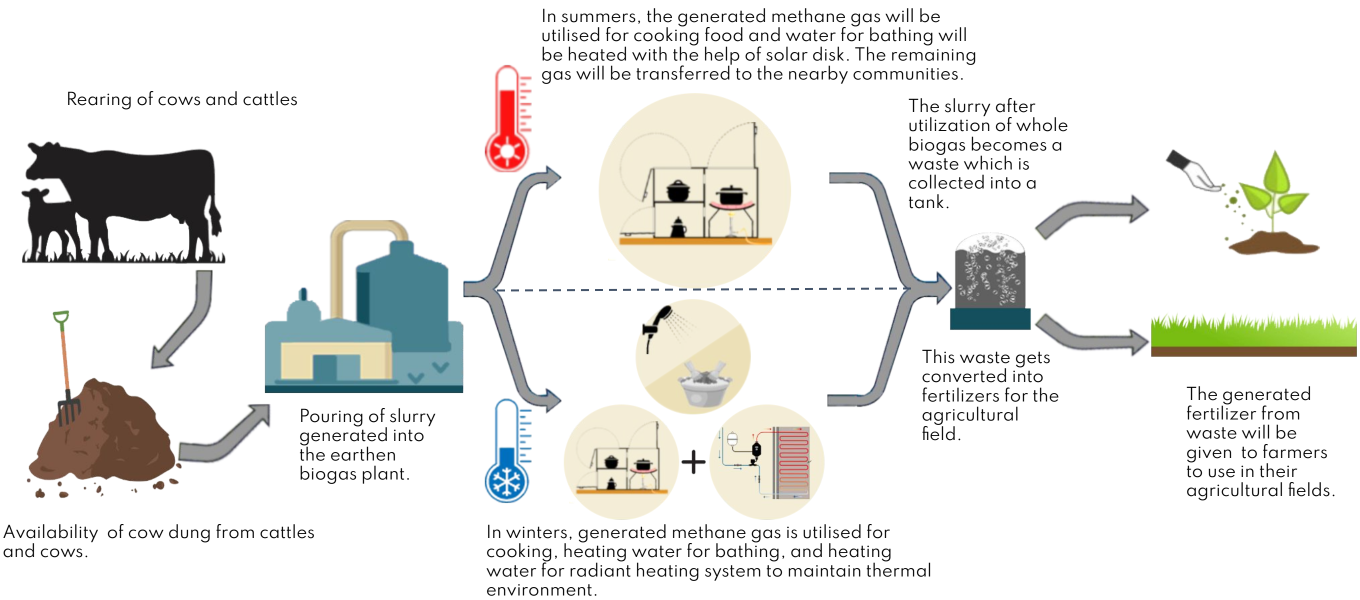


Fig3 **Biogas energy usage flowchart.**

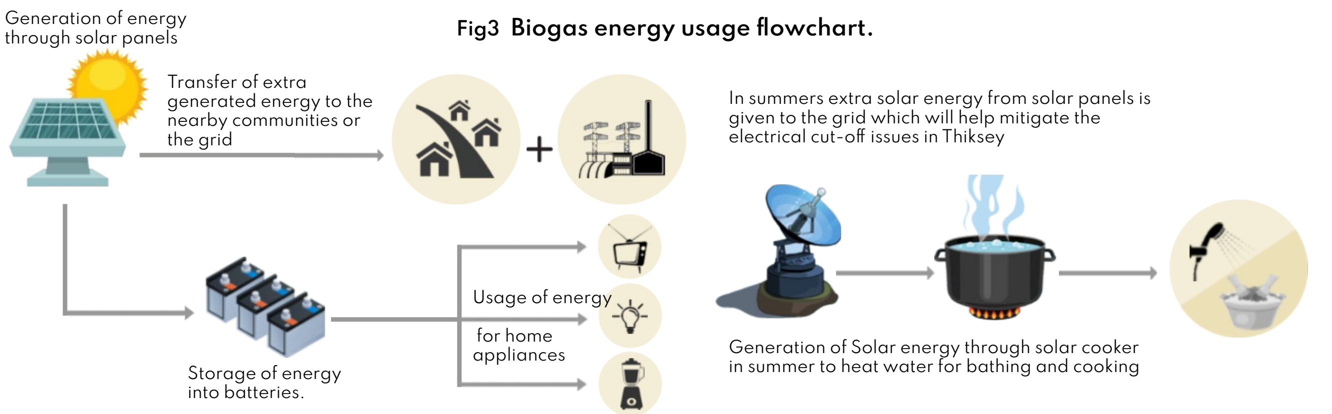


Fig 4 **Solar energy usage statement**

Energy requirement calculation through design builder : DESIGN CASE

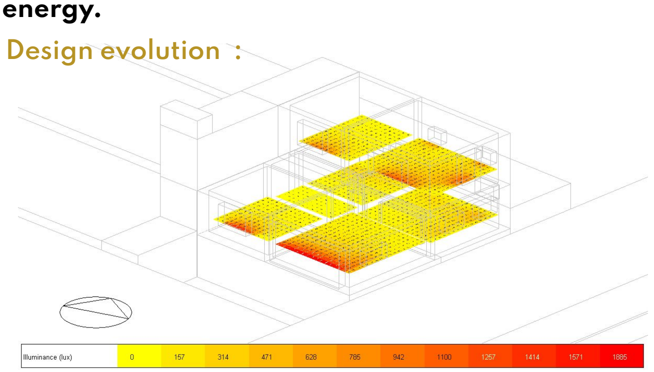
	Total Energy [kWh]	Energy Per Total Building Area [kWh/m2]	Energy Per Conditioned Building Area [kWh/m2]
Total Site Energy	8813.84	66.28	127.28
Net Site Energy	8813.84	66.28	127.28
Total Source Energy	11543.02	86.80	166.69
Net Source Energy	11543.02	86.80	166.69

After implication of design changes such as :

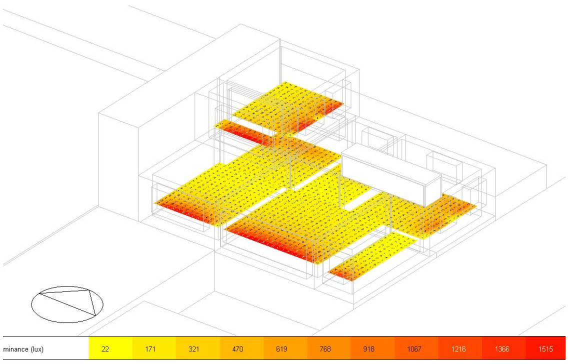
- Improved passive solar heating strategies
- Reduction in window - wall radio (WWR) by 5%
- Increased insulation layer in external walls by 20 % (total insulation thickness= 125 + 25 =150 mm)
- Increased insulation layer in roof by 10 % (total insulation thickness =120 + 12= 132 mm)

From the above design implications the final **EPI** (energy performance index) is **66.28 KWh/sq.m.** Hence, the total energy needed is provided with **70%** with **biogas** and **40%** energy with help of **solar energy.**

Design evolution :



In the preliminary design the operational spaces such as living room, kitchen, prayer room fall short of sufficient daylight.



In the evolved design the operational spaces such as living room, prayer room, kitchen are meeting with sufficient amount of daylight to perform corresponding activity.

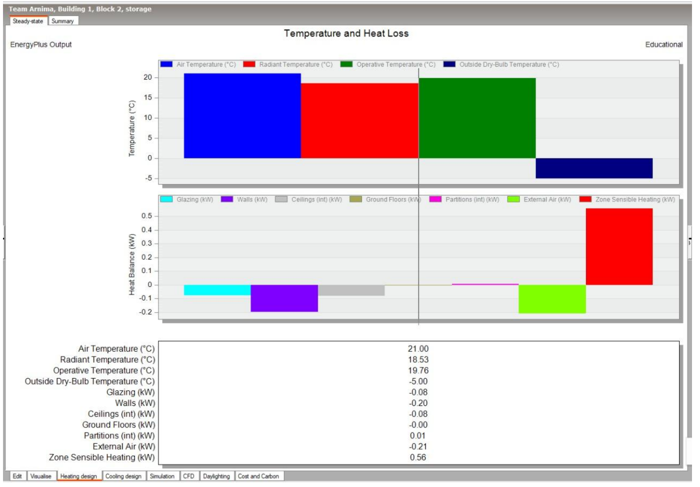
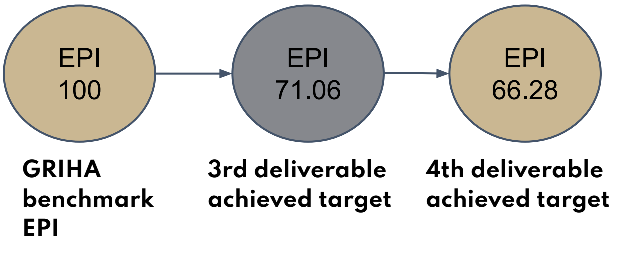


Table 11 Thermal comfort



The external dry bulb temperature being **-5** degree Celsius is overcome by application of passive solar heating strategies & active heating system such as radiant floor heating which raises the temperature up to **21** degree Celsius, achieving thermal comfort in the interiors.

The total amount of **benchmark (GRIHA) EPI** for a residential typology in cold climates is **100 KWH/sq.m per year.** For the design case, from the energy simulation **design builder** software, the total amount of EPI for a single family housing module we achieved is **66.28 KWH/sq.m per year** which is nearly **33.72%** reduction **in energy consumption.**

Water Performance :

The main approach towards **net-zero water** is to preserve the quantity and quality of natural water by utilizing potential alternatives of water sources. Leh being a desert region of Cold climate has an annual rainfall precipitation that averages around **100 mm**, hence there is high shortage of water. Considering the climatic conditions and weather reports, rainwater harvesting will not be feasible due to less rainfall. The overall scenario in the context of lifestyle is that they use the water supplied from the **Thiksey monastery**, which is over the mountain next to the village. The water that they used is mostly based on the underground waters coming from the glaciers, But current climate changes have resulted in depletion of the glaciers, hence impacting the ground waters. Considering this challenge, our main focus was on reusing most of the grey water produced by treating it with **root zone system.** The **dry toilet** concept makes about 17% difference in the water usage and also does not produce any black water, which actually caters their cultural way of being sustainable.

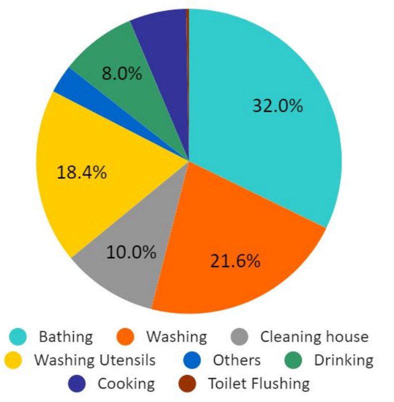


Table 12 -End User Demand

End Use	Percent use	Use in LPD	Greywater in LPD	Blackwater in LPD
Bathing	32.0%	120	120	
Washing	21.6%	81	81	
Cleaning house	10.0%	38	38	
Washing Utensils	18.4%	69	69	
Others	3.0%	11	11	
Drinking	8.0%	30	30	
Cooking	6.0%	23	23	
Toilet Flushing	**0.3%**	**1**		**1**
Total		**372**	**371**	**1**

Table 13 End Use Water Calculation

Dry toilets helps by reducing the 17-20% of water usage and avoid the release of black water. Hence, building level efficiency is being achieved. Furthermore, to make it more efficient, aerators are used for all faucets for having a controlled water flow. Through these various aspects, the challenge for achieving net-zero water status has been tackled, and their traditional ways have been incorporated by enhancing its efficiency

About 80-85% of the allotted water is treated as grey water or for sewage. Along with this, the pipes carrying water are installed deep in the soil, making the water frozen free because of less temperature.

Per Capita daily consumption	Number of occupants	Total daily consumption	Grey water filter efficiency
75	5	375	80%

Table 14 Domestic Use Water Calculation

Calculation for OHT

Water per person per day = 75L
No.of Person = 5
Total no. of units = 8
Tank should have capacity doubled than required.
Tank Capacity = 75x5x8x2=6kL
Consider, circular water tank of radius 'r'
Assume, **h=1**
$1 \times 3.14 \times r^2 = 6$
r = 1.38m
so, r=1.4m
The **diameter** of tank is **2.8 m**
The OHT will **be situated at a height of 21 m** to **supply** the water **with the help of gravitational force.**

Calculation for Treated Water Storage Tank

Greywater filtered in Chlorination tank per unit = 7.6kL
Total no. of units = 8
Total Greywater filtered in Chlorination tank = 7.6kLx 8/30=2.03kL
Tank should have capacity doubled than required.
Tank Capacity = 2.03x2=4.06kL
Storage tank hape capacity 1.5 times the Total capacity = 4.06x1.5=6.09kL
Consider, rectangular water tank of length 'l', width 'b', height 'h'
Assume, l=2b, **h=1.5**
2bxbx1.5= 6.09
b = 1.42 m
so, l=2.84m
The size of rectangular tank is 1.42 m x 2.84 m

Root Zone System

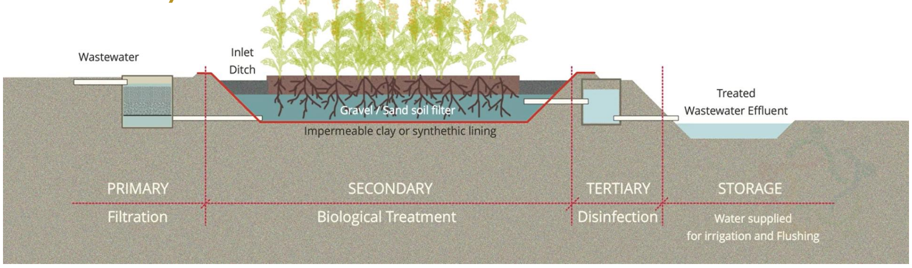


Fig 5 Filtration of water in Root zone Treatment plant

Calculation of Area Required for Root Zone

Area required per person = 2 sq.m

No. of person per unit = 5

Total no. of units = 8

Total no. of person = 8x5 = 40

Total area required = 40 x 2 = **80sq.m**

Name	Properties	Uses	Height	Time required
Canna indica (Kardal)	Large, showy flowers and variegated leaves	Easily digestible and therefore well suited as a health and baby food	0.5 m and 2.5 m	21 Days
Colocasia esculenta (Alu)	A perennial, tropical plant primarily grown as a root vegetable for its edible, starchy corm.	People usually consume its edible corm and leaves. A common dish served in many ways	0.8–1.2 m	21 Days

Table 15 Plants Used in root zone treatment plant

Root zone system has been used at the site level where all the 80-85% of generated grey water would go into the **settling tank** for primary treatment and then released into **root zone system** for secondary treatment. After that, tertiary treatment is carried out into the **chlorination tank.** The chlorinated water is then released into a storage tank, which would again pump the water towards OHT. The **Greenhouse** is built over the Root Zone to maintain the temperature. The extreme temperatures during winter freeze the pipes and water channels and hence to tackle this challenge the pipes are installed 6-7ft inside the soil helping it to get thermal insulation through soil and preventing it from freezing. This system is also known as Reed Bed System.

		CONSUMPTION								WATER SOURCES				
Month	Days in month	Domestic Use (L)	Biogas Use %	Biogas Use (L)	Irrigation Use %	Irrigation Use (L)	Radiant Heating Use %	Radiant Heating Use (L)	Total Consumption (L)	Monastery Water (L)	Rainwater	Greywater (L)	Blackwater (L)	Total Stored
Jul	31	11,625	100%	1,860	70%	1,398	75%	23	14,906	3,397	0	11,509	35	0
Aug	31	11,625	100%	1,860	70%	1,398	75%	23	14,906	3,397	0	11,509	35	0
Sep	30	11,250	100%	1,800	70%	1,353	75%	23	14,426	3,288	0	11,138	34	0
Oct	31	11,625	100%	1,860	80%	1,598	100%	30	15,113	3,604	0	11,509	35	0
Nov	30	11,250	100%	1,800	90%	1,740	100%	30	14,820	3,682	0	11,138	34	0
Dec	31	11,625	100%	1,860	90%	1,798	100%	30	15,313	3,804	0	11,509	35	0
Jan	31	11,625	100%	1,860	90%	1,798	100%	30	15,313	3,804	0	11,509	35	0
Feb	28	10,594	100%	1,695	90%	1,638	100%	30	13,957	3,469	0	10,488	32	0
Mar	31	11,625	100%	1,860	100%	1,997	50%	15	15,497	3,989	0	11,509	35	0
Apr	30	11,250	100%	1,800	100%	1,933	0%	-	14,983	3,845	0	11,138	34	0
May	31	11,625	100%	1,860	100%	1,997	0%	-	15,482	3,974	0	11,509	35	0
Jun	30	11,250	100%	1,800	100%	1,933	50%	15	14,998	3,860	0	11,138	34	0
Total									90,230	22,941	-	67,289		(22,941)

Table 16 Annual Water Calculation

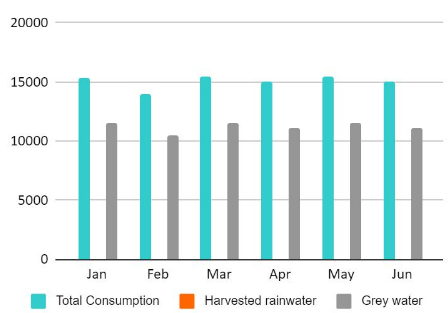
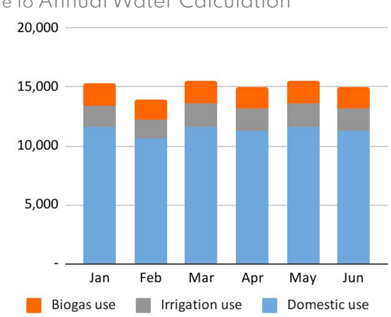


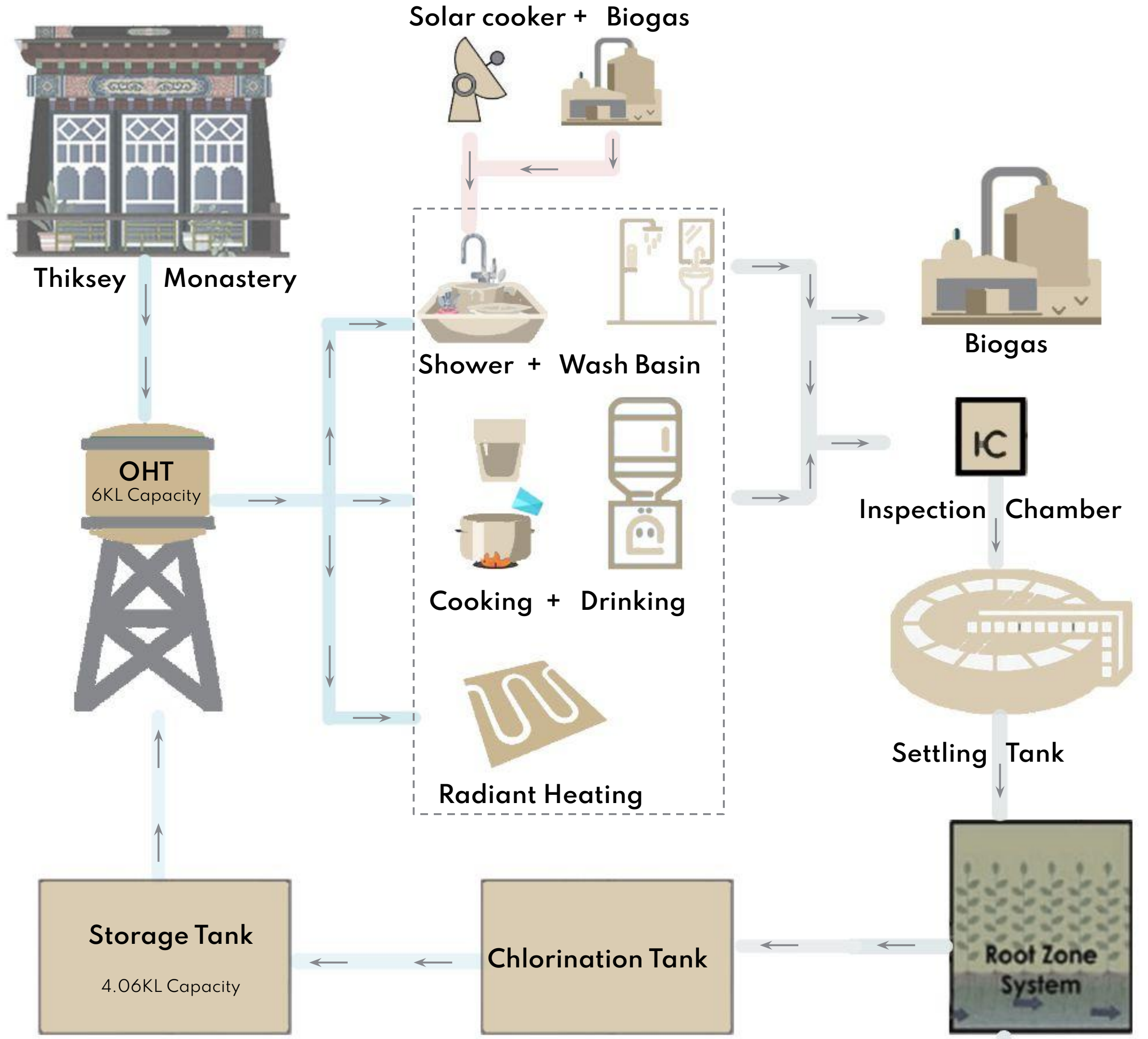
Table 17 Water Balance



Water Consumption

Water use	Quantity	Liters/day
Occupants : {People x l/person}	5	75
Irrigation (max) : {m2 x l/m2}	37.9	1.7
Biogas (max) : {kg x l/kg}	60	1

Table 18 Water Consumption



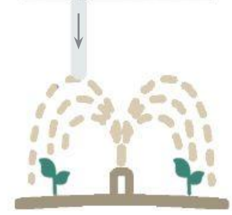


Fig 6 Water Cycle Diagram

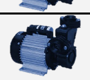
Symbol	Type of Pump	Pump Specifications
	Self Priming Pump	1hp for Monastery water supply line to OHT
	Self Priming Pump	1.5hp for UGT to OHT

Table 19 Pump Specifications

To achieve net-zero in water, available water on site is circulated through various processes of filtrations. Water taken from the **monastery water supply line** considering 75L per person is collected in **OHT** of 6kL capacity situated at the top of the site. The height of OHT being 21M high, the water is pumped up with the help of Self Priming pump. The water further is used for bathing, kitchen, drinking & for radiant heating as per requirement. The fixtures are used with aerators for reducing water flow. An average amount of **1.4kL** of greywater is utilized for the **biogas**. The remaining grey water is collected in a **settling tank** for primary treatment and released into the **root zone system** for secondary filtration. **1.6kL** average water from root zone is used for **irrigation purpose** monthly. The remaining average filtered greywater which is **7.6kL** is filtered into the **chlorination tank** and released into the **storage tank.** This recycled water is then pumped to the **OHT** back again with the help of a Self Priming pump to continue the water cycle. The dry toilet is maintained by drawing out the human compost once after six months. The whole pit is cleaned with water. The generated human compost is then kept for sometime to form manure which is used in agricultural fields. The water required for **drinking and cooking** purposes is filtered with the help of **reverse osmosis** process. The overflow outlet of the storage tank is connected to the Monastery water supply line via water meter. The water meter will count water taken from the Monastery and neglect the amount of water returned to it, helping **to achieve net-zero in water.**

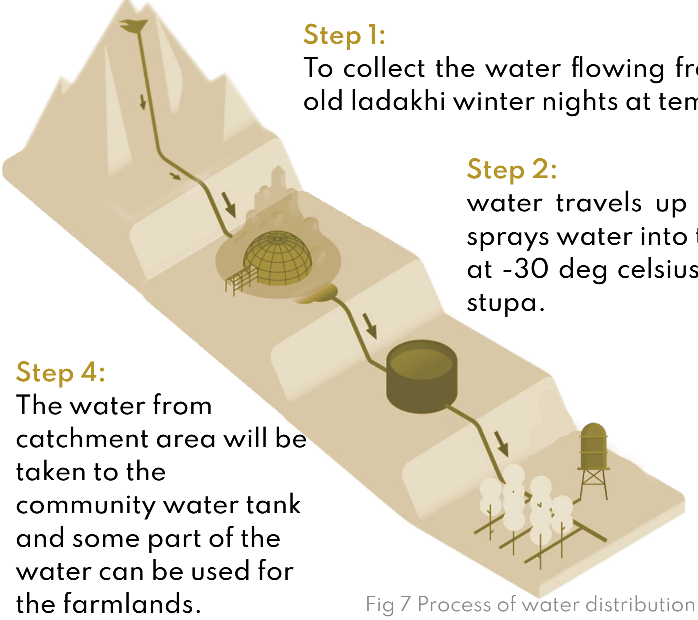
Ice Stupa :

Leh being a cold desert, it receives water shortage issues.Due to water scarcity, during spring time, in April/May, people in Ladakh, mainly farmers fall short of water for agricultural activities as well as for household use. This issue can be solved by the water which melts in the valleys of the mountain ranges and gets connected to the indus river. This water can be used to form ice-stupas (an artificially formed glacier).

The nature of water is to get balanced in any shape it is contained in. This basic phenomenon of water is being applied for the generation of ice stupas.For example water from higher altitude, which travels upto a distance of 3km tends to travel up the head of 100m with the help of gravity forming a ice cone. According to the tests conducted by the SECMOL Institute, a prototype of ice stupa was built upto 7m high on the banks of the indus river, so if this prototype worked in the climatic condition then it will work at any location in ladakh. The results were a success and the stupa lasted for 2 months (april/ may).

To mitigate the water deficit problems, we proposed ice stupa of 7.5 m high in Thiksey village in higher altitude area of mountainous region where water from the mountains can be easily collected with the help of gravity. The formed stupa can generate 2-2.5 lakh litres of water which can be used by 2200 people for two months.

Height (m)	Amount of Water Generated	LPD / person	Total No of Benefitted People
7.5 M	227304.5 L	90 L/day	2200



Step 1:
To collect the water flowing from the mountain range from a height of 10m in old ladakhi winter nights at temperature of -30 deg celsius.

Step 2:
water travels up a head of 8 m due to gravitational force and sprays water into the air for 4-5 months (november - march) which at -30 deg celsius freezes and forms a conical heap called as ice stupa.

Step 3:
The ice melts in spring time of april and may and this water is taken to the water catchment area through pipes where the water is stored and used for four months.

Step 4:
The water from catchment area will be taken to the community water tank and some part of the water can be used for the farmlands.

Fig 7 Process of water distribution by use of Ice Stupa

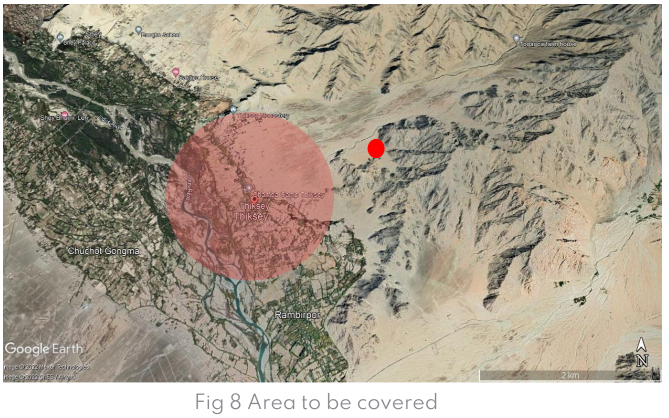


Fig 8 Area to be covered

Water generated from the ice stupas will be transferred to the communities around it . The amount of water generated is 2 lakhs litre. This generated amount will benefit 2200 to 2300 people living in the community.This strategy will solve the water deficiency issues in Thiksey village. This will help to save the water which is taken from Thiksey Monastery for four months. The water requirement for our site is 45,750 litres out of 2 lakhs. Hence, the remaining 1,54,250 litres of water will be beneficial for entire region of Thiksey.

Resilience :

Ladakh, union territory of India, located in the northern part of the Indian subcontinent in the vicinity of the Karakoram and westernmost Himalayan mountain ranges.

Seismic resilience :

According to a article by "Volcanodiscovery.com", Leh since 1900, has had 1 quake of magnitude 6.4, 3 quakes between 5.0 and 6.0, 22 quakes between 4.0 and 5.0, 16 quakes between 3.0 and 4.0, and 2 quakes between 2.0 and 3.0 marking it under highly earthquake prone zone and placed in Zone IV.

So it is necessary to make this structure strong enough to resist these earthquakes. Hence Horizontal and Vertical wooden bands are used to tie structure in both directions, Lightweight materials like compressed stabilized earth blocks and wooden members are used to rescue the dead loads. The structure is planned proportionately and hence is not slender or longitudinal plan making it more stable. Moreover it is supported by pier-beam system forming a grid for better load transfer.This is hold strong by the stepped foundation for the walls constructed with help of stones which will help to resist the dynamic movement of the structure during the earthquake.

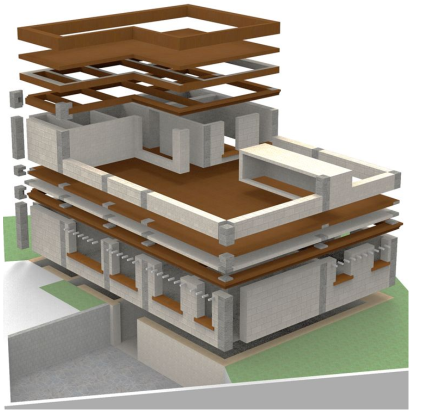


Fig 9 Structural details in exploded view

Water resilience :

According to article of "thebetterindia.com", due to climate change and global warming around 21% of glaciers have melted down which eventually has led to depletion in groundwater in Western himalayas(Leh). Also, being a cold desert region receives average 100 mm rainfall making a worse situation for drought. So first we focused on reusing the grey water produced through Reed bed system, also we are proposing ice stupa system which would cater to solve a macro level water issue.

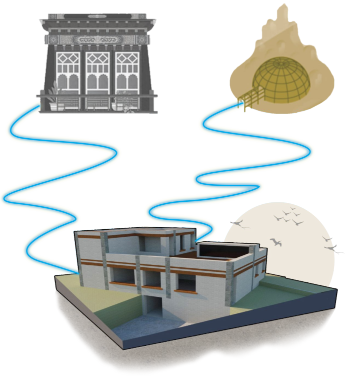


Fig 10 Water supply through monastery and Ice stupa

Energy resilience :

Leh region has only one small hydro power project which generates energy for the region. Hence there are lot of issues of power cuts. To tackle this issue we have provided a 100% off-grid power generation system out of which 15% is generated by Solar PV and 85% by Bio-gas.We also have provided batteries to store power during harsh winters and net-metering will be used which will provide the excess electricity during summers to the nearby communities.

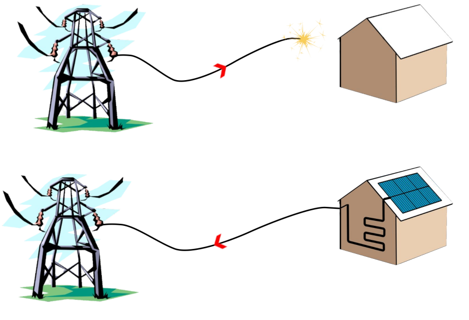


Fig 11 Energy resilience understanding

Climate resilience :

Leh being a cold desert, it receives extreme cold winter ranging from -20 degree to -30 degree celsius and hot summers ranging from 30 degree to 35 degree celsius. Hence our primary approach was to make it resist these harsh temperatures and create a thermally comfortable environment. This is achieved through various Passive and Active solar strategies like, use of trombe wall, providing sunspace, insulated walls and roofs, provision of radiant heating and bukhari system. They overall maintain a good heated environment even if the outer temperature is -5 degree celsius, the inner temperature is around 15-20 degree celsius, eventually making is thermally resilience.

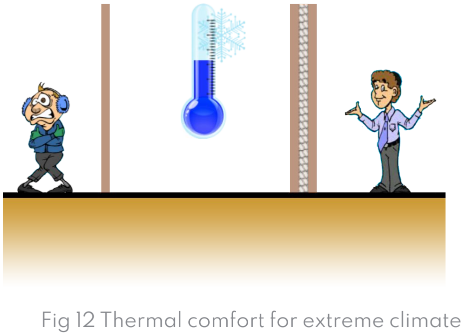


Fig 12 Thermal comfort for extreme climate

Health and Wellbeing:

Leh being a cold desert, it receives extreme cold winter ranging from -20 degree to -30 degree celsius and hot summers ranging from 30 degree to 35 degree celsius. Traditionally, people there use Bukhari as their heating element in cold winters. To overcome this extreme conditions of climate, we have tried to use passive heating strategies at site level as well as at building module level.

Trombe wall : The building is placed facing the south from where maximum solar light and heat can be gained during the daytime, the trombe wall being placed facing the south is painted with bkack or dark colour and leaving a distance of 20-30 cms, another wall of glazing glass is placed which helps in absorbing maximum heat and emit the same during night hours. The cavity in this wall is filled with insulating wool, which will help to retain the internal thermal environment and prevent it from cooling.

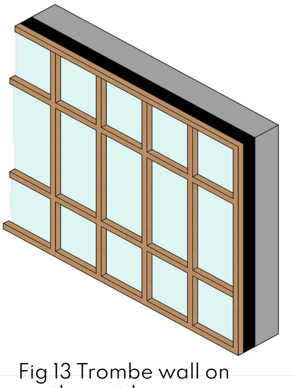


Fig 13 Trombe wall on southern side

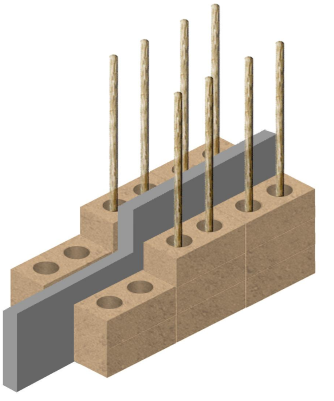


Fig 14 Construction of trombe wall

Radiant heating strategy : To enhance the thermal comfort; hydronic radiant heating systems are installed in the flooring of primarily used spaces such as living room, kitchen and bedrooms. These systems will be operated using biogas as a heating element for the water which will be travelling through these tubes, resulting in radiation of heat into the space above. This will help the to maintain the internal temperature during cold extreme winters when only bukhari strategy alone will not work. This will ensure to have an increase in thermal comfort level of the users.

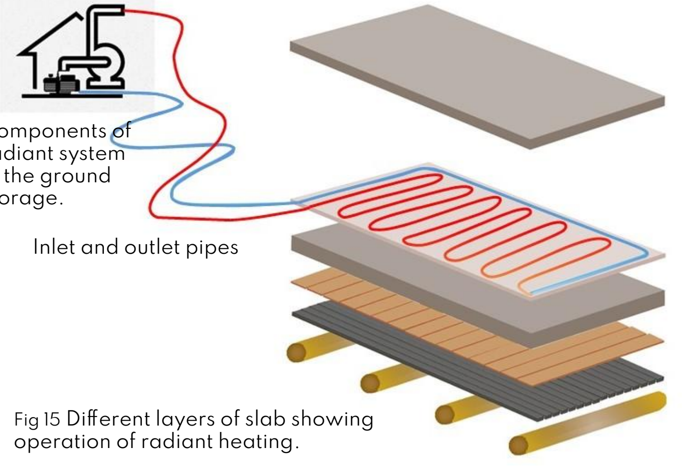


Fig 15 Different layers of slab showing operation of radiant heating.

Earth Berming : The site being a contoured land, its topography helped us to take our spaces semi-underground, primarily those spaces which does not receive south sun and are arranged on Northern side. The ground surface absorbs most of the heat from sun during daytime and earth berming helps in dissipating the heat of the earth in upward direction during night hours. It helps in maintaining the thermal comfort inside the spaces.

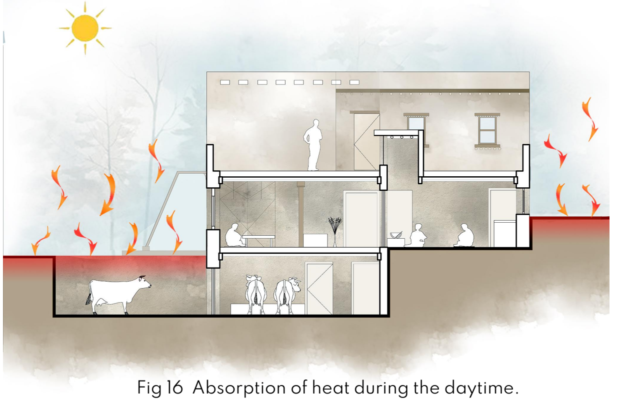


Fig 16 Absorption of heat during the daytime.

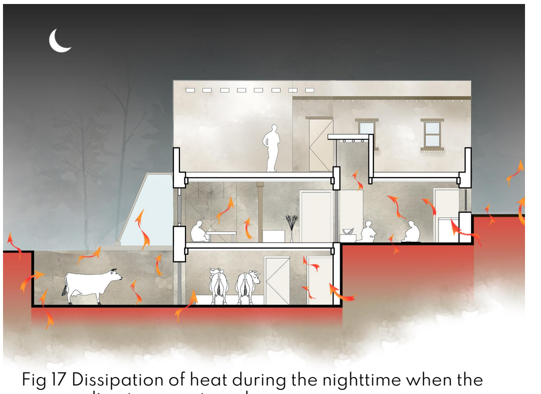


Fig 17 Dissipation of heat during the nighttime when the surrounding temperature drops.

Cattle shed: As per our aim of following the traditional building practice of Leh, the cattle shed space is formed at a certain depth into the ground which will help the cattles and cows to live in a thermally insulated space with the help of earth berming effect. The heat generated by the group of cows in the shed is radiated in upward direction which will warm the living room which is above the cattle shed. This traditional practice will help amplify the internal thermal environment.

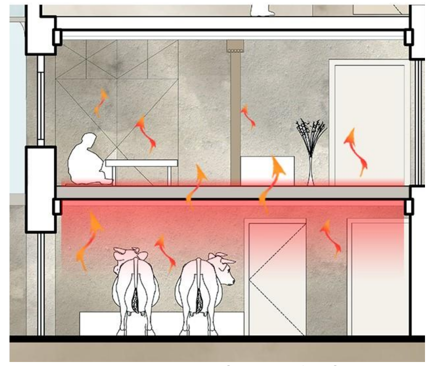


Fig 18 Dissipation of warmth of cattles upwards to the above floor.

Sun space: The south sun in Leh is an important entity which helps to gain light and heat in cold conditions. To take benefit from this, a sun space is placed on the south side, attached to the bedroom. The space is built with a double glazing unit with higher SHGC value to let the south sun in as well as heat that will help amplify the absorption of heat into the ground as well as into the mud walls which will dissipate the heat during night hours. These phenomena will help radiation of heat into the bedroom, adding to the thermal comfort of the user.

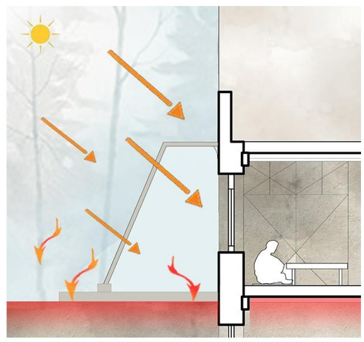


Fig 19 Daytime sunspace working.

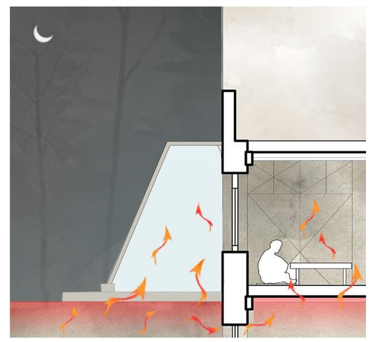


Fig 20 Nighttime sunspace working.

Skylight: To achieve thermal comfort using modern technique of skylight will help the transmission of light into the kitchen space aligned on the northern side. The skylight being implanted on the roof of the kitchen will help trap the heat during the daytime in winters when the sky is clear. This will maintain the thermal environment of the space of kitchen where maximum user activity is focused.

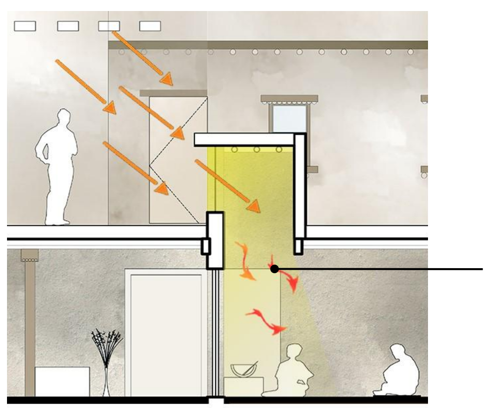


Fig 21 skylight

Roofing: The traditional roofing system of Leh includes wooden members with thach over it covered with a layer of mud, but this roofing system resulted in heat loss as there were gaps involved. We tried developing the same roofing system by addition of an insulation layer between the wooden members and thach in mud, which help in closing the minute gaps and prevent heat loss. The system consists of two layers of insulation, one beneath the mud layer which will help prevent entry of cold winds inside and the second layer between the secondary beams which will prevent heat loss from the interior of space to the external environment. This resulted in retaining the heat inside the space, which helped in maintaining the comfort zone of the users.

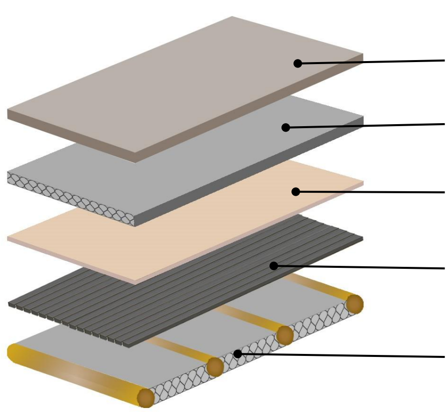


Fig 22 Roofing

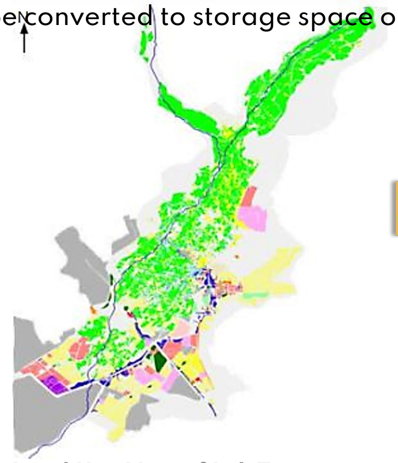
Scalability and Market Potential:

Market Potential:

- The region of Leh majorly depends on tourism and farming activities, due to which there is majority in residential structures. Even in recent years, regions near Leh has seen a growth in migration due to tourism and government union territory rules in 2019. This has eventually seen a rise in residential demand. The context majorly has single families which can be catered with our net-zero single family housing proposal.
- The proposal focuses on 5-6 members in one single family housing module which, for 8 modules, will form a community of 40 peoples.
- The region has its own vernacular style which is being practised since ages and so the market here is favours with the availability of those construction elements like wood, stone and mud. But today due to some benefits of RCC and concrete, slowly the region is shifting towards it and hence a new market is emerging in the region. But this has one disadvantage of transportation of the RCC materials at a greater distance, which is uneconomical. To preserve the traditional architecture and the market, traditional material palette is adopted in the design. Materials such as mud, wood, stone are available locally in abundance. The insulation wool is reused from the waste generated by the nearby Pashmina textile industry. This will help the growth of local market, which will promote the market potential for single family house.
- For the Mechanical systems like Solar PV panels, Biogas and Radiant heating systems we are The maximum use for building material and workmanship from the locality has helped to enhance the cost-effectiveness for 8 such modules and could be a promotion for local craftsman and construction market for future development restoring the traditional style in Leh. Also, the labours are used to this traditional construction technique and hence would be easier and faster for them to build these modules.

Scalability :

As the proposal focuses on 40 people as a community for the housing, the module can also be replicated in surrounding context of Tibetan region which falls in same Cold climatic zone but with some modifications based on the topography and orientation. The strategies like Trombe wall, Radiant heating, Bukhari heating, Sun spaces and orientation and planning could be incorporated in any module in the similar climatic zone as these can be incorporated with help of local masons. The spaces such as Cattle shed and prayer halls are according to the user and project partner which could be converted to storage space or working space as per the client or user.

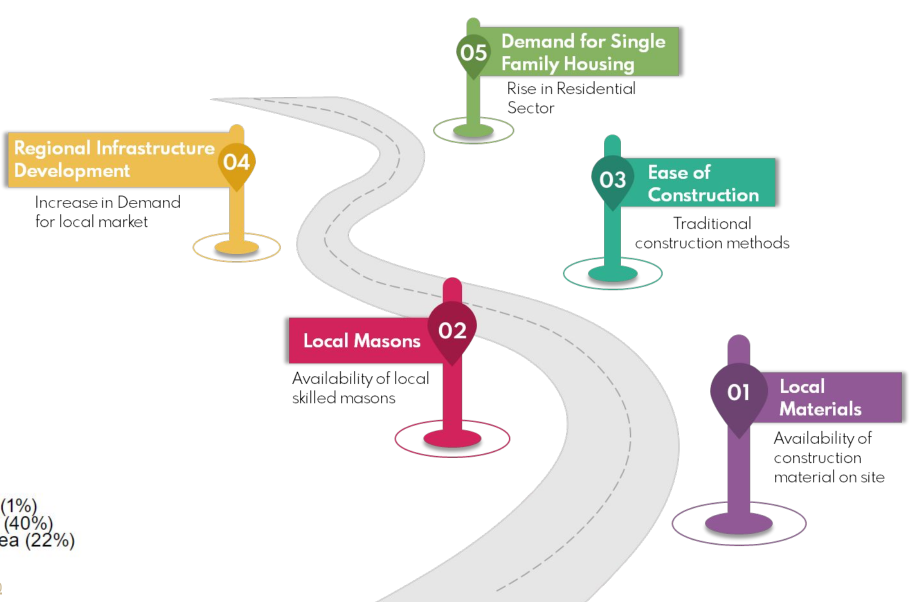


Land Use Map of Leh Town

LEGEND

Old City (1%)
Residential (15%)
Commercial (3%)
Hotels (10%)
Recreation (1%)
Agricultural (40%)
Defense Area (22%)

Source: https://issuu.com/ratichoudhari/docs/ratichoudhari_19089520



Affordability

Affordability as factor is not only dependent on the building architecture but also includes services such as plumbing, electricity, thermal comfort of the user, etc. Following the traditional architectural practice in Leh affordability is considered in:

- Availability of raw materials - Mud as a material is available on site through cut and fill process due to the topography.
- Production of material - Generation and production of sundried hollow CSEB blocks as building material from raw materials available on site. This helps in eliminating the cost of transportation of material required in bulk amount.
- Affordability in wood - From the market potential it shows higher availability of wood from local markets at cheaper rates and usage of the same will also add to their traditional values
- Comfort factor-
  A) Base case: For thermal comfort of the users room heaters were primarily used eliminating the traditional heating system bukhari it led to increase in cost for periodic maintenance of heaters and also due to malfunctioning which makes it uneconomical.
  B) Design case: We used radiant heating system as a replacement for room heater for its advantages such as long-running, no frequent maintenance, heating element as biogas which is affordable and economical.
- Services -
  A) Plumbing: With the help of the terrain, water is transported to the individual houses from the OHT situated at the top terrain of the site with the help of gravity, in turn eliminating the need for a separate OHT for each individual module which in turn reduces the cost of installation of pump and tank for each module.
  B) Electric supply: With availability of cow dung in apple amount it reduces the energy requirement from solar PV plant which further reduces the cost of purchasing the solar PV panels which makes it affordable.

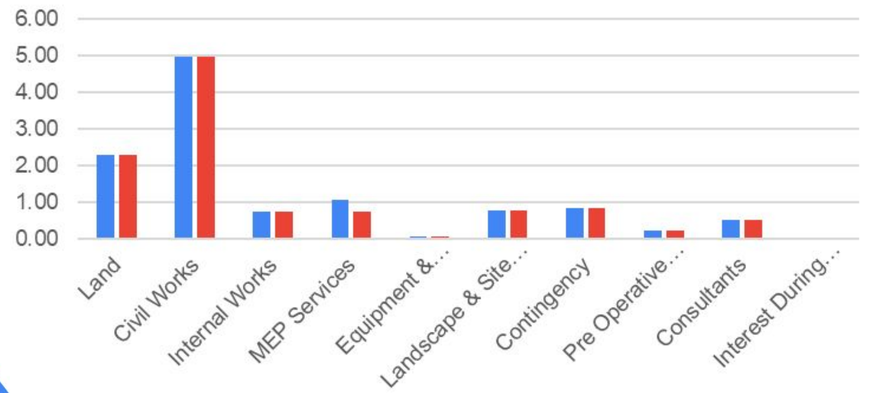
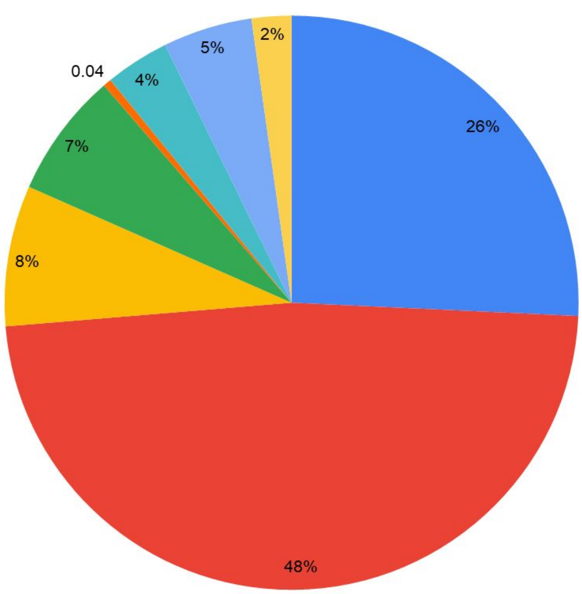


Table 20 Comparison of Baseline & Design Case Estimate



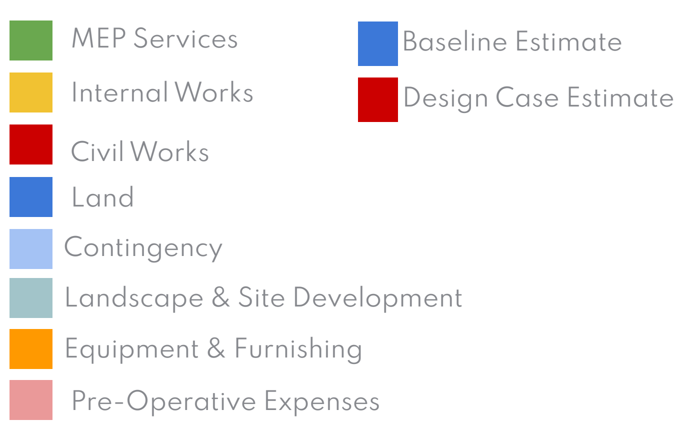


Table 21 Cost Distribution

Architectural Design :

Leh-Ladakh is known for its stunning landscapes, blending with the hues of mountains. Leh-Ladakh is said to be the most well-preserved historic Tibetan architecture's in the world. The use of local materials and wood carvings on beam, column bases, doors, windows, furniture also reflect tibetan art and architecture. Owing to the scenario that the people of ladakh have a tremendous amount of respect for nature, so it is important to preserve their respect for nature, built environment and beauty of the structures that are well merged with the landscape. Hence, the team aims to not disturb the traditional architecture and culture by introducing contemporary ways, but to enhance it for a better lifestyle. This has been achieved through tackling their current issues by giving sustainable, innovative solutions. To achieve this a detailed architectural study was done of that region, additional to this we also studied the SECMOL campus of which some takeaways are mentioned below.

Design Takeaways From Case Studies

The Students' Educational and Cultural Movement of Ladakh (SECMOL)

Solar Energy

1. Solar Electricity:
Photovoltaic panels generate electricity. Batteries store power for nights and cloudy days.
2. Solar Pump:
Drinking water supply comes from a bore-well 130 feet (40 m) deep. Solar panels power an electric pump that fills the domestic water tanks.
3. Solar Cooker:
Two concentrating reflector-type solar cookers cook much of SECMOL food with the sun's heat. The large parabolic reflector is made of common mirrors, which focus the rays of the sun to a secondary reflector under the pots inside the kitchen. This design gives as much heat as a large gas burner, and saves a lot of money while preserving the environment.

Fig 23a Solar panel

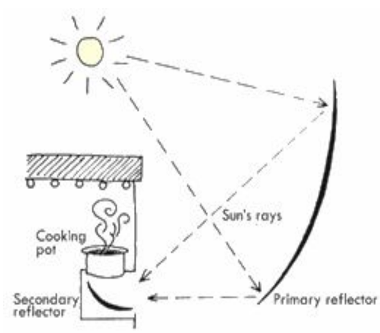


Fig 23b Solar cooker

Passive strategies

The main features that keep the buildings warm are:

- South facing windows, as the sun moves low in the southern sky in winter.
- Greenhouses are attached to the south side for winter.
- Greenhouses are removed in springtime to prevent overheating.
- Skylights are covered with glass or clear plastic to keep warm air indoors.
- Thick earthen walls and floors to store collected heat (thermal mass).
- Insulation in the roof, outer walls, and in some places under the floor.
- Natural lighting, so electricity is not needed for light in the daytime.

In winter, They roll huge UV- stabilized plastic sheets down to make a big greenhouse, which works as a solar collector for each building. In summer, the plastic is rolled up to prevent overheating.

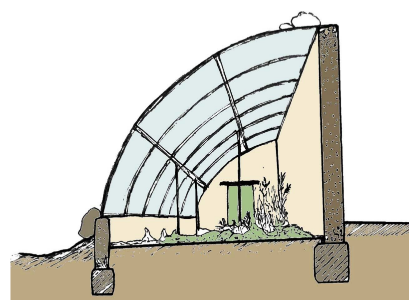


Fig 23c Trench sun spaces

Biogas

The slurry of cow dung and water, has to be about 30 – 35^{0}C. They are able to heat the slurry with solar heat to keep it warm enough.

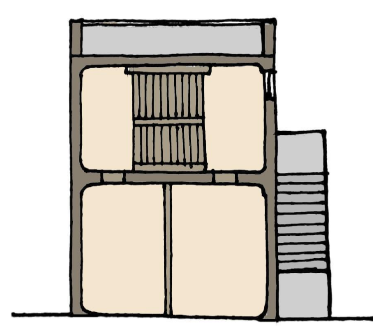


Fig 23d Composting Toilets

To achieve this, the first step was taken by studying the local architecture and their living. Considering a typical house planning in Leh-Ladakh, the design inculcates the compact planning which comprises spaces such as a living room, a prayer room, kitchen, bedrooms and large storage areas with underground cattle shed which warm up the spaces above. The living room is where all the activities in a group are carried out, from lighting up the bukhari to celebrating festivals. A prayer room is where all the family members gather for evening prayers. The kitchen is attached to the living room, so the heat of the fire warms the living room too. A sun space is provided on the south side of the bedroom, to keep it warm in night-time.

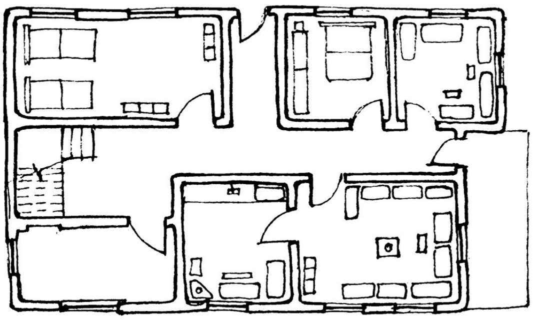


fig 24 Typical plan of house

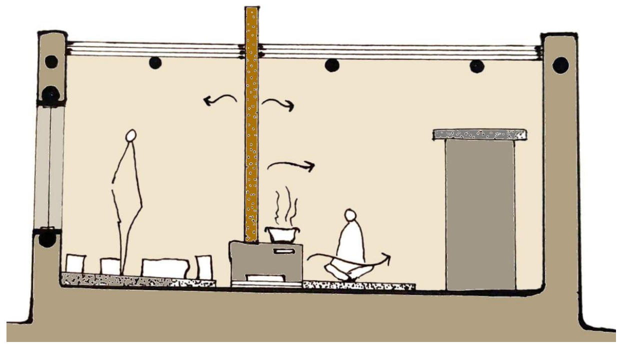
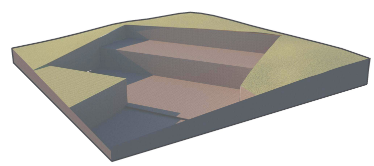


fig.25 Section through living room

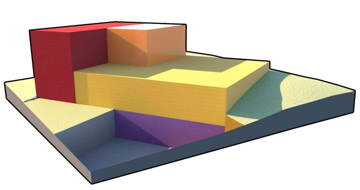
The houses are constructed with locally available materials such as stone, wood, mud and lime. Walls are built 450 mm thick and the Northern spaces are earth bermed to absorb heat during the daytime and emit the same at night-time when the temperature drops to its lowest, which helped in maintaining the thermal comfort of the space. The buildings are oriented towards the south to gain maximum daylight and heat.

The overall site is a sloping land with 7 contours in it, This helped us to take advantage of the topography and cut-fill the land. The heap formed from digging of the land helped us to build the walls of the structure. The dry toilet is arranged on the southern side to receive maximum amplified sunlight through the trombe wall, which will eliminate the foul smell. Their symbiotic way of living along with domestic animals has become a way of life and incorporating the same in our structure to promote the traditional practise.

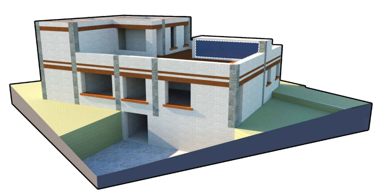
The site of each module is a sloping land of contour difference of 1.5 m.



The sloping land helped us take our building into the ground by cutting some part of the land for experiencing the earth berming effect.



Segregating spaces according to the functions and usage.



Larger openings on southern side to let south sun in.

Services block arranged on West site to block the cold winds

Cattle shed is partly underground to warm up the living space above.

Primary living spaces which are on ground to receive heat gain through the passive strategies.

A prayer room which is occupied erstwhile is planned on the 1st floor

fig.26 Design process

Planning :

The living room and the kitchen are arranged adjacent to each other, which promotes easy accessibility and circulation for these spaces, which are being used at a greater extent. The bedroom and storage spaces are provided with minimum external surface area by service block on its west side and living, kitchen on its east side. This helps keeping the bedroom warm.
The spaces are compact volumes with smaller heights which prevents the heat loss and help maintaining the thermal insulation which is a similar technique used in typical house of Leh. Smaller height also promotes the building height to be smaller, which overcomes the drawback of mutual shading of the building in this climatic zone.
The bedroom on the southern side is attached with the sun space to maximize the heat gain.

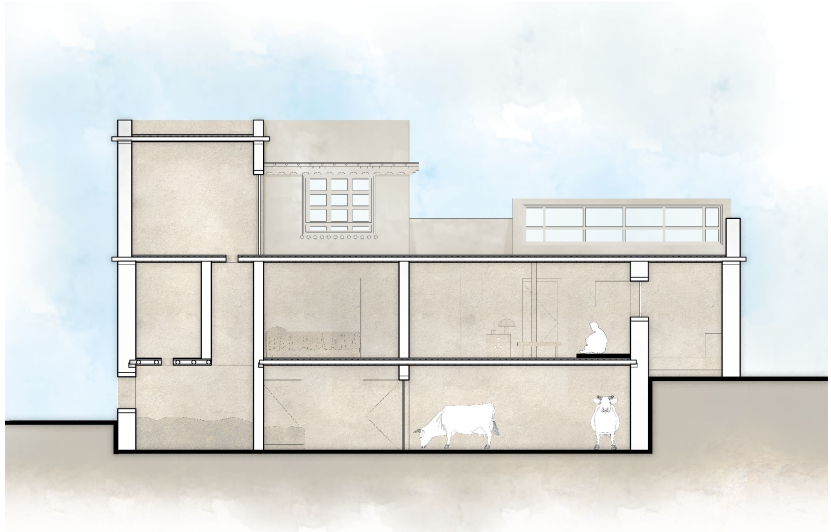
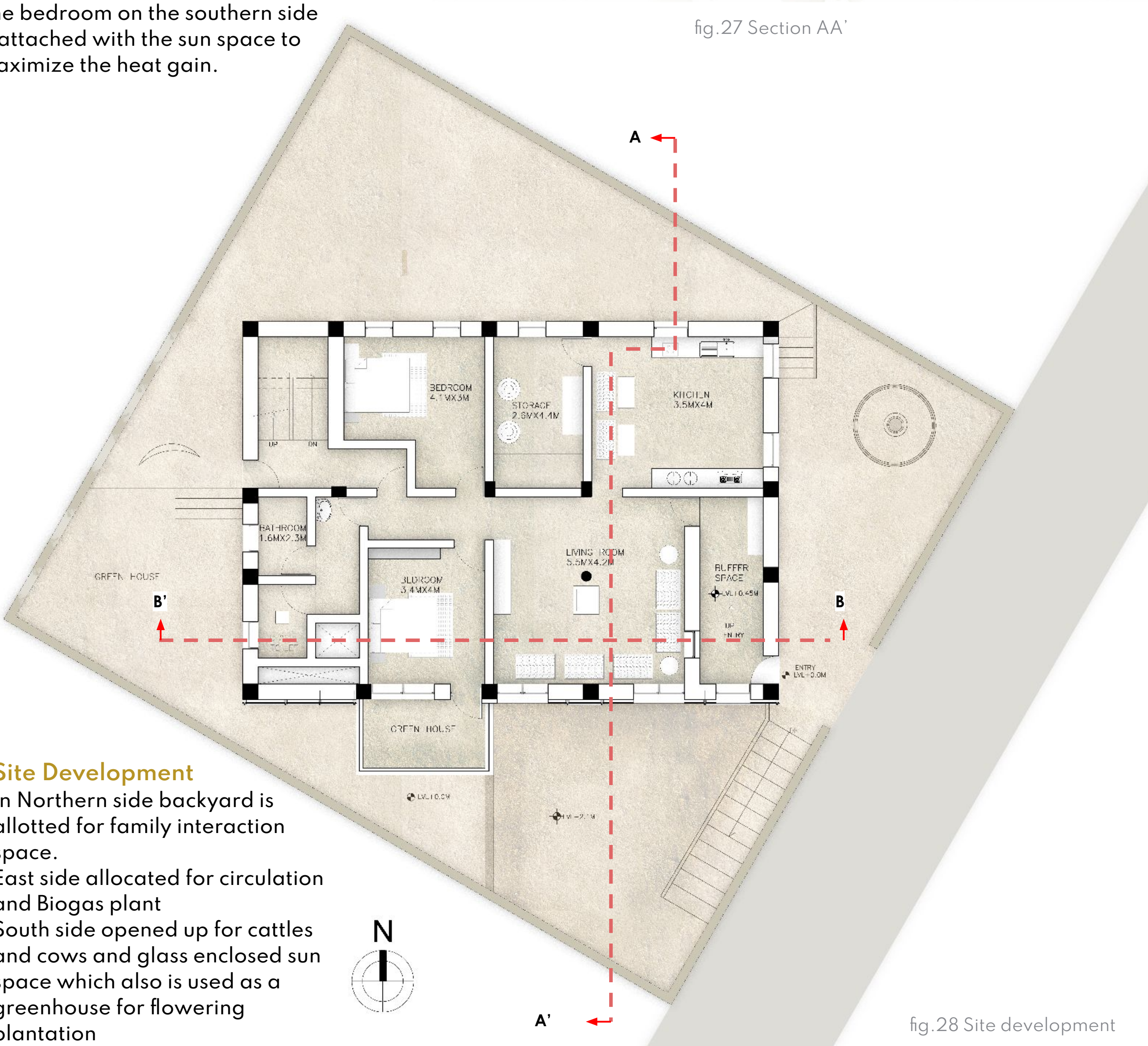


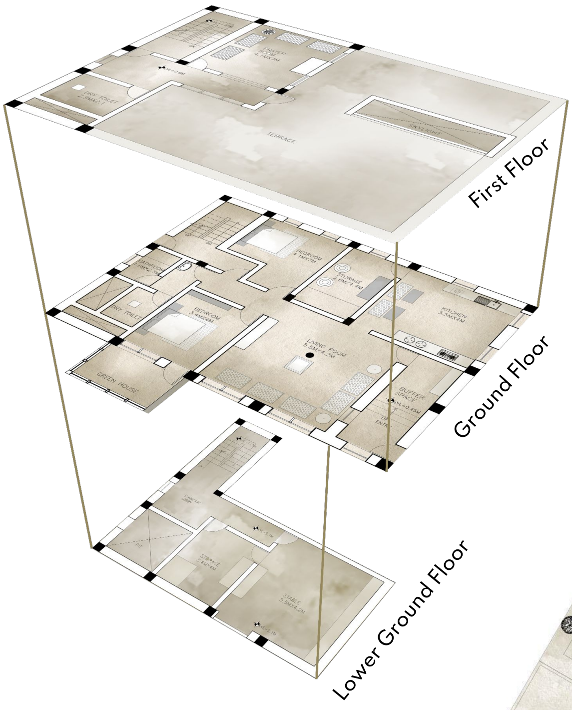
fig.27 Section AA'



Site Development

In Northern side backyard is allotted for family interaction space.
East side allocated for circulation and Biogas plant
South side opened up for cattles and cows and glass enclosed sun space which also is used as a greenhouse for flowering plantation

fig.28 Site development



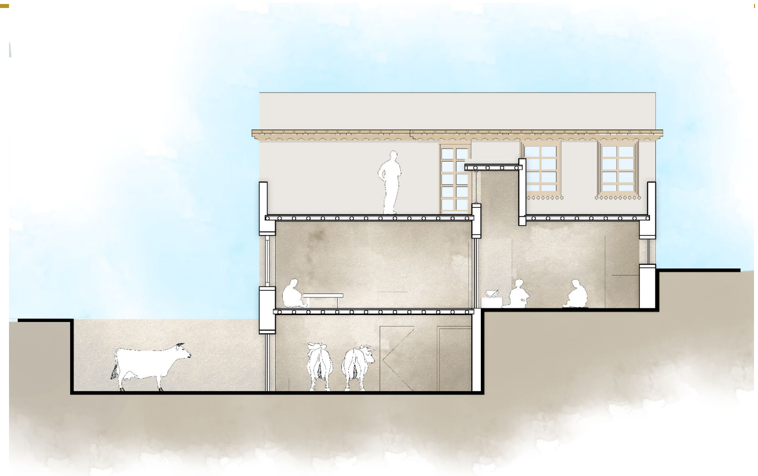


Fig 29. Section BB'

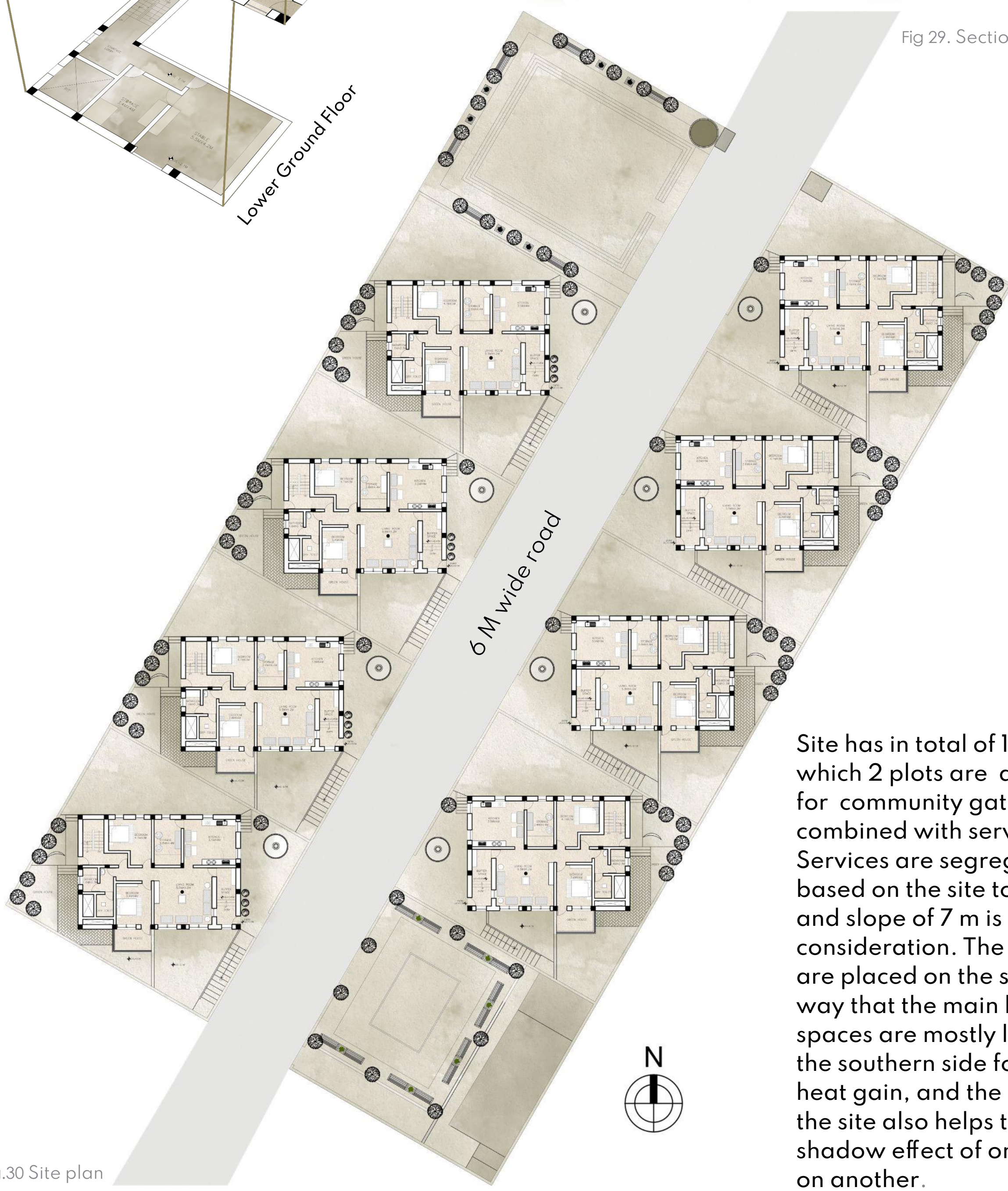
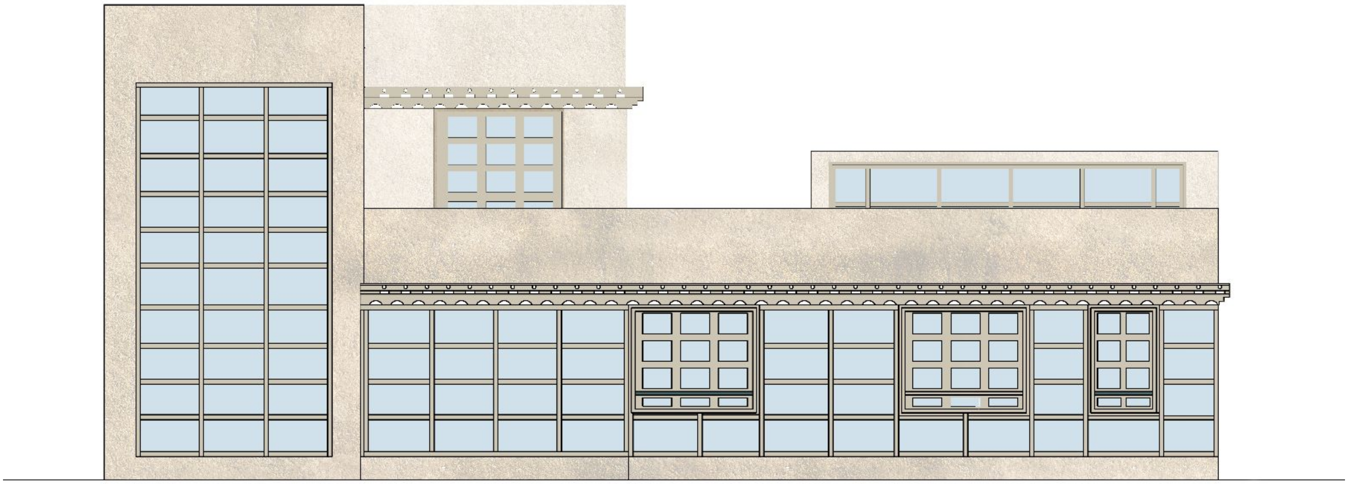
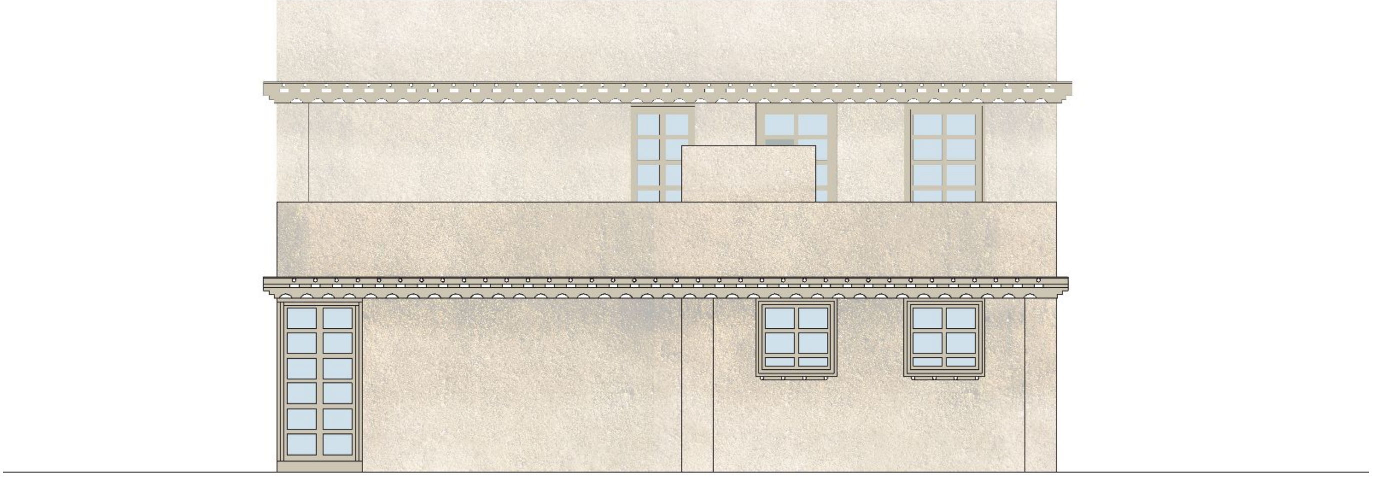


fig.30 Site plan

Site has in total of 10 plots in which 2 plots are dedicated for community gathering, combined with services. Services are segregated based on the site topography and slope of 7 m is taken into consideration. The modules are placed on the site in a way that the main living spaces are mostly located on the southern side for natural heat gain, and the slope of the site also helps to avoid shadow effect of one building on another.



South side elevation



East side elevation

fig.24 Site plan

Engineering Details and Operation :

The construction technology practiced in Leh is a simple language of building houses with traditional means and typical workmanship involved in it. The materials used here are simple in its way of building walls, windows, doors, slabs, floors, etc. So there is no requirement of Hi-Tech equipments and machinery for construction. The local masons here are skilled in using their local materials as a part of built structure as well as aesthetics. Layering of materials on each other, introducing wooden members in between as peripheral beam/lintel not only serves as supportive and resilient part, but also gives a traditional touch of leh house to the building.

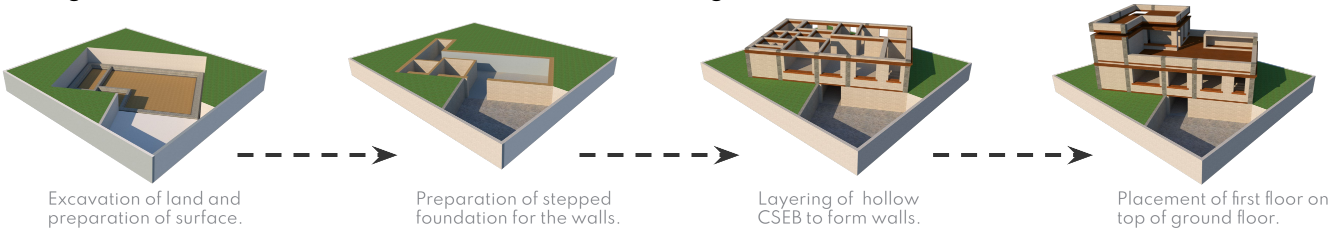


fig.35 design process

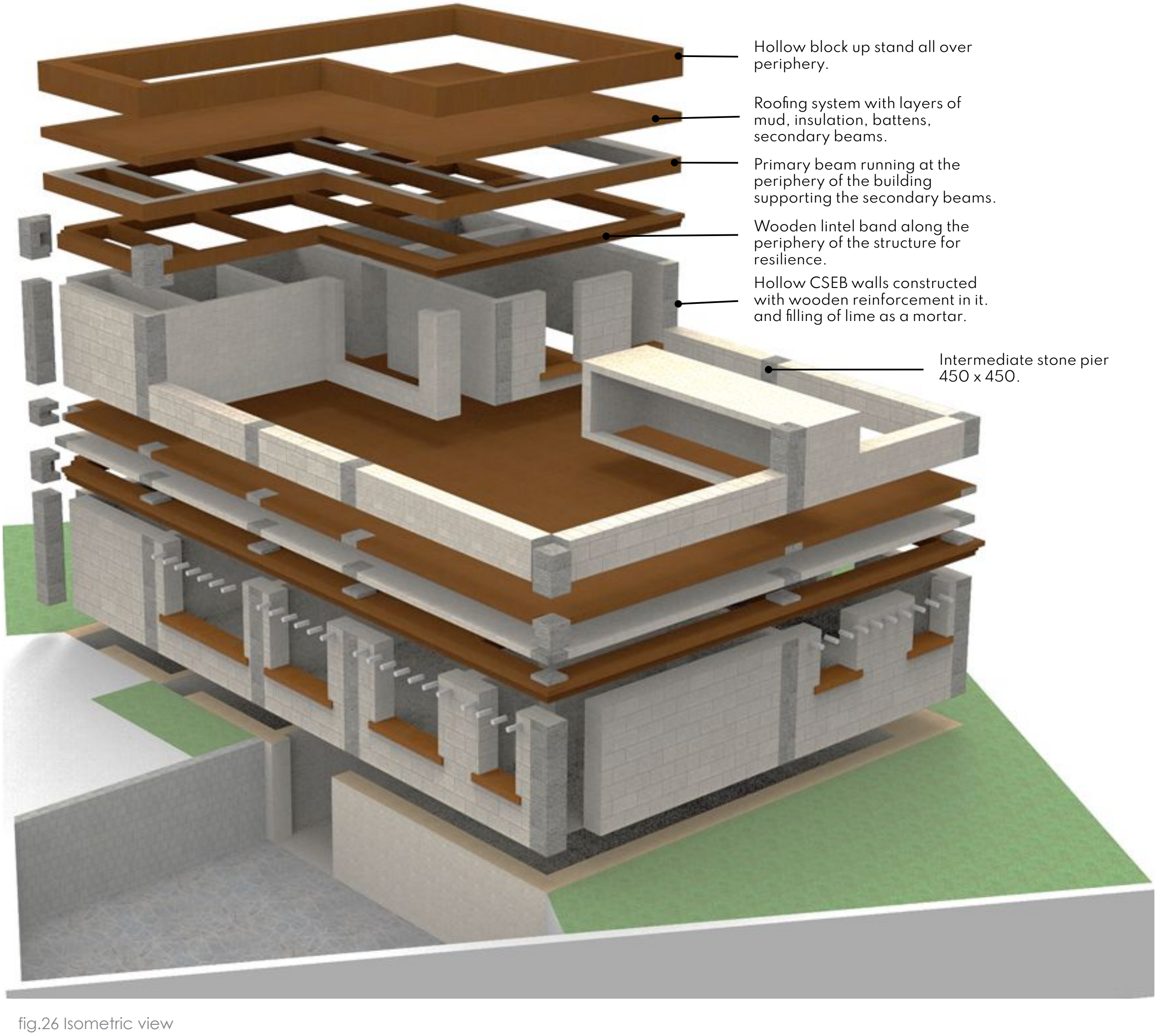


fig.26 Isometric view

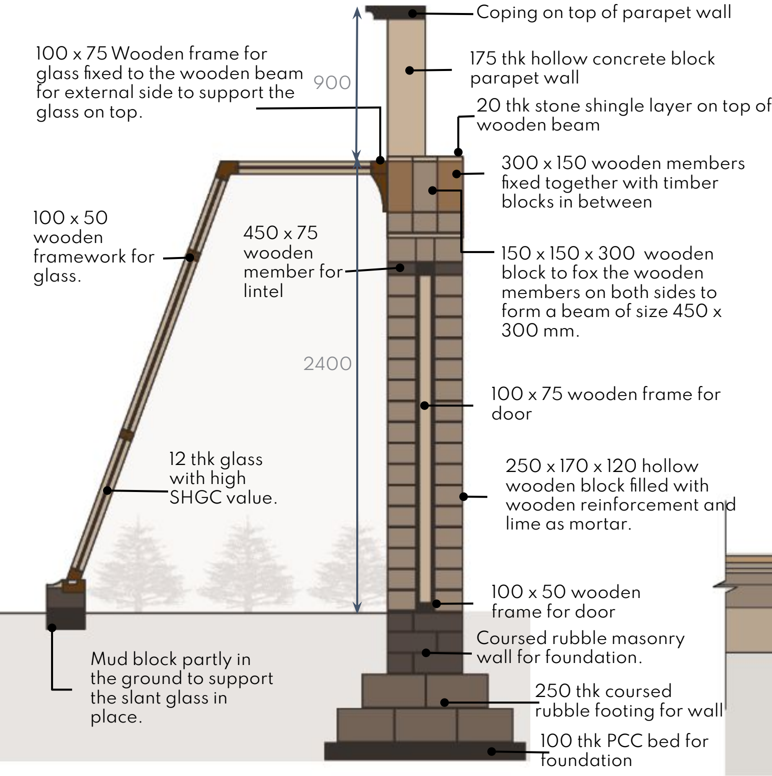


fig.27 Detail section of Sunspace through external wall

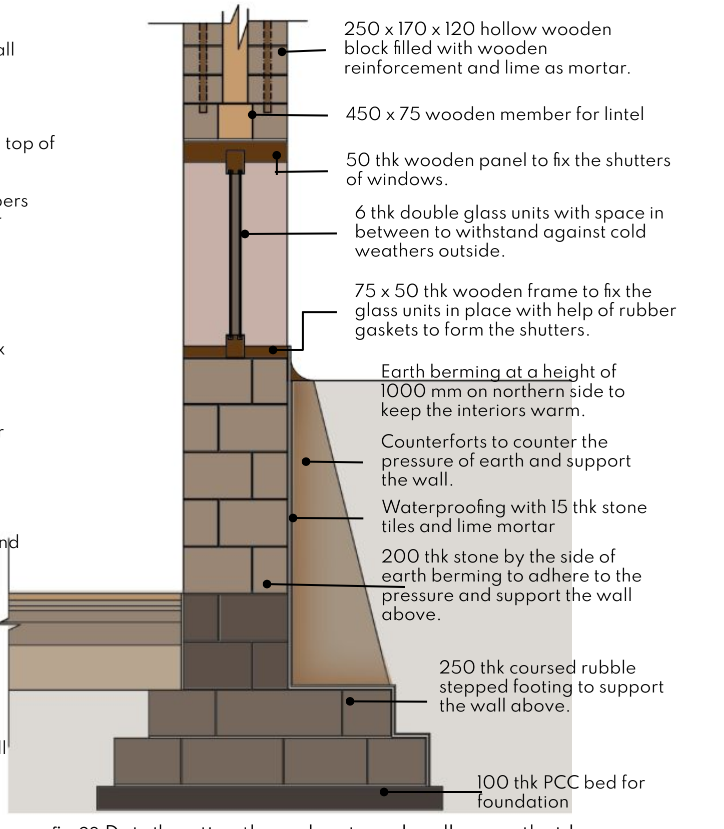
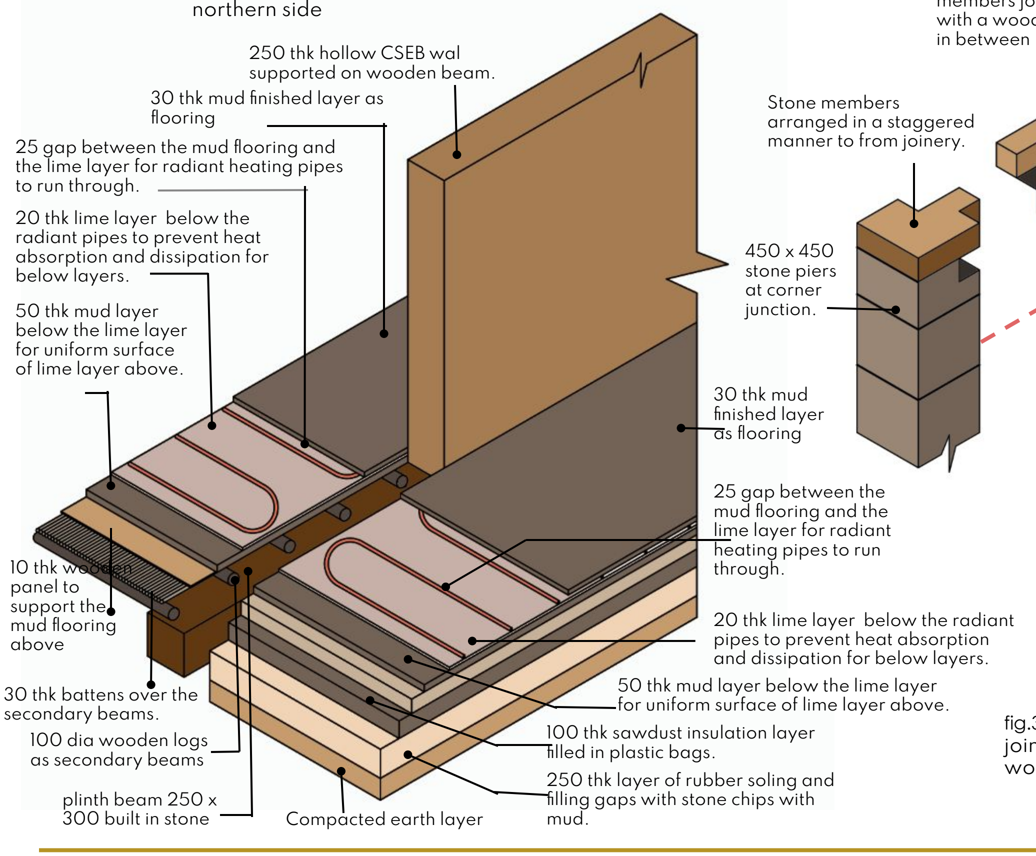


fig.28 Detail section through external wall on north side showing earth berming and foundation details

fig.29 Detail of sectional isometric showing flooring levels on southern and northern side



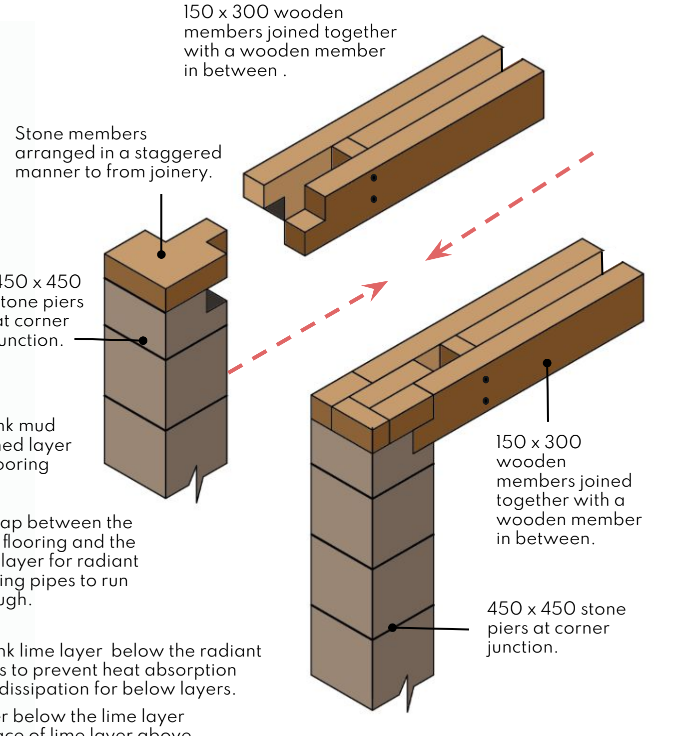


fig.30 Detail of isometric showing joinery detail between stone pier and wooden beam.

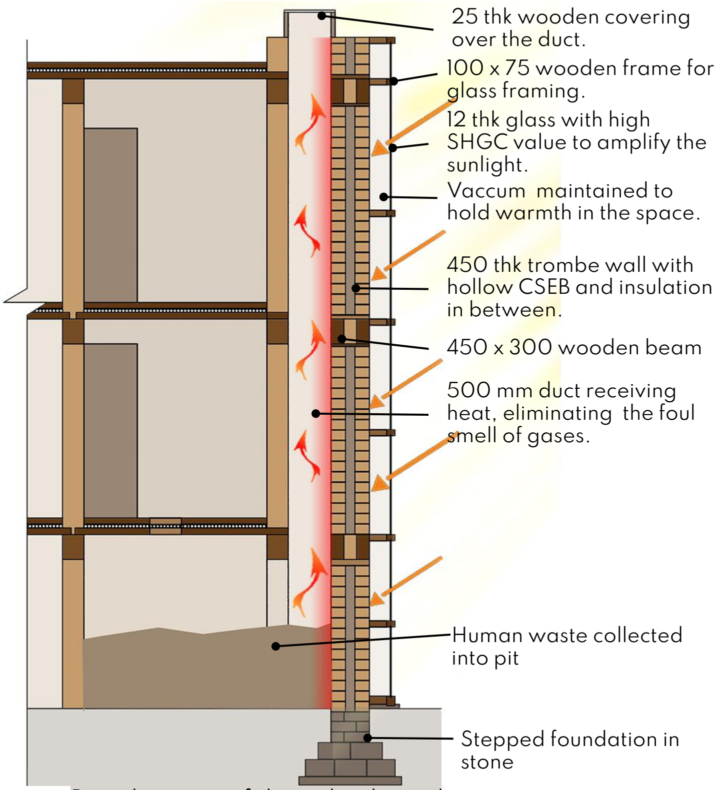


fig.31 Detail section of dry toilet through trombe wall showing operation of duct.

Dry toilet:

Due to less availability of water in the region, use of Dry toilets is their traditional practice, which has been incorporated in the design. There are two toilets stacked one above the other on both floors. There is common duct for ventilation which is located on the southern side which keeps it heated in turn helping the foul gases in the pit to travel upwards through the duct and gets released in the atmosphere. This process eliminates the foul smell from the gas before it is released in the atmosphere.

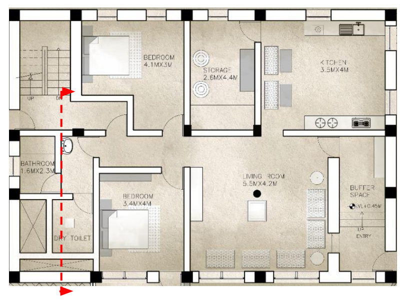


fig.32 Key Plan

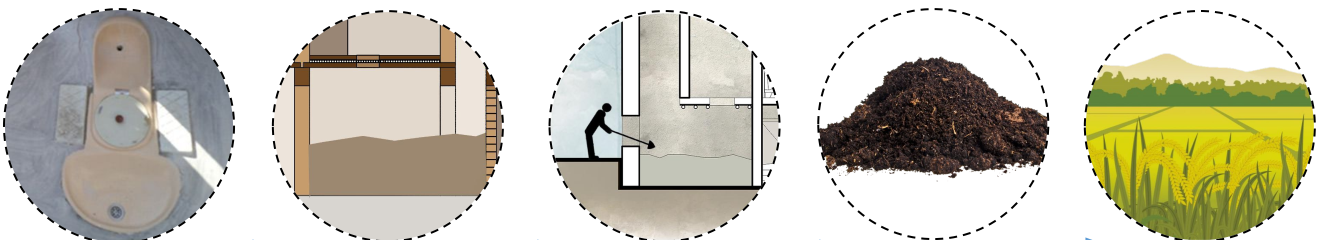


fig.33 Dry toilet flow chart

Radiating Heating:

The mechanism of radiant heating system starts from supply of fresh water to the boiler with an external source. This water is then heated inside the boiler with the biogas as eco-fuel. The water is heated up to 60 deg maximum and then is transferred to the pipes that are laid under the floor in the spaces. The pipes carrying the hot water gets heated and radiates the heat upwards. Here, the flooring system also plays an important role. The material having high conductivity covers the radian pipes from top and the layer beneath the pipes is placed with a material having low conductivity value so that the heat does not radiate to the ground in opposite direction. The water in the pipes, after dissipating all its heat to the space, again is collected into the boiler tank with help of pump. This action is carried out with a thermostat that turns the pump on, which again transports the water back to the boiler. The same water is used in the cycle for 15-20 days.

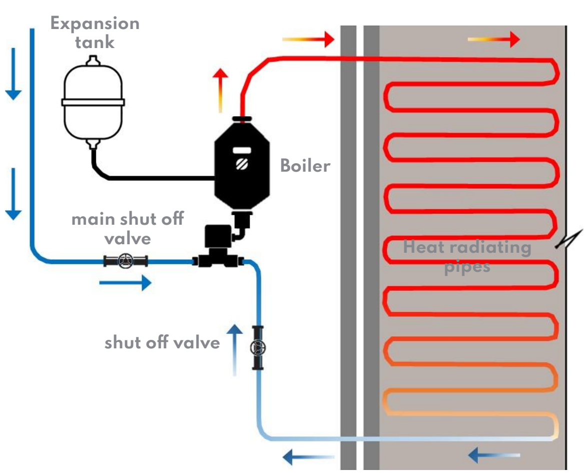


fig.34 Radiant heating system

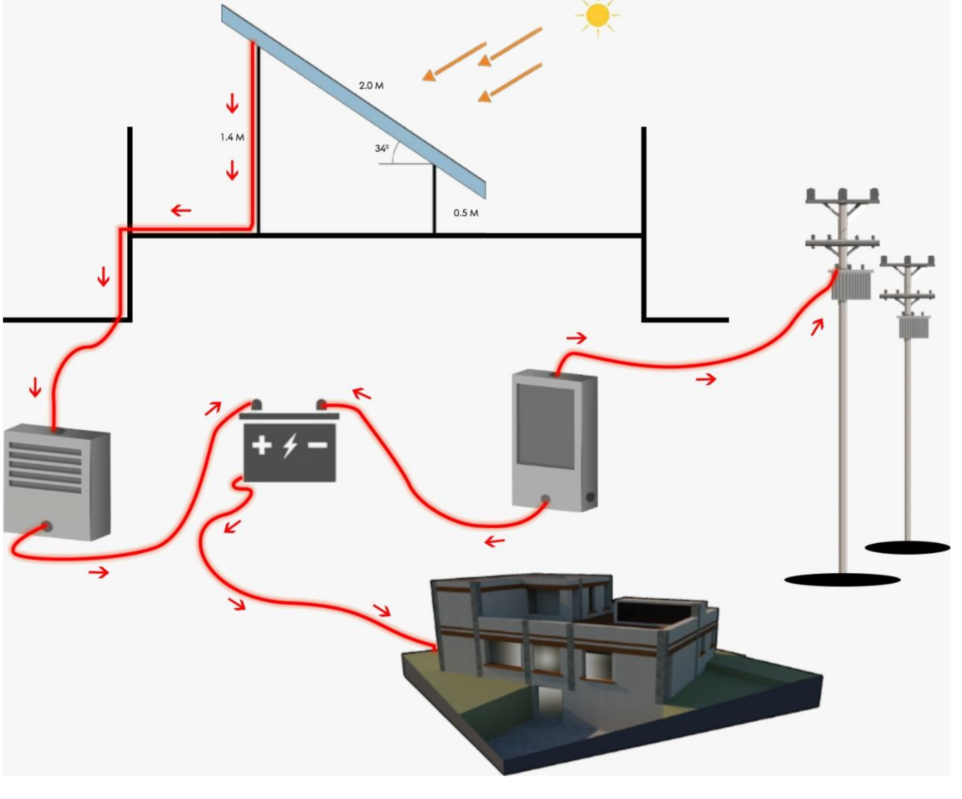
Plumbing layout

Drainage lines provided for grey water collection. Grey water forwarded to root zone system via inspection chambers

Site Plan

Solar panels layout

Panels and batteries location



Innovation :

Keeping our aim of preserving the traditional and cultural aspects of lifestyle in Leh. We adopted their traditional construction techniques with some innovation in it, which will help meet their comfort in a better way.

Their traditional construction style of building structure with mud blocks, stone walls, slabs of mud and roof supported by wooden battens covered with thatch and layer of mud on it. This vernacular style is withstanding the extreme temperatures, which in itself is a sustainable practice. To enhance this building technology, we tried moulding the mud blocks into Hollow CSEB (Compressed Stabilized Earth Blocks), This hollow portion will be useful to insert the wooden reinforcement in it which will help these layers to be in position withstanding the earthquake loads. A cavity wall will be built by these same blocks and filling the cavity by reusing the waste wool produced from the Pashmina textile industry.

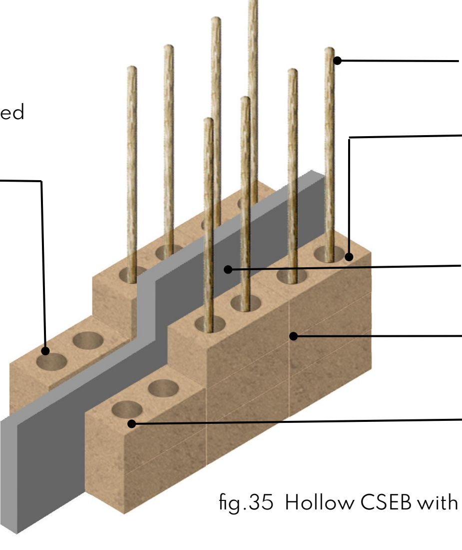
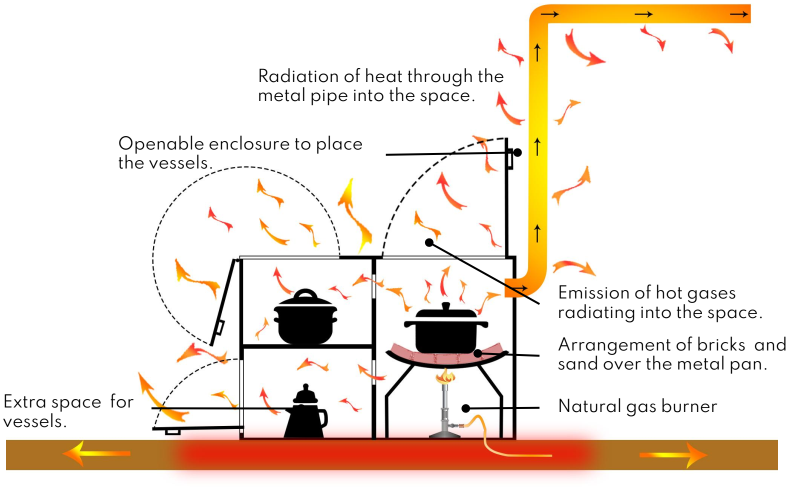


fig.35 Hollow CSEB with wooden reinforcement

The traditional heating systems known as Bukhari which helps heating the interiors of the house and also for cooking. The main problem with this technique was burning of wood and dried cow dung which increases the carbon emission and smoke affecting the health and environment. But being an essential element of their lifestyle, we tried advancing this technique by innovating a new method of litting up the bukhari with the help of biogas. To help this heat to last for longer period of time and also to use Bio-gas efficiently we made use of mud bricks and sand replacing the wood which eliminates the carbon emission or any type of smoke. It also helps to generate flames for cooking. A metal pipe connected to the Bukhari will carry the heat along with it in the living room, which will help heat up the room through radiation.

fig.36 Eco-Bukhari



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Performance Specification:

Renewable Energy Generation - Solar Panals(module level)	
Total enegy generation per day	1.89925 KW
Systeam Type	Grid Connected
Brand	Wolt Solar,Ahmedabad
Wattage	380W
Model Type	WT 144M380
Dimentions	1000cm*2000cm*40cm
weight	22.5kg
cost	₹ 8,800 / Piece
https://m.indiamart.com/proddetail/400w-mono-half-cut-cell-	

Table 5 Renewable Energy Generation

Batteries	
Ampere Hours	200 Ah
Nominal Voltage	24 v
Brand	Luminous Solar LPTT12200L 200 Ah
Cost	21455

Table 6 Solar Energy Storage Batteries

Water pump (Community level)		
	Pump 1	Pump 2
Pump type	Self Priming Pump	Self Priming Pump
Quantity	1	1
Power	1.1kw	0.75 kw
HP	1.5 HP	1.0 HP
deliver capacity	3960- 360 lph	2700-500 LPH
product discription	Kirloskar MEGA 54S	Havells India MX! Series 1 HP
Head Range	10-52 m	6-34m
Cost	8928	6290

Table 7 Water Pumps

Solar Inverter(module level)	
Power	500 W
Output Power(Kw)	1.5kva
Brand	Ryben
Battery Capacity	80Ah to 200Ah
Model	1.5 KVA
Battery Voltage	24V
Cost	12500

Table 8 Solar Inverter

Lighting specification					
Sr no.	Wattage	Lumens	No of luminaries	Spaces used in	Product specifications
1	5	450	5	Passage, Toilet, lobby,	Wipro Garnet E27 Polycarbonate 5W Cool Day Light
2	10	800	3	Staircase, terrace,	wipro 10W B22 LED Cool Day White Bulb
3	13	1100	4	Bedroom, strorage room	Havells E27 13-Watt LED Bulb (White)
4	18	1600	4	Prayer room, stable	Syska SSK-SRL-18W-2 B22 18-Watt LED Bulb
5	19	1800	1	Kitchen	Philips LED Bulb 19W
6	20	1900	2	Living room, cattle shade	wipro 20W B22 LED White Bulb (Garnet)

Table 9 Lighting Specifications

Miscellaneous					
Type	Power	No.s	Total wattage	Brand	Description
Socket 1	12	12	144	Exquisite Export International	Exquisite Export International 3+1 Universal 6/13 amp Multisocket Extension Board Indicator model with 1.5mm 3 Core ISI Copper Wire Cable
Socket 2	12	9	108	Exquisite Export International	Exquisite Export International 3+1 Universal 6/13 amp Multisocket Extension Board Indicator model with 1.5mm 3 Core ISI Copper Wire Cable
Television	80	1	80	samsung	SAMSUNG 80 cm (32 inch) HD Ready LED Smart TV (UA32TE40FAKBXL)
Mixer grinder	400	1	400	Bajaj	BAJAJ 3501 GX 400 W Mixer Grinder
Water filter	35	1	35	Aquagrand	Aquagrand SkyLand 18 Ltr RO + UV + UF + TDS

Table 10 Miscellaneous

Resilience :

- Ladakh, union territory of India, located in the northern part of the Indian subcontinent in the vicinity of the Karakoram and westernmost Himalayan mountain ranges.
- It is a Highly earthquake prone, and it is placed in **Zone IV** of Earthquake Damage Risk zones.
- The Largest Earthquake in Leh this year was of **4.8 Magnitude** at a depth of 24 km and at a distance of 53 km from leh.
- So it is necessary to make this structure resilient, hence there is a need for application of strategies for resilience of the structure.

Source : volcanodiscovery.com

Proposed Strategies -

1. **Horizontal and Vertical wooden bands** are used, which ties the structure tightly and gives the adequate strength to the structure. The structure is well tied with horizontal wooden lintel bands also the same goes for band for roof and floor slabs. These are thus supported by vertical wooden logs acting as reinforcements in the hollow mud blocks.
2. **Lightweight Materials** are used, which will help in earthquake. The materials used are light like hollow compressed stabilized earth blocks and wooden reinforcement which eventually reduces the load on the structure during earthquake and are tied well with the wooden supports.
3. **Planning of Structure is Proportional**, the length to breadth ratio is well thought of and slender or longitudinal planning is avoided so that the loads are distributed equally. The height is to length/breadth ratio is thought of to have a balanced ratio.
4. **The building is a Pier Beam Structure** which will bear a part of the load, which will prevent of transfer of whole load on the walls. The structural grid is worked out with the help of stone piers and wooden beams to have a grid system, as a result it will help to reduce the load on the walls. It will also help in proper load transfer during the earthquake.
5. **The stepped foundation** for the walls constructed with help of stones also will help to resist the dynamic movement of the structure, which will help retain earthquake.

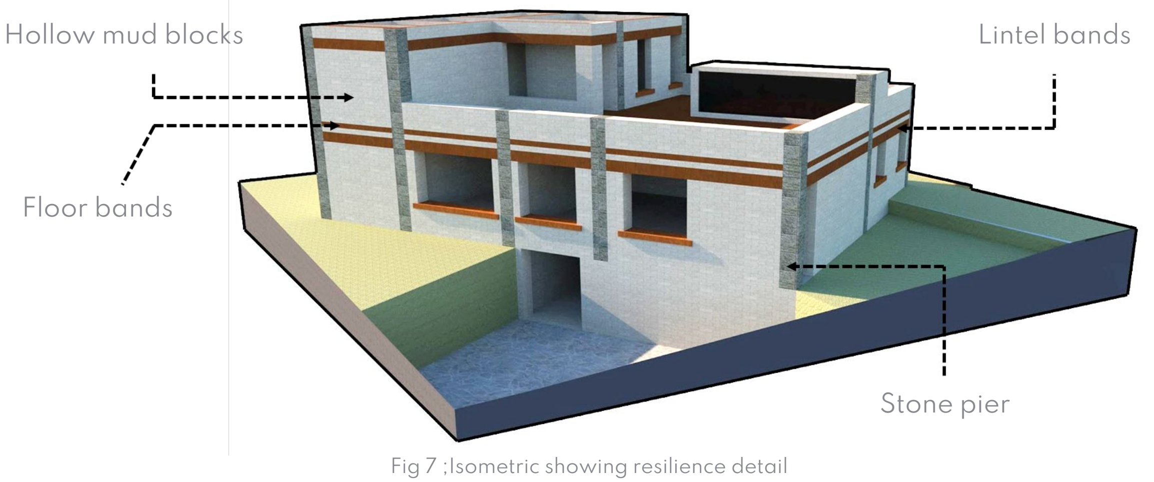


Fig 7 ;Isometric showing resilience detail

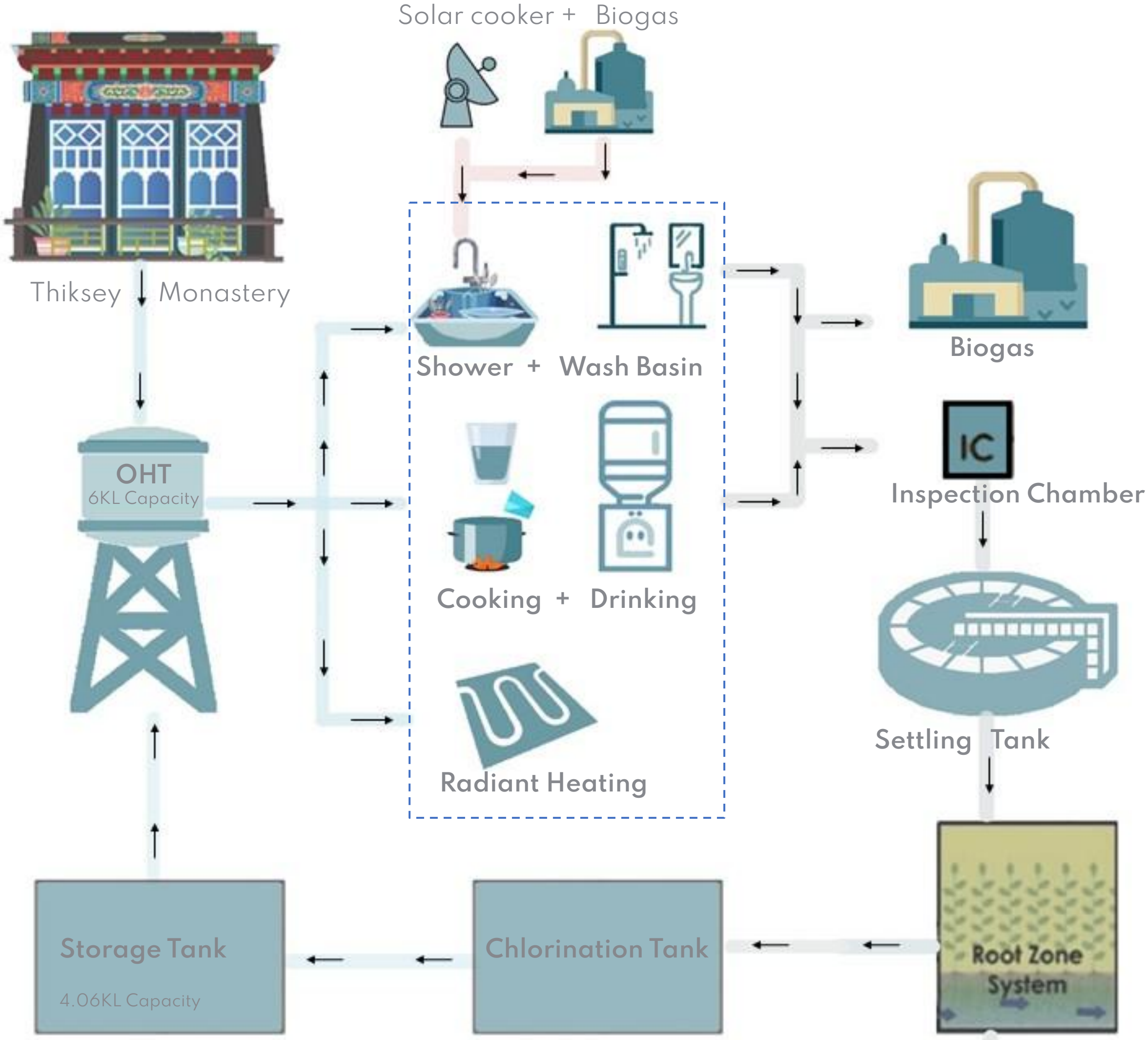


Fig 6 Water Cycle Diagram

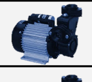
Symbol	Type of Pump	Pump Specifications
	Self Priming Pump	1hp for Monastery water supply line to OHT
	Self Priming Pump	1.5hp for UGT to OHT

Table 19 Pump Specifications

To achieve net-zero in water, available water on site is circulated through various processes of filtrations. Water taken from the **monastery water supply line** considering 75L per person is collected in **OHT** of 6kL capacity situated at the top of the site. The height of OHT being 21M high, the water is pumped up with the help of Self Priming pump. The water further is used for bathing, kitchen, drinking & for radiant heating as per requirement. The fixtures are used with aerators for reducing water flow. An average amount of **1.4kL** of greywater is utilized for the **biogas**. The remaining grey water is collected in a **settling tank** for primary treatment and released into the **root zone system** for secondary filtration. **1.6kL** average water from root zone is used for **irrigation purpose** monthly. The remaining average filtered greywater which is **7.6kL** is filtered into the **chlorination tank** and released into the **storage tank.** This recycled water is then pumped to the **OHT** back again with the help of a Self Priming pump to continue the water cycle. The water required for **drinking and cooking** purposes is filtered with the help of **reverse osmosis** process. The overflow outlet of the storage tank is connected to the Monastery water supply line via water meter. The water meter will count water taken from the Monastery and neglect the amount of water returned to it, helping **to achieve net-zero in water.**

Ice Stupa :

Leh being a cold desert, it receives water shortage issues.Due to water scarcity, during spring time, in April/May, people in Ladakh, mainly farmers fall short of water for agricultural activities as well as for household use. This issue can be solved by the water which melts in the valleys of the mountain ranges and gets connected to the indus river. This water can be used to form ice-stupas (an artificially formed glacier).

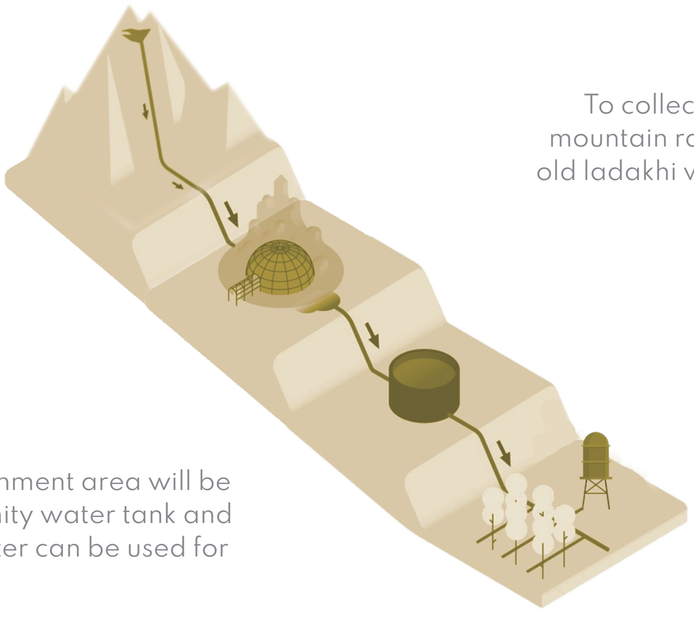
The nature of water is to get balanced in any shape it is contained in. This basic phenomenon of water is being applied for the generation of ice stupas.For example water from higher altitude, which travels upto a distance of 3km tends to travel up the head of 100m with the help of gravity forming a ice cone. According to the tests conducted by the SECMOL Institute, a prototype of ice stupa was built upto 7m high on the banks of the indus river, so if this prototype worked in the climatic condition then it will work at any location in ladakh. The results were a success and the stupa lasted for 2 months (april/ may).

To mitigate the water deficit problems, we proposed ice stupa of 7.5 m high in Thiksey village in higher altitude area of mountainous region where water from the mountains can be easily collected with the help of gravity. The formed stupa can generate 2-2.5 lakh litres of water which can be used by 2200 people for two months.

Height (m)	Amount of Water Generated	LPD / person	Total No of Benefitted People
7.5 M	227304.5 L	90 L/day	2200

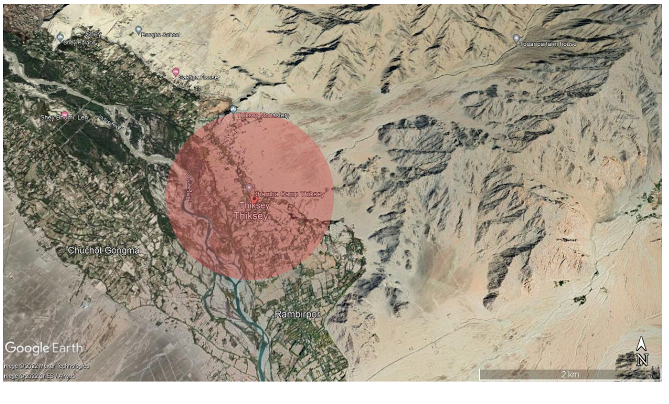
Step 3:
The ice melts in spring time of april and may and this water is taken to the water catchment area through pipes where the water is stored and used for four months.

Step 4:
The water from catchment area will be taken to the community water tank and some part of the water can be used for the farmlands.



Step 1:
To collect the water flowing from the mountain range from a height of 10m in old ladakhi winter nights at temperature of -30 deg celsius.

Step 2:
water travels up a head of 8 m due to gravitational force and sprays water into the air for 4-5 months (november - march) which at -30 deg celsius freezes and forms a conical heap called as ice stupa.



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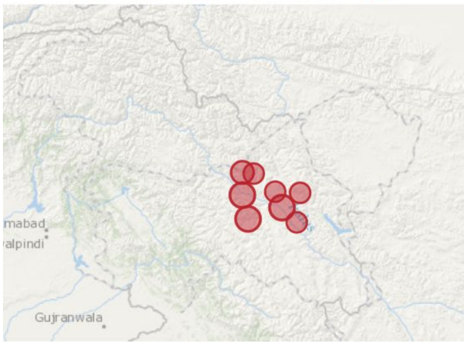
TANAYS DATA

Filter by magnitude:

all 2.0+ 3.0+ 4.0+ 5.0+ 6.0+

Filter by age:

all 1y 3y 5y 10y 30y



Earthquakes in past 1 year with 4.0+magnitude

Date and time	Mag Depth	Location	Details	Map
Sep 4, 2021 7:10 am (GMT +5:30) (Sep 4, 2021 01:40 GMT) *31 weeks ago*	4.1 10 km	46 km southeast of Leh, Ladakh, India	More	Map
Sep 1, 2021 2:42 pm (GMT +5:30) (Sep 1, 2021 09:12 GMT) *32 weeks ago*	4.1 10 km	21 km northwest of Leh, Ladakh, India	More	Map
3 Aug 1:22 am (GMT +5:30) (Aug 2, 2021 19:52 GMT) *36 weeks ago*	4.5 10 km	50 km north of Padam, Kargil, Ladakh, India	More	Map
Jul 18, 2021 10:09 am (GMT +5:30) (Jul 18, 2021 04:39 GMT) *38 weeks ago*	4.6 10 km	8.7 km southeast of Leh, Ladakh, India	More	Map
2021-06-19 13:49:02 IST (Jun 19, 2021 08:19 GMT) *42 weeks ago*	4.6 78 km	69 km west of Leh, Ladakh, India	More	Map
28 May 5:40 pm (GMT +5:30) (May 28, 2021 12:10 GMT) *45 weeks ago*	4.2 10 km	40 km northeast of Leh, Ladakh, India	More	Map
May 24, 2021 12:34 pm (GMT +5:30) (May 24, 2021 07:04 GMT) *46 weeks ago*	4.3 210 km	85 km northwest of Leh, Ladakh, India	More	Map
30 Apr 9:07 pm (GMT +5:30) (Apr 30, 2021 15:37 GMT) *49 weeks ago*	4.1 10 km	70 km northwest of Leh, Ladakh, India 1 report	More	Map
Apr 1, 2021 12:47 am (GMT +5:30) (Mar 31, 2021 19:17 GMT) *1 year 2 weeks ago*	4.9 10 km	74 km northwest of Leh, Ladakh, India 1 report	More	Map

Earthquakes in past 1 year

water crises

The Better India

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13-Jul-2018

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12-Jul-2018

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The people of Khalamarpoo, Hundurmo, Chumikchan of Sankoo sub-division of Kargil in Ladakh Union Territory started making artificial glaciers with community involvement to create an Ice Stupa.

Besides solving the water crisis in the region, these inventive stupas have also become an important tourist attraction in Ladakh. " We face difficulties in summers when there are minimal water resources available for agriculture, thus over the years we have started creating artificial glaciers in many areas near to our fields that help us in irrigation during summer season for farming " Asgar Ali , a local from Kargil said.

power

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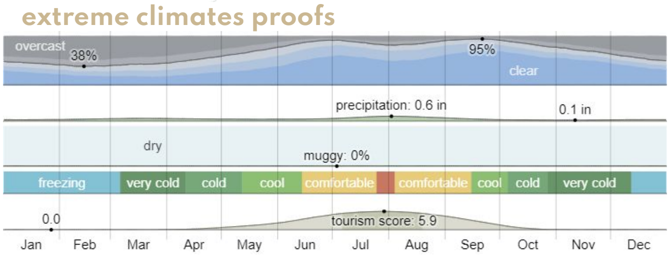
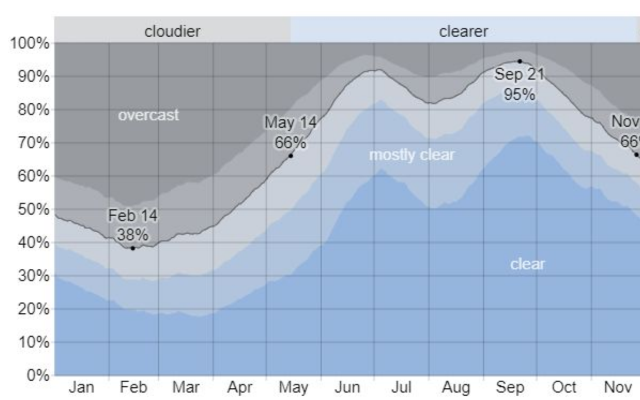
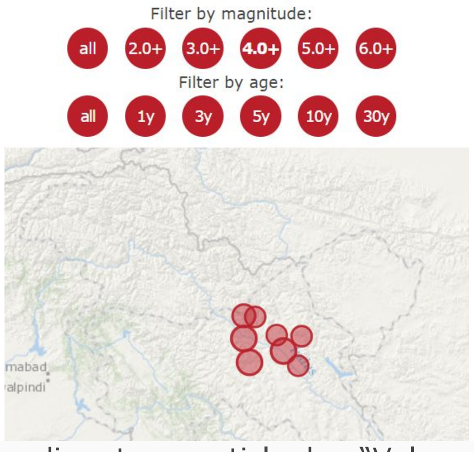
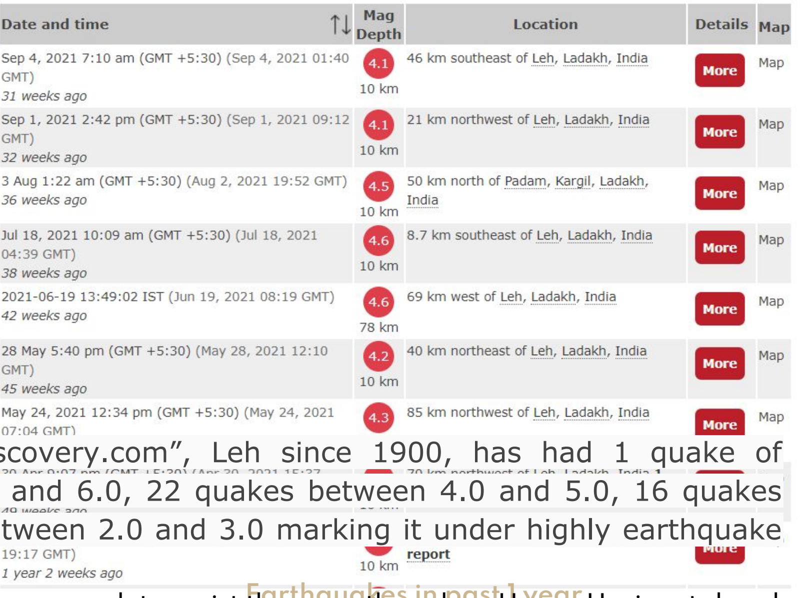
As part of its energy transition efforts, India is working towards the greening of electricity. According to the apex power sector planning body Central Electricity Authority (CEA), by 2030, the country's power requirement would be 817GW, more than half of which would be clean energy. This huge injection of electricity in the grid from infirm sources such as solar and wind require a storage mechanism that can help balance the national electricity grid. According to CEA, there will be a need for a 27GW grid-scale battery energy storage system by 2030 with four hours of storage.

extreme climates proofs









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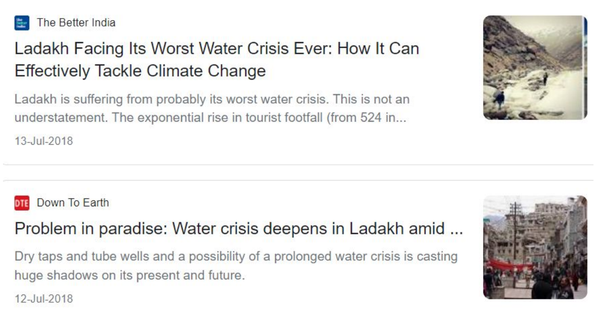
19:17 GMT) 1 year 2 weeks ago	10 km	report	More	

According to a article by "Volcanodiscovery.com", Leh since 1900, has had 1 quake of magnitude 6.4, 3 quakes between 5.0 and 6.0, 22 quakes between 4.0 and 5.0, 16 quakes between 3.0 and 4.0, and 2 quakes between 2.0 and 3.0 marking it under highly earthquake prone zone and placed in Zone IV.

So it is necessary to make this structure strong enough to resist these earthquakes. Hence Horizontal and Vertical wooden bands are used to tie structure in both directions, Lightweight materials like compressed stabilized earth blocks and wooden members are used to rescue the dead loads. The structure is planned proportionately and hence is not slender or longitudinal plan making it more stable. Moreover it is supported by pier-beam system forming a grid for better load transfer.This is hold strong by the stepped foundation for the walls constructed with help of stones which will help to resist the dynamic movement of the structure during the earthquake.



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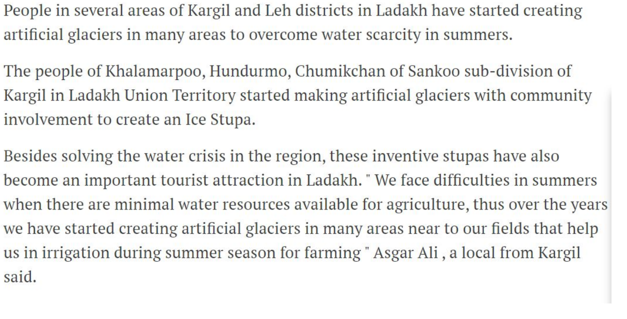

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According to article of "thebetterindia.com", due to climate change and global warming around 21% of glaciers have melted down which eventually has led to depletion in groundwater in Western himalayas(Leh). Also, being a cold desert region receives average 100 mm rainfall making a worse situation for drought. So first we focused on reusing the grey water produced through Reed bed system, also we are proposing ice stupa system which would cater to solve a macro level water issue.

6.	**Thermal Comfort and Indoor Air Quality** 	Designing the building envelope to achieve optimum indoor comfort, both visual and thermal. To mitigate the extreme temperature variations to meet better indoor comfort. To accommodate the building to mitigate the substantial weather changes.	Use of passive solar strategies for envelope such as solar wall, trombe wall, cavity wall for better thermal insulation. To paint the walls with dark colour from the exterior, which absorbs more heat. Smaller windows on all facades other than southern side to help mitigate the entry of cold breeze. The designed wall is capable of withstanding the extreme climatic conditions.
7.	**Innovation and Engineering** 	To Innovate a material palette with reference to indegenious materials for optimum thermal comfort.	Customizing newer technologies for the envelope to improve its insulation and thermal comfort. Floors and roofs can be insulated by closing the air gaps and using straw and waste from wood to increase the insulation.
8.	**Scalability and Market Performance** 	To design a house that serves to the population of Leh irrespective of their occupation (Farmer/ Businessman). To plan smaller time periods for payoff bills over the P.V cell panels and other appliances.	To decrease the energy load by using LED bulbs and energy efficient appliances Use of solar energy for cooking purpose with help of solar reflective panel.
9.	**Site Area for Vegetation** 	To cultivate their own vegetables and fruits. Conserving and planting more trees on site will also help the building in response to the climate.	Greenhouses with sun space strategies can be helpful in growing their own vegetables and fruits at household level. Plantation of trees on West and southwest will help in blocking the cool breeze at night.
10.	**Affordability** 	To consider affordability as an important factor while looking at the total cost.	Using naturally available material generated on site in maximum proportion to build on site. Traditional construction techniques to overcome cost of skilled labor.


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Leh region has only one small hydro power project which generates energy for the region. Hence there are lot of issues of power cuts. To tackle this issue we have provided a 100% off-grid power generation system out of which 40% is generated by Solar PV and 60% by Bio-gas.We also have provided batteries to store power during harsh winters and net-metering will be used which will provide the excess electricity during summers to the nearby communities.

Leh being a cold desert, it receives extreme cold winter ranging from -20 degree to -30 degree celsius and hot summers ranging from 30 degree to 35 degree celsius. Hence our primary approach was to make it resist these harsh temperatures and create a thermally comfortable environment. This is achieved through various Passive and Active solar strategies like, use of trombe wall, providing sunspace, insulated walls and roofs, provision of radiant heating and bukhari system. They overall maintain a good heated environment even if the outer temperature is -5 degree celsius, the inner temperature is around 15-20 degree celsius, eventually making is thermally resilience.