Institute without Boundaries

Modular Housing System Design Charrette

Fall 2009

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Forward

"According to the UN, the planet's population will grow to the level of around eight billion people over the next 25 years. It is estimated that by 2030, there will be a need for 40 per cent more housing and basic infrastructure services than existed in 2005. To meet this need, more than 4000 housing units will need to be constructed every hour, for the next 25 years."[1]

This statistic was published in London England's Architectural Review in 2007. Only one year prior, it was on a similar premise that the World House Project was launched at the Institute without Boundaries. The intention of the project is to generate systems for human shelter that achieve a balance between urban sprawl and urban slums, and enables communities to design dwellings that are based on principles of sustainability, universality, technological responsiveness and balance. Our goal is to propose design concepts that are sensitive to their social, ecological, political and cultural contexts, and to find viable development patterns that will lead to a positive future.

As such, this charrette's topic of investigation, to develop a design for an affordable modular housing system, is closely aligned with the mandates of the World House initiative.

To date, the World House Project has included collaborations with local and international partners, such as the Canada Mortgage and Housing Corporation, the Ministries of Housing and Culture in Costa Rica, Habitat for Humanity Canada, Evergreen Canada and the Toronto Community Housing Corporation.

This charrette collaboration, with entrepreneurs Andy Napier and James Ruehle has, in particular, called to the forefront a concept that is central to the World House Project's work. That is, the ever increasing need to think globally and act locally; and, the tensions that emerge when doing so.

The need for shelter is fundamental, world wide. As well, it may be assumed that the delivery of shelter could be achieved using similar techniques and strategies, internationally. At the same time, the home can be viewed as an interface between an individual and the world - each one a unique expression of cultural and personal values. In addition, each region will possess its own set of abundant resources and trade skills, necessitating use of specific materials and building styles. Although the Institute has completed projects of a similar nature to this one, it has by no means settled on any one design approach or solution - as each of the world's one hundred and ninety five countries present unique characteristics that deserve individual investigation.

Developing a system that could successfully function within the two countries that have served as case studies for this charrette (Canada and Costa Rica) will ultimately demand acute attention to their similarities and disparities – specifically those of climate and culture. Refining the building system will be an exercise in subtle differentiation. One aim of the work presented in this report is to simplify the process of customizing the design for each new site.

Secondly, the project highlights a refreshing practicality – that being, the potential and limitations of contemporary residential construction.

It is no doubt that an industry that is so essential to the prosperity of civilizations would be layered with complexity. Most notably, the overlap between materials extraction and processing, product development and manufacturing, trade labour training, and building policy has created a steadfast chain of supply and demand.

Redeveloping an approach at any point on this chain is best achieved through the collaborative efforts of many. It will involve creative and strategic partnerships, diligent investigation of options, acceptance by governments and steady growth of supporting resources.

Subsequently, a collaborative charrette process is a suitable format through which to investigate this topic. In moving forward, further charrettes involving potential project partners (including institutions, investors and suppliers) could be beneficial.

We would like thank Andy Napier and James Ruehle for inviting the Institute to participate in this design exploration.

The Institute Team

1. Knafo and Kilmor

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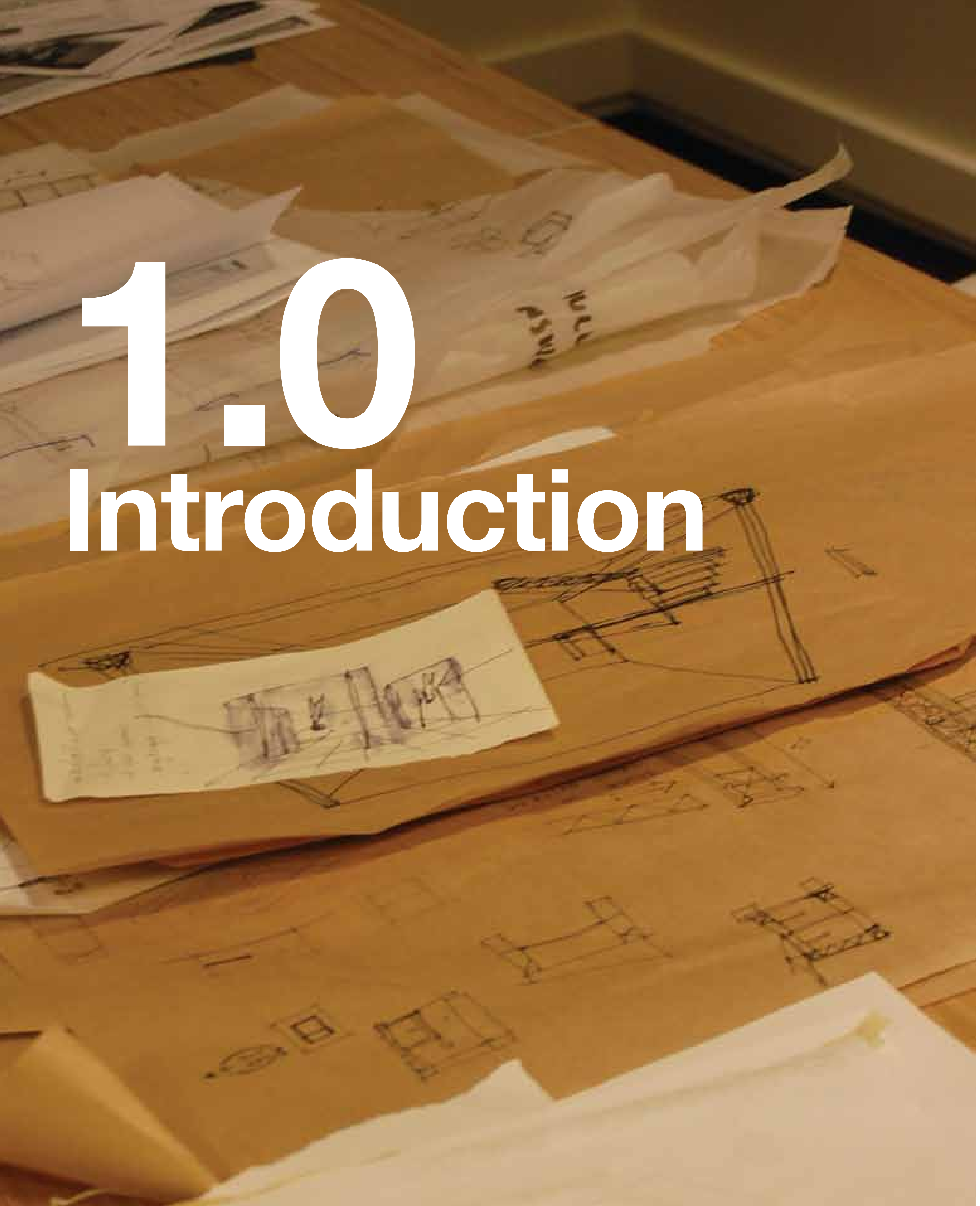


1.0 Introduction

1.1 Project Overview

Shelter is fundamental; and, providing decent shelter for all existing populations should be viewed as both a social responsibility, as well as critical to the evolution of humankind.

In addition, most contemporary building practices are viewed as destructive to the ecosystems that support us. The extent of this damage includes, but is not limited to, destruction of landscape through materials extraction, pollution of air and water during materials processing, generation of waste and wasted water during construction, and destruction of habitats through site excavation.

These two challenges are primary to the housing industry, and many private, non-profit and cross-sector initiatives already exist to address them. For example, benchmarking tools such as LEED, the Hannover Principles and The Natural Step have reshaped approaches to construction, beginning in the planning phases and ending with operations and maintenance. As well, organizations such as Habitat for Humanity ensure availability of affordable housing that also meets specified design standards. Of course, underpinning these issues are ongoing discussions about quality of life.

The Modular Housing System Design Charrette sought to address these two challenges primarily by proposing a practical and simplified approach to the design of shelter that could be implemented on many scales and with a minimal environmental footprint. (For the purposes of this report, we will refer to these two issues as ‘delivery’ and ‘performance’.)

The system that is presented in this report (The Open Lattice) comprises of a modular, structural shell, which could be adapted to suit different sites - therefore simplifying the design process for each subsequent development. For the purposes of this report, the system has been tested using two existing sites - one in Guanacaste, Costa Rica and the other in Southern Ontario, Canada.

The premise of The Open Lattice housing system is that its basic structural components could be repeated across many applications, but its elements of cladding, systems integration, foundation and roof design, in addition to its spatial organization and site orientation, would be modified each time. As the design is filtered and amended according to the demands of each new scenario, it will be enriched.

At present, the design of The Open Lattice is not specific to any particular type of manufacturing, shipping or installation processes - and so the opportunities are open in this regard. These details will ultimately affect certain design decisions however.

1.2 Project Objectives

The intention of the Modular Housing System Design Charrette was to conceptualize a system that could ultimately help provide affordable shelter for all, while also employing design practices that have minimal environmental impact.

Primarily, the building system is intended to display characteristics of:

1. Modularity
Coordinates existing building products, materials and systems into an 'open' housing system to permit simple construction and future expansion of units.

2. Adaptability
Could be customized to suit a variety of sites, users and climate zones. (Specifically, the design was adapted for two existing sites - one located in Southern Ontario, Canada and the other in Guanacaste, Costa Rica - to test its flexibility.

It is important to note that there are a few assumptions that were inherent in the charrette objectives that were not tested explicitly. Namely, that:

- a modular approach to housing design may simplify construction, reducing labour and overall costs;
- a modular approach to housing design may accommodate flexibility of function over time, therefore improving the effectiveness of the space
- all housing developments share universal characteristics, which can be planned in advance

1.3 System Evaluation Criteria

In addition to the project objectives listed in the previous section, the charrette team used a list of eleven criteria to evaluate the suitability of various materials, products and building systems; as well as, the anticipated performance of the final design proposal. This list was generated as an expansion of the overall project goals, as follows:

1. COST
Total construction and installation of fixtures and systems within a basic model results in a total cost of $180/sq ft.

2. VALUE
Design choices result in combined and multiple benefits.

3. EASE OF ASSEMBLY
Minimizes time, specialized equipment and specialized training required for complete installation.

4. EASE OF MAINTENANCE
Minimizes specialized parts equipment and training required for repairs and upkeep.

5. DURABILITY
Resilient to the environmental conditions of the specific climate, natural phenomena, pests and standard usage patterns of a residential unit.

6. SUSTAINABILITY
Performs well on a life cycle cost analysis and demonstrates 'best practices' in sustainable building, including energy efficiency. Can integrate with regionally specific materials.

7. MOBILITY
Light to ship and simple to deconstruct for reuse of parts.

8. FLEXIBILITY
Easy to modify, add and subtract spaces and features.

9. APPLICABILITY
Integrates with cultural and social values of the two study regions.

10. AVAILABILITY
Components can be sourced locally and/or easily.

11. LIVABILITY
Achieves standard quality of living.

2.0 Evaluation: Residential Construction

2.1 Benchmarks and Precedents

For the purposes of this assessment, we will assume that the two over-arching, contemporary challenges for the housing sector are, as were outlined in section 1.2, performance (or sustainability) and delivery (or affordability).

PERFORMANCE (Sustainability)
Reducing the overall environmental impact of housing could be generally accomplished using the following strategies:

1. Select building materials that consume minimal total embodied energy.

2. Use construction processes that consume minimal total embodied energy.

3. Maintain an efficient building envelope to reduce total energy expenditures during the building's operation.

4. Select energy efficient and water efficient appliances.

5. Select low VOC materials.

There are a number of existing models and tools that can help assess the environmental performance of a building, such as the Canada Green Building Council's LEED rating system, the Green Building Initiative's Green Globes (www.thegbi.org), the Athena Institute's EcoCalculator and the National Institute of Standards and Technology's BEES 4.0 (Building for Enviromental and Economic Sustainability Technical Manual and User Guide). (See Figures 1-3.) However, the metrics of these evaluations are not without subjectivity. The following quotes illustrate this debate:

"...material credits have typically evolved from a concensus-based understanding of environmental issues, understandings that, in some cases, have taken on an aura of conventional environmental wisdom that does not always stand up to objective analysis. As well, there is risk of confusing means and ends, with the means becoming objectives in their own right to the possible detriment of environmental performance...Recycling has always been only a means to the objective of reduced flows from and to nature, but over time it has taken on the mantle of an objective in its own right."[2]

"...there are an increasing number of buildings on the ground that have been designed according to criteria established in incentive or rating programs, and these are often associated with certain visible 'green' features, such as exterior window shading, good daylighting, green (landscaped) roofs, and natrual ventilation chimneys. Thus, there is a common misconception that green buildings are solely defined by such obvious features. However, many green building features are subtle or even invisible."[3]

Lucuik goes on to suggest that the best place to start is an overall and comprehensive assessment of total energy consumption, atmospheric emissions, ecological damage, water consumption, material selection, solid waste emissions and indoor air quality as important considerations. He also recommends that "from a design perspective, the key process difference bewteen green and conventional buildings is the concept of integration." [4]

DELIVERY (Affordability)
Reducing the overall cost of housing could be generally accomplished using the following strategies:

1. Seek to achieve time efficiencies in the manufacturing and construction of units by simplifying the process.

2. Seek to use a minimal quantity of building materials.

3. Seek to achieve spatial efficiencies.

4. Seek to achieve economies of scale by reusing a similar design strategy for multiple units.

5.Seek to achieve economies of scale by producing mass quantities of the building components.

6. Seek to achieve economies of scale by sharing services (such as geothermal heating) across many units.

7. Seek to reduce total costs by reducing reliance on infrastructure.

8. Seek to increase property value

9. Seek to use low cost or donated labour and materials. Using materials found on site (such as soil

10. Seek to generate income through the production of energy, or other services.

11. Seek other subsidies or partnerships.

Inspired by models such as the trailer home or the Sears, Roebuck and Company home, the prefabricated housing industry is attempting to achieve these kinds of efficiencies. (For the purpose of this report, the term 'prefabricated' will be generally understood as a dwelling where some or all of the building's components are manufactured in advance to erecting the structure.)

In general, prefabrication is claimed to achieve benefits such as reduced material waste as a result of working to within specified dimensions, increased economies of scale, as a result of mass production, and a higher quality outcome as a result of a controlled production process within a controlled environment.

Approaches to prefabricated housing can vary. Examples range from homes that are completed in an on-site factory, then rolled to the lot; shipping containers, modified with living amenities; compact, mobile homes that can be transported with a standard-sized vehicle and erected on site; shippable modules that can be arranged and connected according to a designed plan; and, building components, that are shipped flat and connected on site.

Following, are a few case examples of both prefabricated homes, as well as 'green' homes.

2. Integrating LCA Tools in Green Building Rating Systems.pg2

3. A Business Case for Green Buildings in Canada.pg4

4. A Business Case for Green Buildings in Canada, pg6

FIGURE 1: TOTAL EMBODIED ENERGY OF CONVENTIONAL BUILDING MATERIALS[5]

Embodied energy refers to the total energy expended to produce a material, transport it to the point of use, and install it.

MATERIAL	Millions of Joules/kg	Millions of Joules/m3
Adobe straw, stabilized	0.5	750
Aluminum, recycled	8.1	21,870
Aluminum, virgin	191.0	515,700
Brick	2.5	5,170
Concrete, ready mix	1.0	2,350
Glass	15.9	40,060
Insulation, cellulose	3.3	112
Insulation, fibreglass	30.3	970
Insulation, polystyrene	117.0	2,340
Lumber, kiln-dried	2.5	1,380
Paper	36.4	33,670
Rammed-earth cement	0.8	
Steel, recycled	10.1	37,210
Steel, virgin	32.0	251,200
Stone, local	0.8	1,890
Straw, baled	0.2	31

5. Excerpted from:
The Good House Book, pg 42

FIGURE 3: LEED FOR HOMES RATING CRITERIA[6]

LEED for Homes measures the overall performance of a home in eight categories:

1. Innovation & Design Process (ID)
Special design methods, unique regional credits, measures not currently addressed in the Rating System, and exemplary performance levels.

2. Location & Linkages (LL)
The placement of homes in socially and environmentally responsible ways in relation to the larger community.

3. Sustainable Sites (SS)
The use of the entire property so as to minimize the project's impact on the site.

4. Water Efficiency (WE)
Water-efficient practices, both indoor and outdoor.

5. Energy & Atmosphere (EA)
Energy efficiency, particularly in the building envelope and heating and cooling design.

6. Materials & Resources (MR)
Efficient utilization of materials, selection of environmentally preferable materials, and minimization of waste during construction.

7. Indoor Environmental Quality (EQ)
Improvement of indoor air quality by reducing the creation of and exposure to pollutants.

8. Awareness & Education (AE)
The education of the homeowner, tenant, and/or building manager about the operation and maintenance of the green features of a LEED® home.

6. LEED Green Building Rating System

FIGURE 4: ATHENA ECO CALCULATOR[7]

The Athena EcoCalculator is a software that provides estimated ecological footprint of over 400 building assemblies. The calculations are based on the following criteria:

Primary Energy
This is the amount of energy used in the extraction, processing, transportation, construction and disposal of each material. Measured in megajoules (MJ).

Global Warming Potential
This is the amount of greenhouse gases created in the extraction, processing, transportation, construction and disposal of each material. Measured in metric tonnes unless specified otherwise.

Weighted Resource Use
This is the amount of raw materials required for the extraction, processing, transportation, construction and disposal of each material. Measured in metric tonnes unless specified otherwise.

Water Pollution
This is the impact on water quality created in the extraction, processing, transportation, construction and dispsal of each material. Measured as an index.

Air Pollution
This is the impact on air quality created in the extraction, processing, transportation, construction and disposal of each material. Measured as an index.

"Intrinsically, the potential of a material to enhance sustainability depends on the interrelationship of its strength, weight and other salient properties, with energy savings and the speed at which the materials can be recycled or grown if organic...Thus a plant like bamboo that is strong, light and easily grown, is important for sustainability."[8]

7. The Athena Institute

8.The Engineering Challenge of Urban Sustainability, pg 62

CMHC Healthy House
Martin Liefhebber
Location: Toronto, Ontario

http://www.cmhc-schl.gc.ca/popup/hhtoronto/v
http://www.architecture.uwaterloo.ca/faculty_projects/terri/cmhc.html

The Healthy House is a completely self-sufficient home, which was the Toronto winner of the Canadian Mortgage and Housing Corporation's (CMHC) Healthy Housing Design Competition. This competition stressed five key components in the design: occupant health, energy efficiency, resource efficiency, environmental responsibility and affordability.

The winning design is a 1700 square foot, semi-detached house built on a vacant infill lot in Riverdale. The building demonstrates an efficient use of land that had been considered unusable due to lack of servicing. Its vertical plan strives to occupy as little space as possible, while its heating, electrical, water and wastewater management systems are operated exclusively using sun and precipitation.

This product is available for sale through affiliate firm logical Homes.

Sustainability ●●●●
Low-E materials are used to improve indoor air quality. The building envelope is sealed by airtight construction, efficient windows and doors, and high R-value insulation. Durisol blocks (wood particle concrete made with 78% recycled, natural raw materials) reinforced with steel and concrete provide the structural wall system. Rainwater is collected, filtered, purified, and stored for drinking and washing. Estimated total water consumption would be approximately 120 litres/day for a family of three (compared to the typical 1050 litres/day). A limestone cistern lowers the acidity of drinking water and improves its taste. A slow sand, activated charcoal and UV light filter purify water. Surplus water is directed into the ground under the front lawn to irrigate fruit trees and flowers. Low-flow faucets are used and greywater is recycled for the shower, washing machine and toilets.

Livability ●●●
The home is designed to provide the maximum amount of usable spac
a small parcel of land.

BedZED
Bill Dunster Architects
Location: London, England

www.designcouncil.org.uk
www.peabody.org.uk/pages/GetPage.aspx?id=179
www.zedfactory.com

The BedZED community is designed to be a net zero fossil energy development, that produces as much renewable energy as it consumes.

The development consists of 99 residential homes, allocated for sale, shared ownership and social housing. It also includes commercial space, an exhibition centre, a children's nursery and a show flat for education purposes. Although densely packed, the community feels spacious due to interlocking design footprint and individual gardens and terraces.

Cost ●●
Homes are owned cooperatively, privately and through social assistance.

Sustainability ●●●●
Roof mounted wind cowls provide ventilation to the super-insulated buildings without using electricity. Selected materials maximizes the use of recycled, reclaimed, low embodied energy or natural renewable options. All wood come from sustainable sources. Each unit has full access to the sun and optimizes passive solar gain. Each house is equipped with energy meters to track energy production and consumption, and monitor household energy performance. Rooftops are equipped with solar panels and green space. An on-site cogeneration plant uses renewable fuel sources designed to provide energy and domestic hot water for the community. Waste water is collected, treated and recycled on-site. Each unit is provided with a private garden.

Flexibility ●●●
Each of the development's units have adaptable floorplans

Livability ●●●●
On-site child day care, an exhibition centre, commercial spaces and green areas enhance resident lifestyle. Residents also have access to a shared electric car, and there are 40 on-site car chargers.

THE CONTAINER HOME

De Maria Design Redondo Beach House
Location: California USA

In this design model, the shipping container becomes the house, with little additional assembly required on site. Refurbishing shipping containers has become increasingly popular and, is the most prevalent type of prefabricated housing found in Costa Rica. Approaches to refurbishing a shipping container as a living space include re-cladding, stacking and bridging two containers with a central roof. Regulations on the use of shipping containers as a home vary regionally. This type of housing only produces one residence per container; and, many design examples use two containers per unit. Ultimately, the cladding and finishing choices will affect the overall cost and performance of the system, as well as its applicability to its climate and users.

Cost: ●●
Many variants cost less than $100 per square foot[1].

Value: ●●●
Container provides load-bearing structural requirements.

Ease of Assembly: ●●●
Minimal assembly required. Connecting containers using a central roof is a simple design alternative. Bolting/connecting through the steel causes a risk of leaks. Cranes and other special machinery are required to position containers.

Mainten●●●●
No structural maintenance required? Rust?

Durability:
Structurally stable and very resistant to wear from weather and pests

Sustainability:
This model is reusing an existing product however, is inefficient to transport.

Mobility: ●●
High shipping volume. Shipping containers are designed for long distance travel on the back of a truck. Large size limits ease of mobility.

Flexibility: ●●●
Stacks well. A container's limited dimensions reduce ease of customization. Modifying these dimensions can be difficult.

Sustainability ●●
Poor thermal properties. Poor ventilation.

Applicability:
In Ontario, municipal regulations may not allow this type of structure? In Costa Rica, this type of housing is used widely.

Livability:
The shipping container aesthetic is suited to distinct tastes and living styles. It is not clear whether these models provide the standard comforts of a traditional home.

Awards:
Examples of recognized container

10 Clever Architectural Creations Using Cargo Containers: Shipping Container Homes and Offices http://weburbanist.com/2008/05/26/cargo-container-homes-and-offices/

This product is now available for sale through an affiliate firm logical Homes.

Cost: ●●●●
$125 USD per sq ft.

Ease of Assembly:
Requires 10 wk build time, and 70% of construction occurs off site, greatly reducing construction waste. The house comprises of 8 containers of varying sizes connected, using conventional building methods.

Maintenance: ●●●
Similar to a conventional home. Container should be kept rust-free.

Durability: ●●●●
Extremely strong, mold free, and fire and termite proof.

Sustainability: ●●●●
Minimal construction waste. Uses formaldehyde-free plywood, recycled shipping containers and tankless water heaters. Offers a variety of energy efficient modifications.

Mobility: ●●●
Shipping container components are mobile but the remaining portion of the house is not.

Flexibility: ●●●
Different variants are available for purchase. Could be renovated using similar means to a conventionally framed home.

Livability: ●●●
The metal container walls define service spaces while wood and steel frame the living spaces, including an artist's studio, master bedroom, and spacious living room with 20 foot ceilings. A container placed below grade serves as a swimming pool. Doors and windows are cut through the walls. The industrial aesthetic of the containers is exposed.

Adam Kalkin's Quik House
Location: New Jersey USA

Cost:
Between $125 USD and $165 USD per sq ft including all products and finishes.

Value: ●●●
High R-values make this home energy efficient. Presentation models create an open feel for the place in spite of its compartmentalized beginnings.

Ease of Assembly:
It appears as though the containers are welded together or joined by a frame.

Ease of Maintenance: ●●●
Steel exterior would have a long lifespan, provided rusting is avoided.

Durability:
Structure is durable, provided it is not punctured. Otherwise, connections might be the only other item that could compromise durability. No serious issues present on any sites discussing the product.

Sustainability:
Made from 75% recycled materials by weight. Further green modifications include solar and wind energy, a green roof system and a super-insulating R-50 system.

Mobility:
Designed for transport. Require machinery to lift.

Flexibility:
Available in 1,000, 2,000, 3,000 and 5,000 sq ft models. Can be customized further at additional cost.

Livability:
There is currently a 6 month waiting list for these homes, indicating that they are well received by the market.

THE MODULAR HOME

Modular prefabricated housing appears to be the most common approach to prefabricated housing. Modules may be divided as two complete halves of a home, or as other smaller sections in varying degrees of completion. Design varieties also range from minimalist to luxury. Most manufacturers offer a specific selection of modules that can be organized in a customized spatial arrangement. Some varieties will offer further customization options. Modules may have wall and floor cavities proportions that demand a high percentage of cubic volume when shipping.

Cost
Varies based on the design and the level of completion of each module. Typically less expensive than a conventionally built home of the same size, but more expensive than a container home (per sq ft).

Value ●●●●
Typically has a higher quality of workmanship than a conventionally-built home.

Ease of Assembly ●●●
Requires considerable manpower and/or specialized equipment to assemble. Companies like Normerica, that produce a variety of house components to fit plans, also provide a list of certified contractors to their clients.

Ease of Maintenance ●●●
Will depend on the quality of the modules, their connections and the climate. Maintenance requirements will vary marginally between a modular home and one that is conventionally-framed.

Durability ●●●
Flexibility in spatial organization and deconstruction may compromise structural integrity.

Sustainability ●●●
Dependant on practices of manufacturer, but presents the potential for waste reduction.

Mobility: ●●●●
Easily shipped and often flat-packed on a truck bed – as a result, could install on sites that are not accessible to large machinery. Smaller modules with a low profile will be easier to transport.

Flexibility: ●●●
Present many customizable options for spatial arrangement. Customization can continue after initial construction provided the modules are designed for future expansion. This may also depend on the future availability of parts from the same system.

Livability ●●●●
A well-designed modular home offers comparable quality of living to a conventional home.

Applicability ●●●●
Available in many styles and with many material options [list them], that could be suited to either region.

Awards
There are many modular home manufacturers, although the quality of their product varies. Renowned examples produced in the United States include: the Kieran Timberlake KT series (the loblolly house was one of architectural records record houses for 2007), Kaplan-Thompson Architects, Marmol Radziner Prefab, Michelle Kaufman designs (now obsolete), Resolution:4 Architecture. Renowned Canadian examples include: GreenPod Development LLC, Maple Homes & Viceroy and Normerica.

Kaplan Thompson Architects/Bensonwood
BrightBuilt Barn

Cost ●●●
$180,000USD for a 2 bedroom. The price is comparable a conventionally built home.

Value ●●●●
The home is considered net zero, and can operate off grid.

Ease of Assembly ●●●
This producer provides assembly of the unit, indicating that the installation process requires specialized knowledge and skills. The system uses simplified chaseways for plumbing and electrical.

Ease of Maintenance Nothing noted.

Durability ●●●●
Designed to last “200 years”. The BrightBuilt Barn is designed and constructed to last indefinitely as a result of both the durable qualities of its materials and by keeping its systems disentangled, allowing for flexibility and adaptability of the design.

Sustainability ●●●●
Designed as a LEED platinum home and achieves low operational energy costs.

Mobility ●●
Shipped to the site on a truck and lifted into place by machinery. Not designed to be moved following installation.

Flexibility ●●●
Designed to be flexible and to accept additional pieces. However, this process may be dependant on using the manufacturer’s installation team. Flexibility is repeated often in the project description but beyond expansion there is little mentioned as to how this flexibility is achieved.

Applicability ●●●
Suitable for the Ontario climate, although likely overbuilt for Costa Rica and other warmer regions.

Livability ●●●
The lack of mechanical systems would be unconventional for many users. Exterior, coloured lights expose the dwelling’s total energy consumption. Otherwise, the home is well-planned.

Method Homes
Built by Method PreFab: same company based out of Seattle USA

Cost:
Approx. $149USD to $170USD per sq ft.

Value: ●●●●
By building in a controlled factory environment, the quality of the outcome is increased and the fabrication time is reduced.

Ease of Assembly: ●●●
Modules are shipped to the site once the foundation is poured. Cranes and other machinery are required to lift them into place. They are assembled using conventional construction methods (hammers, nails etc.)

Ease of Maintenance: ●●●
Finished home is similar to a conventionally framed home in its maintenance requirements.

Durability:
No issues with durability beyond what is typical of a conventionally built home. Wood siding is specialized to resists rot and or could be treated against other kinds of weathering with sealants.

Sustainability:
Achieves a fresh indoor air quality using radiant heat and increased ventilation, and by eliminating VOC finishes and other harmful chemicals. Target LEED for homes 2.0 Gold certification or higher. Include FSC certified framing materials, reclaimed fir and cedar siding, energy-efficient lighting and plumbing fixtures, hydronic radiant heating, whole-house ventilation systems, solar options and enhanced insulation applications.

Mobility: ●●●
Shipped by truck and then assembled on site. It is not intended to be dismantled and repositioned on another site following installation.

Flexibility: ●●●
Different variants of this model are available. The home would be renovated using a similar approach to a conventionally-framed one. Method does not advertise additional parts for renovating all though there would be no barrier from ordering additional segments to the existing structure. This being said the existing structure is not specifically designed to easily accommodate such additions.

Livability:
The system’s use of ‘eco-friendly’ materials and energy efficiency make it an attractive option. Online blogs indicate consumer interest in this design. The system’s lifestyle characteristics are comparable to those of a conventional home.

Applicability: ●●●
The design is most applicable for the North American west coast and/or cottage market. The company is currently revising their stock of options intended for an urban setting.

KIT OF PARTS

●●●● High
●●● Medium
●● Low
● Lowest

In this approach to prefabrication, individual housing components are tooled, pre-drilled, cut to size and shipped — similar to a do-it-yourself furniture kit.

A popular approach is to use structurally insulated panels (SIPs), which is an old technology that has benefited from new developments in materials and manufacturing techniques. SIP panels achieve efficiency in their function by combining structure and insulation in one. They are popular because of their energy efficiency and their ability to pack flat (as a result of their limited profile and controlled dimensions). They are also commonly used in modular systems

KIT OF PARTS

Cost
Costs vary by manufacturer. Since they are sold as kits, cost savings may be achieved for the buyer.

Ease of Assembly ●●●
Complexity of assembly will vary with the system, and could potentially require specialized skills. In general, assembly will involve connecting interlocking pieces with nails or bolts.

Ease of Maintenance ●●
Some systems may require specialized replacement parts.

Mobility ●●●●
A kit of parts strategy typically achieves a low shipping volume. As a result, builders can feasibly fit many homes within one shipping container. Wall sections are manufactured in pieces, so are easy transport around the site, depending on the size of each segment.

Flexibility ●●
The kit system may be limited to a specific design or set of designs.

SIPs

Value ●●●●
SIPs possess high inherent R-values, with rigid insulation that is as good as a paneled wall (this value will likely increase with interior finishing).

Ease of Assembly ●●●●
SIP construction decreases framing time. Also, sections can be manufactured with openings roughed-in so additional work to walls is minimal. The panels can be cut on site if necessary.

Ease of Maintenance ●●●
According to some trade sites, there can be issues with SIP panels' breathability, and they may require additional venting to address interior moisture.

Durability ●●●
Panels are up to 2.5 times stronger than conventionally-framed sections. The OSB face board is prone to rot and decay and insects and pest may burrow in the foam interior. Durability is ultimately a function of the combined pieces as there are different manufacturers of SIPs there are likely different warranty measures for each product. Durability will be a function of this and the quality of the final assembly.

Also, the EPS or XPS soft foam core attracts rodents and/or other pests such as ants. Additionally, the OSB cover prevalent in many SIP systems is prone to deterioration. As such, it is critical that sections are assembled to specification. (Most of this criticism relates to SIPs that have been purchased as base building materials, rather than as part of a kit).

Sustainability ●●●
SIPs have a higher initial insulation value than most other building products and, as such, could be viewed as energy efficient.

Mobility ●●●●
Wall sections are manufactured in pieces, are easy to ship and also to transport around the site, depending on the size of each segment.

Flexibility ●●●●
Additions with SIPs are relatively simple, as is adding openings to existing walls.

Applicability ●●●
The system is well suited for northern (temperate) climates. The insulation is unnecessary in warmer ones.

Livability ●●●
SIPs can produce homes of any dimension, could be cut in different shapes and could be clad with a variety of materials, resulting a customized aesthetic. Their built-in insulation would generally translate into a comfortable interior environment.

Awards
There are a number of notable SIP housing manufacturers including Scott Homes (Washington) and Place House (British Columbia).

Usonian Home
Frank Llyod Wright
Location: United States

www.pbs.org/flw/buildings/usonian/usonia.html
www.thewileyhouse.com

The Usonian home is founded on the principle of providing affordable and beautiful shelter for the common person. Wright developed a series of designs with the intent of creating a formula and construction method where families could build their own home.

Wright believed in the moral and political model exemplified in home ownership; and, felt that well-designed, tasteful dwellings could produce happy, harmonious and enlightened societies.

The typical Usonian design is based on a single storey plan, divided into public and private wings. The two wings are joined by a 'service core' common area, comprising of a kitchen, a bathroom and a hearth.

Value ●●●●
Wright's design and construction strategy was intended to achieve a low-cost home that was also desirable.

Ease of Assembly ●●●●
A customized formula for construction was easy to follow by unskilled labour.

Sears Catalogue Home
Sears, Roebuck & Company
Location: National

●●●● High
●●● Medium
●● Low
● Lowest

http://www.searsarchives.com/homes/
http://en.wikipedia.org/wiki/Sears_Catalog_Home
http://www.oldhouseweb.com/stories/Features/Sears_Kit_Houses/

Sears mail-order homes took leading designs of the 20th century and devised a revolutionary way to construct and distribute them across the nation - making home ownership accessible and affordable.

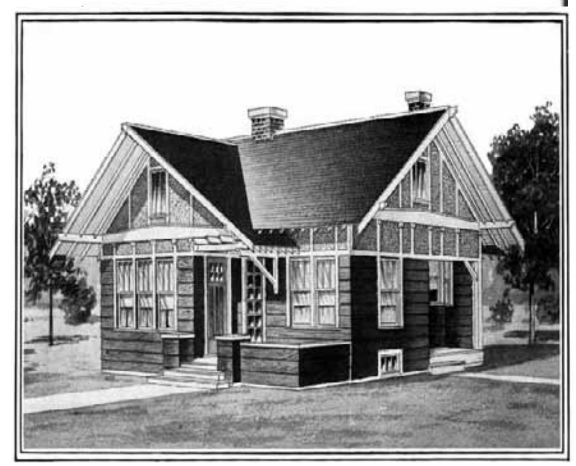
Value ●●●
Sears introduced an affordable financing plan where buyers could pay in installments.

Ease of Assembly ●●●●
In many instances homeowners would complete the installation themselves, with the help of friends and neighbours. Occasionally, a contractor was hired.

Sustainability ●●●●
Sears homes used the latest technology available, including central heating, indoor plumbing and electricity - systems that would not be considered efficient or sustainable today. Some of the larger, more expensive homes were most lacking in efficiency, in terms of their heating, lighting and space utilization. Some of the smaller, simpler homes, many of which were used as cottages, have since been retrofitted with new, alternative energy strategies.

Mobility ●●●●
Houses were shipped by rail or truck in over 30,000 pieces.

Flexibility ●●●
Prospective homeowners could flip through a catalogue and select their home according to its style and cost. Following this, consumers had endless options to choose from for the finishing details.



Eames House
Charles and Ray Eames
Location: Pacific Palisades, California USA

Case Study: The Eames House. Architecture Week. September 8, 2006
www.architectureweek.com

The Eames House was part of the Case Study Homes program sponsored by John Entenza's Art and Architecture magazine. The intension of the project was to produce inexpensive and efficient homes to address post World War II housing demands. The goal was to integrate the technologies and materials of the war into the design of the home.

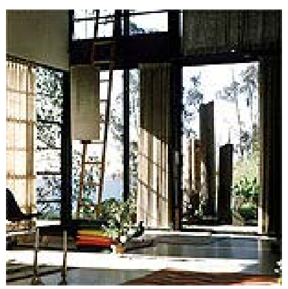
The first design for the Eames Case Study was called the "Bridge House" and was designed by Charles Eames and Eero Saarinen. All of the materials for this home were ordered from catalogues, and were delayed in shipping as a result of post-war shortages. Once the materials arrived, Charles and Ray had a new design planned. In the end, this was accomplished with only one additional beam.

Ease of Assembly ●●●
The steel frame of the house was assembled in one and a half days and is viewed as an early step toward prefabricated housing.

Mobility ●●●●
All materials were ordered from catalogues and delivered to the site.

Flexibility ●●●
The redesign was accomplished using the same material order as the first concept.

Livability ●●●●
The new design included 1500 square feet of living space and 1000 square feet of studio space, as well as an outdoor courtyard.



Cellophane House
Kieran Timberlake

The cellophane house presents an advanced approach to the typical prefabrication options, as it is a completely demountable structure.

"Cellophane House encompasses the architects' beliefs in a holistic approach to design: allowing architecture to grow out of its opportunities and constraints. It is a material moment of equilibrium that surrenders itself to any and all entropic forces that may come its way. At its core, the project is no more than a framework from which a designer or client creates an enclosure using a virtually infinite palette of off-the-shelf entities, a veritable model of customization. Through simple modifications, the house can adapt to a range of site conditions, as well as to material, textural, and color options as required by the budget and tastes of the client.

A building is, at root, nothing more than an assemblage of materials forming an enclosure. We recognize that these materials came from somewhere, are held together for a time by the techniques of construction, and will at some future time transition into another state. While we tend to think of buildings as permanent, they are in fact only a resting state for materials, a temporary equilibrium that is destined to be upset by the entropic forces that drive the physical universe. " – Kieran Timberlake

Cost: UNAVAILABLE

Value: ●●●
This design provides vast opportunity for customization, which would be attractive to buyers.

Ease of Assembly: ●●●
Diagrammatically speaking, assembly of the interlocking, extruded frame appears simple. It is not clear whether it is easy to attach the walls and floors to the frame.

Ease of Maintenance: ●●●
One visitor raised an issue with gaps in the floor at the MOMA exhibit, which would lead to issues with cleaning spills:

"I went to the MOMA exhibit and toured the Cellophane House. I loved it except for one slight problem: the heavy plastic floor panels have about a 1/4 gap, meaning that if you spilled any sticky substance (coke, orange juice, etc.), you would pretty much have to pressure wash the floor from the top and from the room below because the substance would leak onto the steel beams in the floor below the spill. Is there a way to seal these gaps in the flooring when you build the permanent structure? If there were a way around that problem, I would live in a Cellophane house in a minute. Great design, lots of space, really wonderful except for the flooring issue."

This issue is likely a result of the exhibit being a prototype and not a complete home.

Sustainability: ●●●●

The structure is designed to be reusable. Additionally, the exhibit has embedded photovoltaic cells to provide electricity. The design has the capability to incorporate other 'sustainable technologies'.

Mobility: ●●●●
The house is designed to be shipped on a truck and assembled on site. Additionally, it is easy to dismantle and reassemble on another site.

Flexibility: ●●●●
This system is designed to accommodate a variety of finishing materials. While this particular variant uses a 2 bedroom and 2 bathroom scheme, most KT modular designs offer a number of variants (and this one may as well). The building structure and connections are simplified to allow many modifications.

Livability: ●●●●
This design has been very well received at the MOMA exhibit, which indicates that the public deems it desirable. Most comments have been favorable other than a few about the transparent walls in the washroom.

Applicability: ●●●●
This model could be applicable to either environment. With flexible envelope materials, the system allows for the greatest amount of customization according to climate.

2.2 Building Products & Materials

The Good House Book, by Clarke Snell, uses the following classification for building materials:

TRADITIONAL

- Earth
- Stone
- Mud (cob, rammed earth, adobe, brick, wattle and daub, earth plaster)
- Metal
- Glass
- Plants (grass, wood)
- Animal Products

MODERN

- Plastics

ALTERNATIVE

- Recycled/Waste (tires, straw, wood-based, concrete-based)
- Local (earth, plants)
- Natural

The section that follows lists and evaluates the applicability of these materials for the modular housing system. The data presented in the following charts is intended to compare characteristics between existing structural and finishing materials. This comparison is divided between the two regions, assessing the materials' anticipated performance when exposed to the climatic factors listed in the previous section. Of course, all materials will decay over time as a result of exposure to environmental phenomenon. It is important to note that this evaluation is not based on any kind of product testing.

In general, the assessent is intended to achieve the following:

1. Determine which materials, products and building systems would be most suitable for use in a modular housing system.

2. Determine which materials, products and building systems would be most suitable for a housing system located in either or both of the specified climate zones (tropical and temperate).

"…modern buildings often overuse concrete in their foundations and overuse structural wood members in their walls. These materials create pollution in their manufacture and transport...As green builders our general structural strategy has to be to use just enough of the right materials to create a structure that will be as strong as we need it in the worst case scenario, i.e those times when loads are the most extreme in our specific situation." Snell and Callahan, Pg 47-48

●●●●● Very High
●●●● High
●●● Medium
●● Low
● Lowest

STRUCTURAL COMPONENTS

Southern Ontario

MATERIAL	COST	VALUE	EASE OF ASSEMBLY	EASE OF MAINTENANCE	DURABILITY	SUSTAINABILITY	MOBILITY	FLEXIBILITY	APPLICABILITY	AVAILABILTY	LIVABILITY
WOOD											
OSB	●●● Compara-tively inexpensive	●●●●	●●●●	●●	●●●● May contain resin or plastic to deter insects.	●●●● Made with small pieces of wood	●●●●	●●●●	●●●●	●●●●	
Laminate Strand	●●●	●●●● Preengineered	●●●● Preengineered	●●	●●●● Stronger than typical wood Resists pests and weather	●●●●	●●●●	●●●●	●●●●	●●●●	
Laminate Chip	●●●	●●●● Preengineered	●●●● Preengineered	●●	●●●● Stronger than typical wood Resists pests and weather	●●●●	●●●●	●●●●	●●●●	●●●● Not widely available	
Local Rough Cut	●●	●●●●	●●●● Made to order	●●	●●●● Deteriorates if exposed to the elements and pests	●●●	●●●	●●●●	●●●●	●●●●	
METAL											
Light Steel	●●●	●●●●	●●●●	●●	●●●●	●●●	●●●●	●●●● Difficult to modify	●●●●	●●●● Not widely available	
HSS Column/or Beam					●●●● Equally strong as an I-beam		●●● 52% lighter than I-beams				

●●●●● Very High
●●●● High
●●● Medium
●● Low
● Lowest

...structural components, Southern Ontario cont'd

MATERIAL	COST	VALUE	EASE OF ASSEMBLY	EASE OF MAINTENANCE	DURABILITY	SUSTAINABILITY	MOBILITY	FLEXIBILITY	APPLICABILITY	AVAILABILTY	LIVABILITY
I-Beam									Shape is conducive to receiving a panel		
Tension Rods	●●	●●●●	●●●●	●●	●●●●	●●●	●●●● Light	●●●	●●●	●●●●	
Aluminum	●●●●	●●●	●●●	●●	●●●●	●●●	●●● Lighter than steel	●●●●	●●●●	●●●●	
CONCRETE											
Prestressed	●●●●	●●●	●●	●●	●●●●	●●	●●	●●	●●●●	●●●●	
Block	●●	●●●●	●●●	●●	●●●● Weather resistant	●●	●● Heavy and expensive to transport Fixed once set	●●	●●●●	●●●●	
Cast	●●	●●●●	●●●	●●	●●●● Weather resistant	●●	●● Heavy and expensive to transport Fixed once set	●●●●	●●●●	●●●●	
STONE											
Block	●●●●	●●●●	●●●	●●	●●●●	●●	●● Heavy to transport	●●●●	●●●●	●●●●	
Brick	●●●●	●●●●	●●●	●●	●●●●	●●	●● Heavy to transport	●●●●	●●●●	●●●●	

STRUCTURAL COMPONENTS
Guanacaste

●●●● High
●●● Medium
●● Low
● Lowest

MATERIALS	COST	VALUE	EASE OF ASSEMBLY	EASE OF MAINTENANCE	DURABILITY	SUSTAINABILITY	MOBILITY	FLEXIBILITY	APPLICABILITY	AVAILABILITY	LIVABILITY
WOOD											
Finger Jointed	●●● Comparatively inexpensive	●●●●	●●●●	●●	●●●●	●●●● Made with small pieces of wood	●●●●	●●●●	●●●●	●●●	
Laminate Strand	●●●	●●●● Preengineered	●●●● Made to order	●●	●●●● Stronger than typical wood Resists pests and weather	●●●●	●●●●	●●●●	●●●●	●●● Not widely available	
Laminate Chip	●●●	●●●● Preengineered	●●●● Made to order	●●	●●●● Stronger than typical wood Resists pests and weather	●●●●	●●●●	●●●●	●●●●	●●●	
Local Rough Cut	●●	●●●●	●●●● Easy to work with	●●●	●●●● Deteriorates if exposed to the elements and pests	●●●●	●●●●	●●●●	●●●●	●●●●	
Bamboo	●●	●●●●	●●●●	●●	●●●●	●●●●	●●●●	●●●●	●●●●	●●●● Available locally	
METAL											
Light Steel	●●●	●●●● Higher fire resistance	●●●● Frames faster Requires special tools	●●	●●●● Pest resistant	●●●	●●●●	●●● Difficult to modify	●●●	●●● Not widely available	
HSS Column/or Beam					Equally strong as an I-beam		52% lighter than an I-Beam				

...structural components, Guanacaste cont'd

MATERIALS	COST	VALUE	EASE OF ASSEMBLY	EASE OF MAINTENANCE	DURABILITY	SUSTAINABILITY	MOBILITY	FLEXIBILITY	APPLICABILITY	AVAILABILITY	LIVABILITY
I-Beam									Shapis conducive to receiving a panel.		
Tension Rods	●●	●●●●	●●●● Requires specialized knowledge (engineering)	●●	●●●●	●●● Light	●●●●	●●●●	●●●●	●●●●	
CONCRETE											
Prestressed	●●●●	●●●	●●	●●	●●●●	●●	●●	●●	●●	●●	
Block	●●	●●●●	●●●	●●	●●●● Weather resistant	●● Heavy and expensive to transport Fixed once set	●●	●●●	●●●	●●●	Potentially unattractive
Cast	●●●	●●●●	●●	●●	●●●● Weather resistant	●● Heavy and expensive to transport Fixed once set	●●	●●●	●●●	●●●	
STONE											
Block	●●●●	●●●	●●●	●●	●●●●	●● Heavy to transport	●●	●●●●	●●●●	●●●●	Aesthetically appealing
Brick	●●	●●●●	●●●●	●●	●●●●	●● Heavy to transport	●●	●●●●	●●●●	●●●●	Aesthetically appealing

STRUCTURAL COMPONENTS
Structure | Products for Investigation

Lite Steel Beam

MANUFACTURER
Troutville, Virginia, http://www.litesteelbeam.com.au/litesteelbeamau/

MATERIALS
DuoSteel (380/450 grade)

PRODUCTS AND DIMENSIONS

Available in 12 sizes with a nominal beam depth ranging from 8-14”

The LiteSteel™ beam (LSB®) is a structural beam with the strength of steel and the workability of wood. It is 40% lighter than hot rolled steel and engineered wood.

The beam can be cut, drilled and screwed on site using standard power tools. It can also be carried like a wood beam, eliminating the need for expensive handling equipment. LSBs are on average 40% lighter than hot rolled steel or engineered wood. As such, the manufacturer claims that designing with a LiteSteel beam over hot rolled structural steel beams or engineered wood will result in significant cost and time saving. Existing self-drilling screws, bolts, joist hangers and brackets allow the easy use of LSB in support beam applications.

The beams are produced using a patented cold forming process to arrive at a unique profile with the tortional rigidity of hot rolled steel. The product is produced in Troutville, Virginia and used throughout Australia.

FINISHING COMPONENTS

Southern Ontario | Exterior Cladding Options

●●●● High
●●● Medium
●● Low
● Lowest

MATERIAL	COST	VALUE	EASE OF ASSEMBLY	EASE OF MAINTENANCE	DURABILITY	SUSTAINABILITY	MOBILITY	FLEXIBILITY	APPLICABILITY	AVAILABILTY	LIVABILITY
WOOD											
OSB	●●	●●	●●●●	●●●●	●● Deteriorates if exposed	●●●●	●●●● Packs Flat	●●●●	●●●●	●●●● Comes in large sheets	
Plywood	●●	●●	●●●●	●●●●	●● High strength to weight ratio Deteriorates if exposed	●●●●	●●●● Packs Flat	●●●●	●●●●	●●●● Comes in large sheets	
Fibreboard	●●●	●●●	●●●	●●●	●●● Non-structural (weak)	●●●●	●●●● Packs Flat	●●●●	●●●●	●●● Comes in large sheets	
Hardboard	●●●	●●●	●●●	●●●	●●● Non-structural (weak)	●●●	●●●● Packs Flat	●●●●	●●●●	●●●● Comes in large sheets	
Siding	●●	●●●●	●●● Easy to work	●●●	●●● Requires treatment to withstand ele-ments (some variet-ies excepting)	●●●●	●●●● Packs Flat	●●●●	●●●●	●●●●	Aesthetically ap-pealing
Shakes	●●	●●●	●●●	●●●	●●●	●●●●	●●●● Packs Flat	●●●●	●●●●	●●●●	
METAL											
Sheet	●●●	●●●	●●●●	●●	●●● Subject to leaks if installed improperly	●●	●●●● Packs Flat	●●●●	●●●	●●● Comes in large sheets	Aesthetically ap-pealing
Siding	●●●	●●●●	●●●● Easy to work with	●●	●●● Subject to leaks if installed improperly	●●	●●●● Packs Flat	●●●●	●●●	●●●	Potentially unattractive

●●●● High
●●● Medium
●● Low
● Lowest

...finishing components, exterior cladding Southern Ontario

MATERIAL	COST	VALUE	EASE OF ASSEMBLY	EASE OF MAINTENANCE	DURABILITY	SUSTAINABILITY	MOBILITY	FLEXIBILITY	APPLICABILITY	AVAILABILTY	LIVABILITY
STONE	●●	●●●●	●● Labour Intensive	●●●	●●●●	●●●●	N/A built on site	●●●●	●●●●	●●●●	
Stucco	●●	●●●●	●●●	●● Requires routine maintenance	●●●●	●●●●	●●	●●●●	●●●●	●●●●	Popular aesthetic
Stone/Brick	●●●	●●●●	●● Labour Intensive	●●	●●●	●●	●●	●●●●	●●●●	●●●●	Aesthetically appealling
Concrete Block	●●	●●●●	●●●	●●	●●●● Also durable in sheet form	●●	●●	●●●●	●●●●	●●●●	Potentially unattractive
Ceramics	●●●	●●●	●● Labour Intensive	●●	●●●●	●● Thermally resistant	●●	●●●●	●●●●	●●●●	Aesthetically appealling
GLAZING											
Glass	●●●●	●●●● Allows transfer of natural light	●●●●	●●	●●●●	●● Low thermal resistance	●●● Fragile	●● Many product types available	●●●●	●●●●	
Polycarbonate	●●●●	●●●●	●●●●	●●●	●●●● Deteriorates if not UV resistant	●● Low thermal resistance	●●●● Packs Flat	●● Transparent or transluscent	●●●	●●● Available in stock or corrugated panels.	

FINISHING COMPONENTS

Guanacaste | Exterior Cladding Options

●●●● High
●●● Medium
●● Low
● Lowest

MATERIAL	COST	VALUE	EASE OF ASSEMBLY	EASE OF MAINTENANCE	DURABILITY	SUSTAINABILTY	MOBILITY	FLEXIBILITY	APPLICABILITY	AVAILABILITY	LIVABILITY
WOOD											
OSB	●●	●●	●●●●	●●●●	●● Deteriorates if ex-posed	●●●●	●●●● Packs Flat	●●●●	●●●●	●●●● Comes in large sheets	
Plywood	●●	●●	●●●●	●●●●	●● High strength to weight ratio Deteriorates if ex-posed	●●●●	●●●● Packs Flat	●●●●	●●●●	●●●● Comes in large sheets	
Fibreboard	●●	●●	●●●●	●●●●	●● Non-structural (weak)	●●●●	●●●● Packs Flat	●●●●	●●●●	●●●● Comes in large sheets	
Hardboard	●●●	●●●	●●●	●●●	●●● Non-structural (weak)	●●●●	●●●● Packs Flat	●●●●	●●●●	●●● Comes in large sheets	
Siding	●●●	●●●	●●●	●●●	●●● Requires treatment to withstand ele-ments (some variet-ies excepting	●●●	●●●● Packs Flat	●●●●	●●●●	●●●●	Aesthetically appealling
Bamboo	●●	●●●●	●●●	●●●	●●● Pest resistant	●●●●	●●●● Packs Flat	●●●●	●●●●	●●●● not available worldwide	
METAL											
Sheet	●●●	●●●	●●●●	●●	●●● Subject to leaks if installed improperl	●●	●●●● Packs Flat	●●●●	●●●	●●● Comes in large sheets	Potentially unattractive

...finishing components, exterior cladding Guanacaste cont'd

MATERIAL	COST	VALUE	EASE OF ASSEMBLY	EASE OF MAINTENANCE	DURABILITY	SUSTAINABILTY	MOBILITY	FLEXIBILITY	APPLICABILITY	AVAILABILITY	LIVABILITY
Siding	●●●	●●●●	●●●● Easy to work with	●●	●●●	●●	●●●● Packs Flat	●●●●	●●●	●●●	
STONE											
Compressed Earth Brick	●●	●●●●	●● Made on site Labour intensive	●●	●●●● Susceptible to entrance of insects and ground water	●●●● Incorporates local materials	N/A Built On Site	●●●●	●●●●	●●●●	
Stucco	●●	●●●●	●●●	●● Requires routine maintenance	●●●●	●●	●●	●●●●	●●●●	●●●●	
Stone/Brick	●●●	●●●●	●●	●●	●●●●	●●	●●	●●●●	●●●●	●●●●	
Concrete Block	●●	●●●●	●●●	●●	●●●●	●●	●● Heavy to transport Fixed once set	●●●●	●●●●	●●●●	Popular aesthetic
Ceramics	●●●	●●●	●●	●●	●●●●	●● Thermally resistant	●● Heavy to ransport	●●●●	●●●●	●●●●	Aesthetically appealling
GLAZING								●●●●	●●●●	●●●●	Aesthetically appealling
Glass	●●●●	●●●● Allows transfer of natural ligh	●●●●		●●●●	●● Low thermal resis-tance	●●● Fragile	●● Many product types available	●●●●	●●●●	Aesthetically appealling
Polycarbonate	●●●●	●●●●	●●●●	●●●	●●●● Deteriorates if not UV resistant	●● Low thermal resis-tance	●●●● Packs Flat	●● Transparent or transluscent	●●●	●●●	

FINISHING COMPONENTS

Southern Ontario | Interior Cladding Options

●●●● High
●●● Medium
●● Low
● Lowest

MATERIALS	COST	VALUE	EASE OF ASSEMBLY	EASE OF MAINTENANCE	DURABILITY	SUSTAINABILITY	MOBILITY	FLEXIBILITY	APPLICABILITY	AVAILABILITY	LIVABILITY
WOOD											
OSB	●●	●●●●	●●●●	●●	●●●● Deteriorates if texposed	●●●● Off-gases	●●●●	●●●●	●●●●	●●●● Comes in large sheets	
HardBoard	●●	●●●●	●●●●	●●	●●●● Deteriorates if exposed Non-structural (weak)	●●●● Off-gases	●●●●	●●●●	●●●●	●●●● Comes in large sheets	
Plywood	●●	●●●	●●●●	●●	●●●● High strength to weight ratio Deteriorates if ex-posed	●●●●	●●●●	●●●●	●●●●	●●●● Comes in large sheets	
Tongues & Groove	●●●	●●●●	●●●●	●●	●●●● Requires sealant or treatment	●●●●	●●●●	●●●●	●●●●	●●●●	Aesthetically appealing
WALLBOARD											
Sheet Rock	●●	x●●●●	●●●●	●●	●●●● Durable if installed correctly Deteriorates when wet	●●●●	●●●●	●●●●	●●●●	●●●●	
Perlite	●●●	●●●	●●● Easy to work with	●●	●●●	● Contains recycled content	●●●● Lighter than sheet rock	●●●●	●●●	●●● Not widely available	
Hardboard	●●●	●●● Good sound-proofing	●●●	●●	●●●● Deteriorates if ex-posed Non-structural (weak)	●	●●●●	●●●	●●●	●●● Comes in large sheets	

High
Medium
Low
Lowest

STRUCTURAL COMPONENTS

Cladding and Infill | Products for Investigation

Panolite

MANUFACTURER
Lac-Mégantic (Québec).
http://www.panolite.com

MATERIALS
Core: Honeycomb paper cell made from recycled fibres Layers: Two panels made from particle board, MDF, HDF, plywood or hardboard
Adhesive: A reactive, hot-melt glue (Polyurethane Reactive PUR) with high initial tack and high bonding strength.

PRODUCTS AND DIMENSIONS
Available in 4x8' or 5x8' panels with thickness ranging from 1-3".

These lightweight panels are made of honeycomb paper cell and recycled wood particles (particle board or MDF)?, and have been in production since 2008. The product could be used for interior panels, including floor, wall, and partitions; or as (modular) furniture, including tables, chairs and shelving.

Strawboard

MANUFACTURER
http://www.buildingforhealth.com/proddetail.php?prod=STR

An alternative to industrial-grade particleboard, StrawBoard is made from wheat straw and a non-toxic, emission-free binding agent. It meets or exceeds all specifications for conventional particleboard, and is suitable for use in all of the same applications. Stronger, 7 to 10% lighter, more moisture resistant, and Urea Formaldehyde-free, the board provides good matching and laminating properties

Kingspan

MANUFACTURER
Toronto and Vancouver, Canada.
http://www.kingspanpanels.ca/

MATERIALS
Various

PRODUCTS AND DIMENSIONS
Various

These energy efficient, pre-engineereed insulated panel can be used for interior and exterior applications such as roof, wall, ceiling, roof and wall panel system which claim to reduce building emissions by up to 40%. The product has been tested for structure, air filtration, water penetration, fatigue, freeze and heat cycle, adhesion, humidity, autoclave, acoustics, toxicity and fire resistance. They come with a one year limited warranty.

Surface Treatment

Surface Treatment paulownia-wood siding is a sustainable substitute to conventional vinyl siding. Fast-growing paulownia wood is well-suited to architectural applications, as it is lightweight, easily worked, resists warping, and rarely succumbs to infestation. The siding weathers much like cedar, providing a beautiful, natural façade. Designers Kate Wise and Anna Motzer propose Surface Treatment to integrate functional ornamentation into a dilapidated building façade. "The last few decades have had so much cheap, bad construction," Wise says. "More compelling facades would improve the urban environment, and that's where our wood siding comes into play" (http://www.metropolismag.com/cda/story.php?artid=2546).

●●●●● Very High
●●●● High
●●● Medium
●● Low
● Lowest

FINISHING MATERIALS

Cladding and Infill | Products for Investigation

Construcel (plastic)

Especially suited to large, curved spans, this plastic brick does not require any supporting steelwork or concrete. The polycarbonate triangular prisms can be bolted together to create varying forms, and are easily assembled and disassembled, making the product optimal for reuse in temporary buildings and disaster relief shelters (Fuad-Luke, 243).

XPotential Products

Manufactured from 100% recycled materials, XPonential Products offer a proven alternative to wood. Postconsumer plastics and non-metalic byproduct from recycled automobiles are used to create a product that provides superior durability and exceeds the compressive strength of wood. Products have a life expectancy of 75 to 100 years, and are not greatly affected by severe temperatures, submersion in fresh or salt water, or freeze/thaw cycles. They are also resistant to insect damage, termites, rodents, road salt, and periodic contamination with oil, gasoline and other corrosive chemicals. XPonential Products include Impact-Posts™ (6 x 6), Impact-Curbs™, landscape ties (2.5" x 3.5") and four by fours (http://www.xpotentialproducts .com/main.htm).

FINISHING MATERIALS
Cladding and Infill | Products for Investigation

●●●● High
●●● Medium
●● Low
● Lowest

Celbar Cellulose Insulation

MANUFACTURER
http://www.buildingforhealth.com/proddetail.php?prod=INC_CCI

Comprised of 100% recycled materials, this insulation conserves energy use in the home, reduces load on landfills, and requires substantially less energy to manufacture than conventional products. Available as loose fill or blown insulation, Celbar eliminates drafts, energy loss and condensation caused by air leakage. It can also be produced with minimal ink, making it one of the cleanest products currently on the market

UltraTouch Insulation

MANUFACTURER
(http://www.buildingforhealth.com/proddetail.php?prod=BLI_UTI)

Natural Cotton Fibre insulation provides effective sound absorption and thermal performance. It contains no chemical irritants or volatile organic compounds, and meets testing standards for fire and smoke ratings, fungi resistance and corrosiveness. Made from 85% post-industrial recycled natural fibres, this product is ideal for human health and the health of the environment

MemBrain

MANUFACTURER
CertainTeed. Valley Forge, PA.
http://www.certainteed.com

MATERIALS
Polyamide-based
(For technical information on this product, including materials standards, fire resistance, water vapour permeance, fungi resistance and corrosivity, visit:)

MemBrain is a smart vapour barrier, designed to allow moisture to escape from a wall by changing its permeability in response to relative ambient humidity. When the relative humidity increases, its permeability increases dramatically, allowing water vapor to escape the wall cavity easily. This allows buildings to increase their drying potential throughout dramatic seasonal changes.

Membrane is a polyamide-based material that is designed to be applied over unfaced fiberglass insulation, loose-fill applications and spray foam. The recycled content of CertainTeed fiberglass insulation meets the EPA Recovered Material Guideline for fiberglass products, 20-25% consisting of pre-consumer and post-consumer glass cullet. Most CertainTeed fiberglass insulation products have been certified by the GREENGUARD Environmental Institute and meets the GREENGUARD standards for low Volatile Organic Compound (VOC) emissions, including formaldehyde.

Using this product is claimed to add an additional $300-500 to the total cost of a new home (based on an approximate exterior wall space for 2400 sq feet)

●●●● High
●●● Medium
●● Low
● Lowest

...finishing components, interior cladding, Southern Ontario cont’d

MATERIALS	COST	VALUE	EASE OF ASSEMBLY	EASE OF MAINTENANCE	DURABILITY	SUSTAINABILITY	MOBILITY	FLEXIBILITY	APPLICABILITY	AVAILABILITY	LIVABILITY
Fibreboard	●●●	●●●●	●●●	●●	●●●● Non-structural (weak)	●●	●●●●	●●●	●●●	●●● Comes in large sheets	
Newsprint	●●●	●●●●	●●●●	●●●	●●●●	●●●● Contains recycled content	●●●●	●●●●	●●●	●●● Not Readily Available	
Ceramics	●●● More expensive than other options	●●●●	●●●●	●●●	●●●	●●●● Thermally resistant	●●●● Heavy to transport	●●●●	●●●	●●●	Aesthetically appealling
Stone/ Brick	●●●	●●	●●	●●●	●●●	●●	●● Heavy to transport	●●	●●●	●●●	Aesthetically appealling

FINISHING COMPONENTS

Guanacaste | Interior Cladding Options

●●●● High
●●● Medium
●● Low
● Lowest

MATERIAL	COST	VALUE	EASE OF ASSEMBLY	EASE OF MAINTENANCE	DURABILITY	SUSTAINABILITY	MOBILITY	FLEXIBILITY	APPLICABILITY	AVAILABILTY	LIVABILITY
WOOD											
OSB	●●	●●●●	●●●●	●●	●●●● Deteriorates if exposed	●●●● Off-gases	●●●●	●●●●	●●●●	●●●● Comes in large sheets	
Plywood	●●●	●●●●	●●●●	●●	●●●● Pest resistant	●●●● Off-gases	●●●●	●●●●	●●●●	●●●● not available worldwide	
Hardboard	●●	●●●	●●●●	●●	●●●● Non-structural (weak)	●●●●	●●●●	●●●●	●●●●	●●●● Comes in large sheets	
Bamboo	●●	●●●●	●●●●	●●	●●●● High strength to weight ratio Deteriorates if exposed	●●●●	●●●●	●●●●	●●●●	●●●● Comes in large sheets	
Tongues & Groove	●●●	●●●●	●●●●	●●	●●●● Requires sealant or treatment	●●●●	●●●●	●●●●	●●●●	●●●●	Aesthetically appealling
WALLBOARD											
Sheet Rock	●●	●●●	●●● Easy to work with	●●	●●● Durable if installed cor-rectly Deteriorates when wet	● Contains recycled conten	●●●● Lighter than sheet rock	●●●●	●●●	●●●	
Perlite	●●●	●●● Good sound-proofing	●●●	●●	●●●●	●	●●●●	●●●	●●●	●●● Not widely avail-able	

...finishing components, interior cladding, Guanacaste cont'd

MATERIAL	COST	VALUE	EASE OF ASSEMBLY	EASE OF MAINTENANCE	DURABILITY	SUSTAINABILITY	MOBILITY	FLEXIBILITY	APPLICABILITY	AVAILABILTY	LIVABILITY
Hardboard	●●●	●●●●	●●●	●●	●●●● Non-structural (weak) Deteriorates if exposed	●●	●●●●	●●●	●●●	●●● Comes in large sheets	
Fibreboard	●●	●●●●	●●●●	●●●	●●●● Non-structural (weak) Deteriorates if exposed	●●●●	●●●●	●●●●	●●●	●●● Comes in large sheets	
Newsprint	●● More expensive than other options	●●●●	●●●●	●●●	●●●	●●●● Contains recycled content	●●●●	●●●●	●●●	●●● Not easily available	
Ceramics	●●	●●	●●	●●●	●●●	●● Thermally resistant	●● Heavy to transport	●●	●●● Not suited to all designs	●●●	Aesthetically appealing
Stone/Brick	●●●	●●●●	●●●●	●●	●●●●	●●	●● Heavy to transport	●●●	●●●	●●●	Aesthetically appealing

FINISHING

Guanacaste | Roofing Material Options

●●●● High
●●● Medium
●● Low
● Lowest

MATERIAL	COST	VALUE	EASE OF ASSEMBLY	EASE OF MAINTENANCE	DURABILITY	SUSTAINABILITY	MOBILITY	FLEXIBILITY	APPLICABILITY	AVAILABILTY	LIVABILITY
METAL											
Sheet Steel	●●	●●●●	●●●●	●●●	●●●●	●●●	●●●●	●●●	●●●●	●●●●	
Steel Shingles	●●t	●●●●	●●●●	●●● Requires periodic painting	●●●● Weather impervious	●●● Contains recycled content	●●●● Lightweight	●●●●	●●●●	●●●●	
Sheet Aluminum	●●●	●●●●	●●●●	●●●	●●●●	●●● Recyclable	●●●●	●●●	●●●●	●●●● Comes in large sheets	
Aluminum Shingle	●●	●●●●	●●●●	●●● Requires periodic painting	●●●● Weather impervious	●●● Contains recycled content	●●●● Lightweight	●●●●	●●●●	●●●●	
Corrugated	●●●	●●●●	●●●● Easy to work with	●●●	●●●● Subject to leaks if installed improperly	●●● Prone to radiate heat (shold include ample ventilation)	●●●● Lightweight and compact	●●●	●●●●	●●●●	Potentially unattractive
CERAMIC											
Terra Cotta	●●	●●●●	●●●●	●●	●●●●	●●●	●●		●●●●	●●●●	
OTHER											
Asphalt	●●●	●●●	●●●●	●●	●●●●	●●	●●●●	●●●●	●●	●●	
Plastic	●●●	●● Allows transfer of light	●●●●	●●	●●●●	●●	●●●●	●●●● Many product types available	●●	●● New to the market Not widely avail-able	

FINISHING

Southern Ontario | Roofing Material Options

●●●● High
●●● Medium
●● Low
● Lowest

MATERIAL	COST	VALUE	EASE OF ASSEMBLEY	EASE OF MAINTENANCE	DURABILITY	SUSTAINABILITY	MOBILITY	FLEXIBILITY	APPLICABILITY	AVAILABILITY	LIVIABILITY
METAL											
Sheet Steel	●●●	●●●●	●●●●	●●	●●●●	●●●	●●●●	●●●●	●●●●		
Steel Shingles	●●●●	●●●	●●●●	●● Requires periodic painting	●●●● Weather impervious	●●● Contains recycled content	●●●● Lightweight	●●●●	●●●●		
Sheet Aluminum	●●●	●●●●	●●●●	●● Requires periodic painting	●●●●	●●● Recyclable	●●●●	●●●●	●●●●	Comes in large sheets	
Aluminum Shingle	●●●●	●●●	●●●●	●●	●●●● Weather impervious	●●● Contains recycled content	●●●● Lightweight	●●●●	●●●●		
Corrugated	●●	●●●●	●●●● Easy to work with	●●	●●●● Subject to leaks if installed improperly	●●● Prone to radiate heat (should include ample ventilation)	●●●● Easy to ship	●●●●	●●●●		Potentially unattractive
STONE											
Cement	●●	●●●●	●●●	●●	●●●●	●●	●●	●●●●	●●●●		
Slate	●●●●	●●●	●●●	●●	●●●●	●●	●●	●●●●	●●●●		
Terra Cotta	●●●●	●●●	●●●	●●	●●●●	●●	●●	●●●●	●●●●		
ASPHALT											
Felt Based	●●	●●●●	●●●●	●●	●●●● Attracts moss Not long lasting	●●	●●●●	●●●● Available in different colours	●●●●		
Fibre Glass	●●●	●●●●	●●●●	●●	●●●● Attracts moss More durable than felt-based	●●	●●●●	●●●●	●●●●		
WOOD											

●●●● High
●●● Medium
●● Low
● Lowest

...Finishing Components, Roofing, Southern Ontario cont'd

MATERIAL	COST	VALUE	EASE OF ASSEMBLEY	EASE OF MAINTENANCE	DURABILITY	SUSTAINABILITY	MOBILITY	FLEXIBILITY	APPLICABILITY	AVAILABILITY	LIVIABILITY
Shakes	●●●	●●●●	●●●●	●●● Easy to replace	●●● Long lasting if maintained, otherwise prone to deterioration	●●●● Insulates	●●●●	●●●●	●●●●		
Shingles	●●●	●●●●	●●●●	●●●	●●●	●●●●	●●●●	●●●●	●●●●		Aesthetically appealing
TAR/GRAVEL	●●	●●●●	●●●● Messy installation	●●●	●●● Attracts moss	●● Contains recycled content	●● Lightweight	●●●●	●●●●		Aesthetically unappealing
Plastic	●●●	●●● Allows transfer of light	●●●●	●●	●●●●	●●	●●	●●●● Many product types available	●●●●	New to the market Not widely available	

2.3 Sustainable Systems

The section that follows presents an overview of existing technologies and techniques within the systems of energy capture, heating/ventilation/air conditioning (HVAC), and water and sewage management.

Together these systems encapsulate a kind of exchange between the home and its environment. As such, the distinct characteristics of the two sites will have a strong influence on the design decisions for these features.

In this assessment, it is assumed that the units will function independently from each other, and also operate, at least partially, on grid.

“The concept of high-performance design is a major but still embryonic step beyond that of energy-saving ‘green buildings’. Its goal is to create buildings that are not only as energy self-sufficient as possible, and ecologically benign, but also smart, healthy, enhancing of the comfort, productivity, and security of their occupants, capable of accommodating changing future need, and deconstructable, so that their components and the energy embodied in them could be reused.”
Bugliarello, pg 59

HEATING VENTILATION AIR CONDITIONING (HVAC)

Thermal Mass

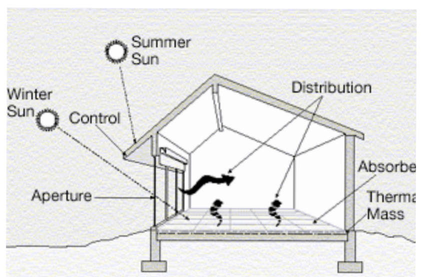
Materials with High Energy Storage Capacity: poured concrete, concrete block, adobe, brick, stone

Materials with Low Energy Storage Capacity (but high heat loss resistance): strawbales, rubber tires, wood, carpet, logs, ICFs, autoclaved aerated concrete, drywall

Sustainability: ●●●●
Passive energy storage

Livability: ●●●●
Since heat is stored in the walls and floor, rather than the air, spaces can be vented without losing heat

Mobility: ●
Increased mass decreases mobility, especially since the best masses are constructed from brittle material such as brick and concrete



http://www.thenaturalhome.com/passivesolar.html
http://www.presentationcenter.org/Environment/Welcome_Center/Energy/passive_solar.html

Solar Water Heater

Solar water heaters are the most widely used, small-scale form of renewable energy available. Panel types include: vacuum tubes (most efficient), glazed flat plates, unglazed flat plates (most inexpensive)

Cost: ●●●

Value: ●●●●
Long life (25+ years). Hot water can account for two thirds of a home's energy consumption

Ease of Maintenance: ●●●●

Mobility: ●●●●

Flexibility:
Works even on cloudy days

http://www.capture-energy.co.uk/solar-panels/heating/index.html

Natural Ventilation

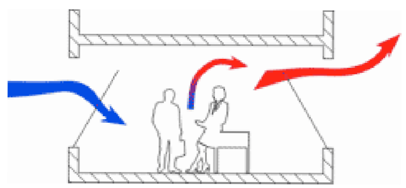
There are two types of natural ventilation: buoyancy (stack effect) and wind-driven. Both types rely on pressure differences to move fresh air throughout the building. Design strategies include: operable windows, ridge vents, clerestories, vented skylights, attic ventilation

Cost: ●

Ease of Maintenance: ●●●●

Sustainability: ●●●●

Livability: ●●●●



http://www.wbdg.org/resources/natural-ventilation.php
http://www.dyerenvironmental.co.uk/natural_vent_systems.html

Ground Source Heat Pumps

This system consists of a long loop of plastic pipes, filled with liquid (usually antifreeze and water), which are either buried in the ground (less than 10ft deep) or submersed into a body of water. A heat exchanger pumps the fluid through pipes that run at least 6ft (and up to several hundred feet) into the ground. The mixture absorbs heat from the earth and converts it into a gaseous state. A second heat exchanger lowers the temperature of the gas and expells it into the house, where it cools off and returns to a liquid state, starting the process all over again.

Cost: ●●
Low operational costs

Value: ●●●●
Long life (25 years). Very efficient (up to 400%)

Mobility: ●

Sustainability: ●●●●
In the summer the system acts as a heat sink, extracting excess heat and returning it to the ground.

Livability: ●●●●
Quiet, dependable and safe

Radiant Floor Heating

Supplied by either pipes (hydronic or air) or wiring (electrical) that are located under the floor (ex. can be cast into concrete slab or under wood flooring), heat radiates from the ground up.

Air-heated flooring is not efficient for homes though, since air is a poor heat carrying medium and conventional methods for heating it are wasteful. The alternative method is to heat the air with solar energy, which doesn't work at night when the demand for heat peaks.

Sustainability: ●●●●
Saves energy.

Livability: ●●●●
Silent and discreet. Provides uniform temperature throughout the home. Increases health of home since it doesn't spread dust and germs.

Heat Pumps:
http://www.alternative-heating.com/geothermal-heating-and-cooling.html
http://www.capture-energy.co.uk/ground-air-source-heat-pumps/index.html
http://www.renewableenergyworld.com/rea/tech/geoheatpumps
http://www.cs.ualberta.ca/~jag/courses/cde/assign/heatpump/heat/res_geo_earth_cut-away.jpg

Raised Floor Air Distribution

Applicability: Not for residential use

Radiant Floor:
http://www.alternative-heating.com/radiant-floor-heating.html
http://planetgreen.discovery.com/home-garden/green-home-radiant-heat.html
http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12590

Earth Tube Heat Exchange

In this system, air moves through thin, plastic pipes that are layered around the foundation. The system can be passive or driven by an electric fan. The average number of tubes used in a home is six, separated by at least 4".

http://www.earthshelters.com/files/ky2_slide_show_2_manifold_detail.jpg

Indoor Planter Beds

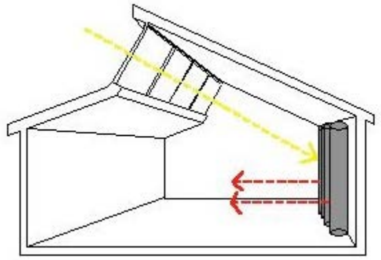
Cost: ●●

Ease of Maintenance: ●●●
Crops would require routine upkeep throughout the year.

Mobility: ●●●

Sustainability: ●●●●
Soil in planter beds stores heat for slow release.

Livability: ●●●●
Plants also filter air and provide a beautiful aesthetic



Fiberglass Heat Storage Tubes

Fiberglass tubes, filled with water, provide heating or cooling in a space. As a thermal mass they help to control temperature fluctuations during the day and night. Available in standard heights of 4', 5', 8', 10'.

Value: ●●●●
Can provide up to 100% of the room's heat

Ease of Assembly: ●●●●

Durability: ●●●
Self supporting.

Flexibility: ●●●
Must be in direct sunlight; ideal for a greenhouse or solarium.

Masonry Stoves

A wood-burning stove that acts as a thermal mass so that a short, hot fire can slowly radiate heat for hours following.

Cost: ●●●

Sustainability: ●●●●
Very Efficient.

Livability: ●●●●
Doesn't dry air

Mobility: ●

Pellet Stoves

Heats homes through forced air supplied by small contained fire, adjustable by a thermostat or on the actual stove. These stoves are convenient and more efficient than wood burning stoves. Pellets can be made from waste material, but cost more than wood and can sometimes be harder to come by. Stoves are small, but unlike masonry stoves, they are mechanically driven, therefore are not silent and require more maintenance.

http://www.thenaturalhome.com/earthtube.htm
http://www.earthshelters.com/files/ky2_slide_show_2_manifold_detail.jpg

http://www.thenaturalhome.com/passivesolar.html

http://www.solar-components.com/tubes.htm
http://www.thenaturalhome.com/heatstorage.htm

Clarke Snell, The Good House Book (Lark Books, 2004), 85
https://www.profoundit.com/search.php?soption=csi&csi1=10&csi2=&csi3=&set=9

http://www.daviddarling.info/encyclopedia/P/AE_pellet_stove_pros_and_cons.html
http://www.alternative-heating.com/wood-pellet-stoves.html

SUSTAINABLE SYSTEMS
HVAC | Products for Investigation

12-Volt/110-Volt MightyKool Model MW1

SPECIFICATIONS
$300
9 ¾” x 8 x 7 ¼” / 0.33 cu ft / 3 lb

Although generators are expensive, a single unit of this 4-gallon tank model could be shared across 2-3 homes. This generator will run for 8 hours on full power or 10 hours on half power.
www.duropower.com

“Thoughtfully placed deciduous trees and plants create cooling shade and evaporative cooling around a building in summer and, after losing their leaves, allow solar heat to access and heat up thermal mass inside a building in winter.” Clarke and Snell, pg 52

“Thermal mass can be too much of a good thing, though. If you have too much mass in your floor, for example, it will be able to store a substantial amount of heat, but it will also take a lot of heat to warm the floor once it has cooled down.” Clarke and Snell, pg 54

ENERGY CAPTURE

Solar Panels

Cost: ●●●
Depends on: quantity of panels, slope/orientation of panels, amount of sun, labour cost, equipment.

Value: ●●●●
• Long lasting (25 – 30+ years)
• Can recover expenses up to 3x of the initial cost over life of the panels
• Increases value of the home
• Initial investment reduces energy costs over life of the system

Ease of Assembly: ●●
Labour is about 15% the initial costAn average family needs about 300 – 600 sq ft of south facing, shade free roof

Ease of Maintenance: ●●
Requires occsional cleaning
Invertors need to be replaced several times throughout the panel's life, which costs several thousand dollars.

Durability
Often guaranteed up to ¾" hail, but moisture can cause cracking. Animals can damage to wiring.

Sustainability: ●●●●

Mobility: ●●●●

Flexibility: ●●●●
Available in all sizes and quantities, systems can be expanded

Livability: ●●●●
Silent operation

Applicability: ●●●●
Yes (Canada and Costa Rica)

Location of Designer/Manufacturer
Local

Considerations
Best to orient panels angled toward the south in 100% sun exposure

Solar (and solar hot water panels) work best when tilted for the appropriate season. Therefore a manual adjustment should be done 2 or 4 times a year. For a strictly fixed panel adjust for the season when the most power is required. Panels that automatically track the sun perform the best.

Ontario Suppliers:
http://www.ecobusinesslinks.com/clean_solar_wind_energy_canada.htm

Costa Rica Suppliers:
http://energy.sourceguides.com/businesses/byGeo/byC/CostaRica/CostaRica.shtml

http://solarpanelspower.net/solar-panels/solar-panels-cost
http://www.sunrunhome.com/learn_about_solar/cost_of_solar/
http://www.capture-energy.co.uk/solar-panels/photovoltaics/index.html
http://www.macslab.com/optsolar.html

Wind Power

Cost: ●●●

Value: ●●●
• Long lasting (up to 40+ years)
• Energy produced is proportional to wind speed cubed (small increase in wind results in a significant increase in power)

Ease of Maintenance
Minimal maintenance required

Durability: ●●●●

Sustainability: ●●●●

Mobility: ●●●

Livability: ●●
Potentially noisy, although quieter models are becoming available

Applicability: ●●●
Yes (Canada and Costa Rica)

Location of Designer/Manufacturer:
Local

Considerations:
Should be placed in area of prevailing winds, free from obstructions (which cause turbulence), and also away from neighbouring properties

Since PV panels and wind turbines both produce DC power, which needs to be converted to AC, they can be connected to the same inverter sys-

http://www.capture-energy.co.uk/wind-turbines/what-makes-a-good-site/index.html
http://www.endurancewindpower.com/index.html

Geothermal Electricity

Applicability:
Most effective on a large scale

Biogas

Applicability:
Digesters utilize cow and pig manure to produce electrical or thermal energy. Not appropriate away from large farms that would supply the manure.

Clarke Snell, The Good House Book (Lark Books, 2004), 140

http://www.biofuelswork.com/biogas/
http://www.biogas-energy.com/site/technology.html

ENERGY CAPTURE
Products for Investigation

Flexible Solar Cell

This supple solar cell can be easily bent or manipulated. Its application will greatly increase the possibilities of eco-energy construction, removing the previous limitations of rigid solar panels. The flexibility of the cell is enabled by the use of ETFE Film, a protective material that encases the amorphous silicon generator panel. The lightweight ETFE Film offers 10% greater transparency than that of glass, provides high impact resistance, and allows for decreased bulk. The highly functional material is also heat resistant, not easily ripped, fire-retardant, and does not easily allow condensation. It has been conventionally used in limited areas, such as green houses, aerospace technologies, and insulating materials. The New Energy and Industrial Technology Development Organization (NEDO) in Japan has taken up the flexible solar cell as an important area of research (http://www.agc.co.jp/english/company/04.html)

Sunlight-Transport System

Developed by Swedish-based company Parans, this system uses fibre-optic cables to transmit sunlight into interior spaces receiving little or no natural light, such as basements or windowless offices. Outdoor collector panels are placed at varying angles to capture maximum sunlight as it moves across the sky throughout the day. Light is directed indoors through a well-designed overhead fixture, which combines different types of beams to create a tree-filtered effect (Steffen, 161).

“Passive solar design is the conscious placement of a building and associated materials so that the sun’s direct energy is manipulated to affect the temperature inside the building….There is simply no other long-term solution.” Clarke and Snell, Pg 50-51

SUSTAINABLE SYSTEMS
Energy Capture | Products for Investigation

65Kw Super Silent Diesel Generator

SPECIFICATIONS
$2000
36” x 21” x 29” / 12 cu ft / 400 lbs
6500 W max output
120/240 v AC or 12 v DC power

Although generators are expensive, a single unit of this 4-gallon tank model could be shared across 2-3 homes. This generator will run for 8 hours on full power or 10 hours on half power.
www.duropower.com

“Some materials are both good thermal masses and decent insulation. One such material is cob, a combination of mass (clay and sand) and insulation against conduction (straw). Another example is composite block made of wood chips bonded with concrete.” Clarke and Snell, Pg 54

WATER AND SEWAGE MANAGEMENT

Wastewater Treatment

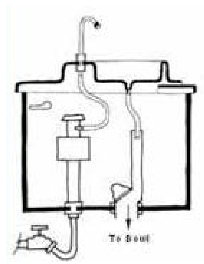
The following systems can stand alone, or connect to a septic tank, and are not appropriate for on-grid homes:

Wetland Systems:
Large-scale, man-made wastewater system
Secondary Wastewater Treatment:
System attaches to septic tanks to optimize biological filtration
Eco Machines:
Uses aquatic plants and organisms to digest water pollutants. Water can be recycled as non-potable.
Membrane Filtration:
Employs microfiltration and reverse osmosis to remove contaminants in an area that is much smaller than a conventional water treatment plant.

Institute without Boundaries, Watershed: The World House Guide to Designing Water's Future. George Brown College, 2007
Home Water Management Checklist
http://www.bae.ncsu.edu/programs/extension/publicat/wqwm/he213.html

Water Reduction Strategies

Fixtures:
- Ultra Low-Flow Toilets (6 LPF)
- Air-Flush Toilets (1.5 LPF)
- Dual Flush Toilet (3 LPF / 6 LPF)
- Waterless Composting Toilet (0 LPF)
- Low-Flow Shower Heads (9.5 LPM)



Toilet Lid Sink:
Fills toilet bowl with clean water that runs from a faucet like in a standard sink, saving both greywater and space

Tankless Water Heater:
Heats water on demand, avoiding the need to constantly heat, store, and maintain a tank of hot water.

Tap Inserts:
A cheap addition to conventional faucets, that provides a dual flow function
Low-Flow Faucet Aerators:
Provides increased pressure with constant flow

Greywater Management Systems:
Reuse water from sinks, laundry, and showers for non-potable functions

Rainwater Collection

Can be used as greywater in the home, or for irrigation. If purified, can replace grid-supplied water.

Must be able to capture (from roof), filter, and store water.

http://www.livingoffgrid.org/wp-content/uploads/2008/12/toilet-lid-sink.jpg

http://www.rwh.in/
http://www.inhabitat.com/2009/03/05/cista-rainwater-cachement-by-moss-sund-and-figforty/

Home Water Management Checklist

- If possible, locate the hot water heater as close as possible to bathroom, kitchen and laundry areas. The closer the heater is to the faucet, the less water has to be run. For this reason. it's sometimes better to have two small water heaters located in strategic places.

- Use the "gray" water that siphons from your washing machine into a laundry tub for cleaning, to flush the toilet, or water plants. See directions for using "gray" water on plants. Use all "gray" water as soon as possible. Do not store longer than 24 hours.

- Try "trickle" or "drip" irrigation systems in outdoor gardens. These methods use 80-90 percent less water than hose or sprinkler methods. A tiny plastic tube runs along the ground near plants. The trickle system provides many tiny holes to water closely placed plants. The drip system tubing contains holes or openings at strategic places for tomatoes and other plants that are more widely spaced.

Excerpted Highlights from http://www.bae.ncsu.edu/programs/extension/publicat/wqwm/he213.html
k

Stormwater Management

- Direct water away from building

- Limit impervious surfaces (for example, utilize open grid pavement when possible)

- Vegetation buffer strips to filter water and slow runoff

- Replace grass with natural landscaping. Trees and shrubs absorb 14 times more water than grass.

- Faster infiltration means less standing water, which can decreases the risk of contamination and disease.

- Onsite treatment methods:
  - Constructed wetlands
  - Bioswales
  - Bioretention basins
  - Vegetated filter strips

http://www.mde.state.md.us/programs/waterprograms/sedimentandstormwater/home/index.asp
CaGBC LEED NC 1.0 Reference Book

SUSTAINABLE SYSTEMS
Water Capture | Products for Investigation

Collapsible Rain-saver from Bulk Handling Australia

MANUFACTURER
CertainTeed. Valley Forge, PA.
http://www.certainteed.com

SPECIFICATIONS
1120 x 1120 x 950 mm/ 4 cu ft / 20 kg

PRODUCTS AND DIMENSIONS
The large, 1000 L rainwater tank is collapsible and includes a hose to connect to a pipe. While large, it could supply several houses with rainwater.
www.bha.com.au

Shurflo RV Pump

MANUFACTURER
CertainTeed. Valley Forge, PA.
http://www.certainteed.com

SPECIFICATIONS
$50/unit
24” x 18” x 11”/ 2.75 cu ft / 52 lbs (for 12 units)
12v pump
2.8 gpm flow
7 amp draw

PRODUCTS AND DIMENSIONS
This system is sold in packs of 12.
www.shurflo.com

3.0

Modular Housing System:

Charrette Process Work

The Modular Housing System Design charrette took place over the course of one week. In this time, the team's primary intention was to uncover potential for innovation in residential construction methods, working within the parameters of a scheme that would be modular and adaptable. This development work can be summarized as follows:

1. BUILDING TYPOLOGIES
The team began by analyzing existing building typologies. From this, it became apparent that these typologies could be characterized as achieving innovation within one or more of the following areas:

Structure
Designs that achieve structural innovations may do by reducing the quantity of structural components required by staggering their placement strategically, or increasing their strength.

Fabrication
Designs that achieve innovation in the area of fabrication may do so by reducing the time and complexity of the manufacturing and installation of components. Parts may be designed to pack flat and 'snap' or 'slide' into place on site.

Systems
Designs that achieve systems innovation may incorporate a passive systems integration approach, increase systems efficiency by grouping services within a complex, seek complementary pairings of technology, or use 'smart' technology.

Connections
Designs that innovate in the area of connections may do so by accomplishing the majority of connections using only one type of joint.

Materials
Designs that achieve materials innovation may do so by re-purposing retired parts and recycling old products, or working exclusively with products sourced on site. Materials innovation could also be described as allocating materials specific functions within the system based on their inherent properties of heat retention, air filtration or light reflection.

2. STRUCTURAL TYPOLOGIES
Next, the team experimented with developing and combining these building typologies to determine if the assets of each would increase when overlapped.

Schemes that were explored in this phase included:

Structure
Industrial Sheds
Domes
Tension Wire
Panel/Void

Fabrication
Fold-Out
Spin-Out
C-Connection
Accordian
Ribbon

Systems
Super Structure
Modules
Clustered Amenities
Panel/Void

Materials
Woven Panels
Stacked Components
Infill

This results of this exploration were to:

- Seek efficiencies by developing components that could serve multiple functions. For example, sand and soil, when filled in bags, can act as both structure and insulation.
- Seek to develop components that become stronger when connected, such as the weave or tension rod system.
- Seek to develop a structure that responds to and manages the features of its surrounding environment

Two key priorities that were reiterated at this point in the first review were:

- Remove the use of complicated mechanisms that could possibly fail. As such, the team abandoned schemes involving expansion on site.
- Create something that would be solid enough to withstand harsh weather. As such, the team abandoned schemes involving light fabrics

3. TWO DESIGN SCHEMES

From here, the concepts were synthesized into two design schemes, which were developed over the next two days: The Modular Grid and the Spatial Frame.

4. ONE DESIGN SCHEME

Finally, the core elements of each scheme where combined as one, to arrive at the final modular system: The Open Lattice.

The pages that follow illustrate the development process of the Open Lattice system.

Day 1
Monday, September 21
Exploration of Structural Typologies and Typology Combinations

Day 2
Tuesday, September 22
Exploration of Two Schematic Variations

Day 3
Wednesday, September 23
Development of Two Schematic Variations

Day 4
Thursday, September 24
Synthesis of Two Schemes Into One Scheme

Day 5: Friday, September 25
Design Development

CHARRETTE PROCESS WORK

Building Typologies

Innovations in residential building typologies could be classified in the categories of structure, fabrication, systems, connections and materials. The charrette team spent the first day investigating the assets and drawbacks of these schemes.

STRUCTURE-CENTRIC

Post and Beam

Balloon Frame

Geodesic Dome
Icosoles triangles are attached at their ends to form a rigid dome. (Buckminster Fuller)

Monecoque
Roof, foundation and walls are formed as one complete unit.

Industrial Unit
A large, open space is enclosed as a warehouse from which one could hang other parts.

Treehouse
A central, structural core stands vertically, from which one could hang other parts.

Void House
A structure is fashioned in alternating segments that could fold together as one flat piece.

SIP (Structurally Insulated Panels)
Insulation and structural are combined in one component.

FABRICATION-CENTRIC

Mold
Housing components are precast. (Frank Lloyd Wright)

Prefabrication
Building components are manufactured and/or assembled in a factory prior to erection on site.

Flat Pack
Components are designed to fit together efficiently within a shipping container or flatbed truck. (United States Company)

Inflatable House
An insulated bubble travels flat to be inflated on site.

Jack
A unit is shipped flat and jimmied into form with a jack mechanism on site.

Slinky (telescope, accordion, weave, screen)
A unit and its parts contract to ship and expand to make a space on site.

SYSTEMS-CENTRIC

House within a House
An exterior shell encloses and protects the interior living core. (St.Mark's Convent)

Service Spine
Amenities such as water and electricity are grouped in one region of a unit or complex.

Service Core
Living areas are added concentrically around a central core.

Modules
Unit spaces are efficiently organized according to their function within complete, premanufactured compartments.

Senai
Mechanical services and amenities are grouped within vertical, structural tubes. Alternatively, these tubes could also be used as living spaces.

CONNECTIONS-CENTRIC

Universal Joint
One joint is designed to accept standard building elements of similar dimensions. This joint can then serve many functions within the system.

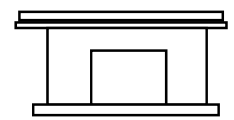
Snaps
Building components snap into place on site. As such, they could also unsnap for dismounting.

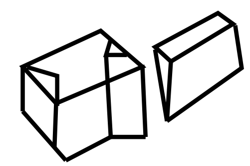
Hardware
A building system is designed around one or more customized hardware pieces.

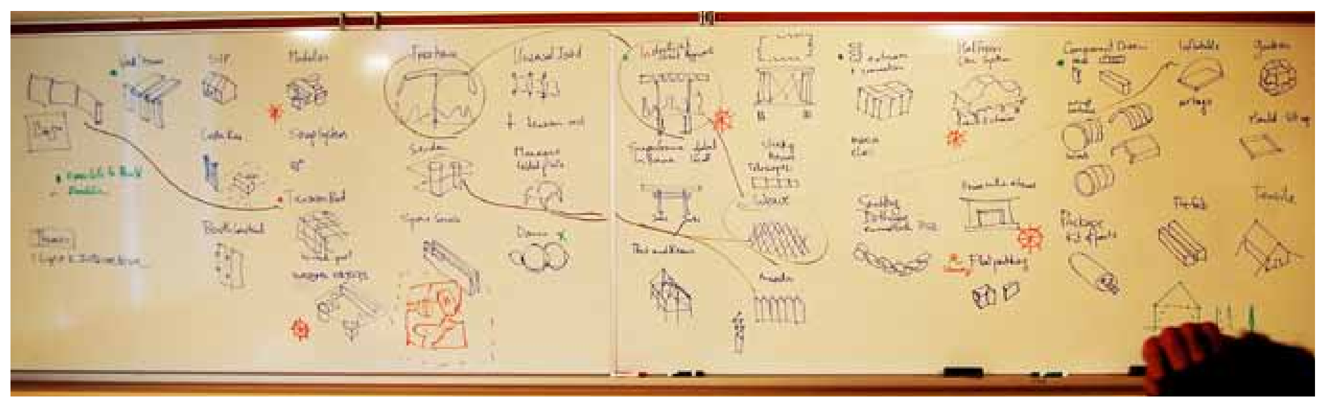
MATERIALS-CENTRIC

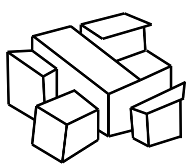
Recycled Components
Shipping palettes, aircraft containers and shipping containers are reused as key structural elements.

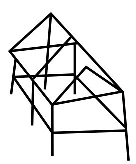
Earth Structure
Elements found within the natural environment, such as sand, soil and straw, are used as primary building materials. Often these materials will be more affordable, although construction is labour intensive.

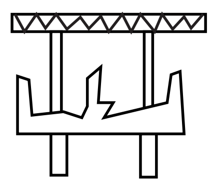

House in a House


Flatpakking




Modules

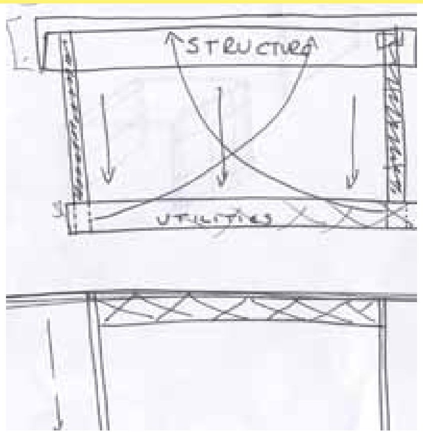

Post and Beam


Industrial Unit

CHARRETTE PROCESS WORK

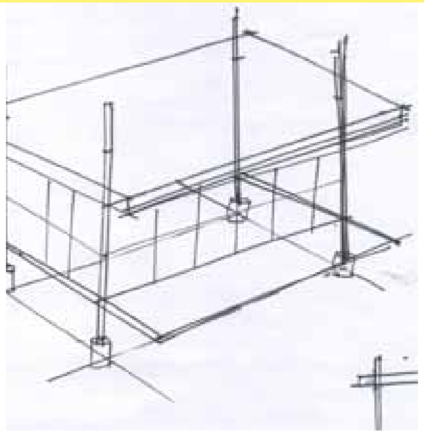
Typology Combinations | Structure

- Charrette Day 1
- Charrette Day 2
- Charrette Day 3
- Charrette Day 4
- Charrette Day 5

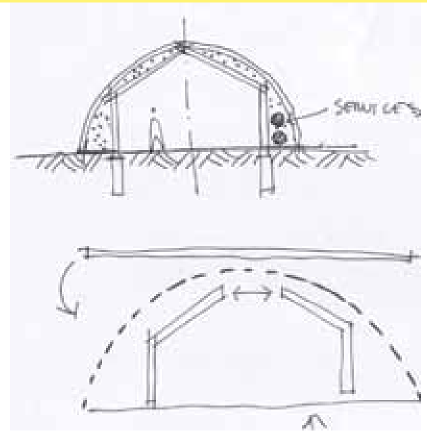


Industrial Shed: With the structure contained in the surrounding frame, wall panels could be suspended from the ceiling.

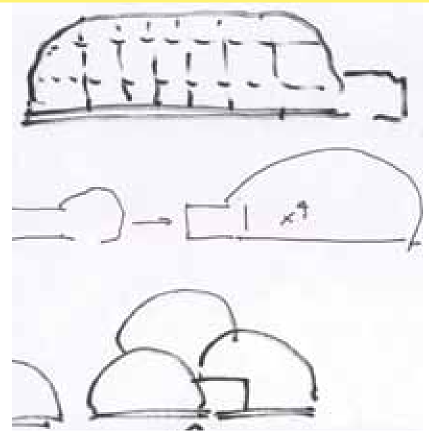
The system is stackable, versatile and can be raised on piers to achieve minimal site disruption. The quality of the living space would depend on the finishes.



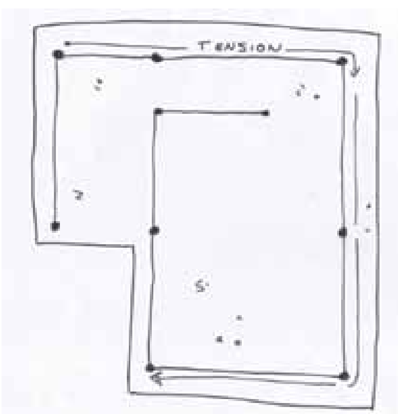
The system may be difficult to insulate in colder climates. An expandable column could carry a large amount of services.



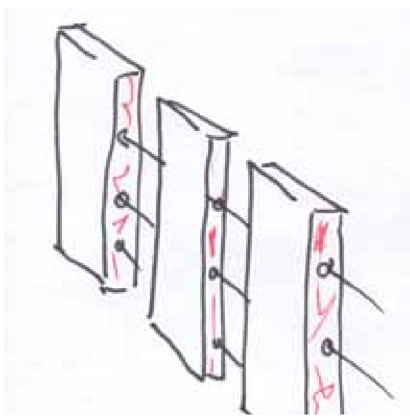
Dome: The strength and simplicity of this form is timeless. The system could accommodate a green roof, and be insulated with sand or dirt. It could also be shipped flat.



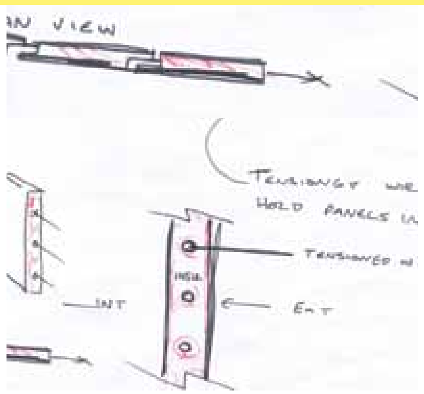
The dome form could also be executed as an inflatable super-bubble with separate units. Potential for stacking would need to be explored.

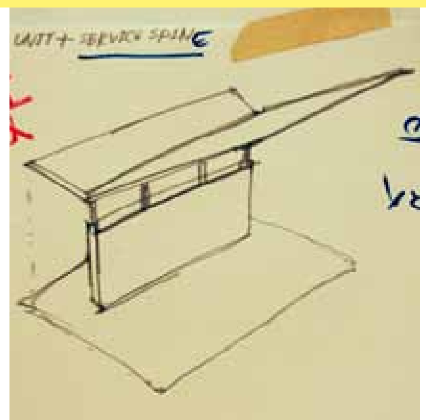


Tension Wire: Tension wires could be used to hold cladding in place and secure the structure.



This system would require precision and is not easy to expand once constructed.



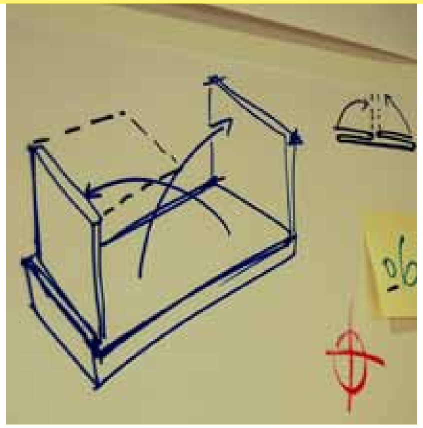


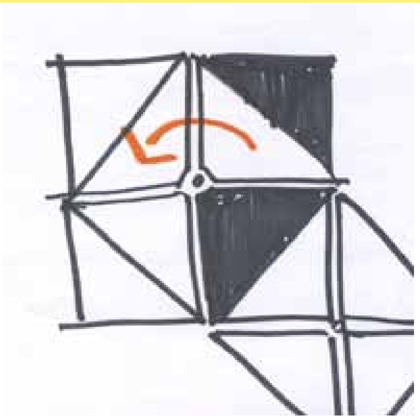
Panel/Void: In this system, material is saved by placing the panels only where required for structural rigidity. The open spaces could be filled with glass or plastic. The configuration could vary.

CHARRETTE PROCESS WORK

Typology Combinations | Fabrication

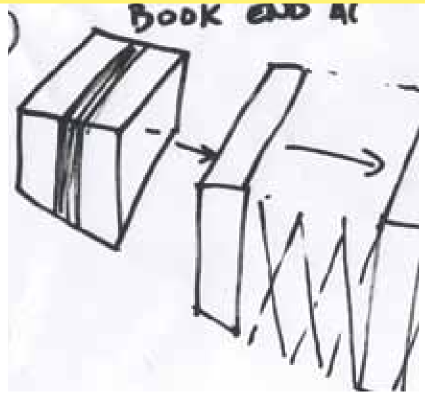
- Charrette Day 1
- Charrette Day 2
- Charrette Day 3
- Charrette Day 4
- Charrette Day 5

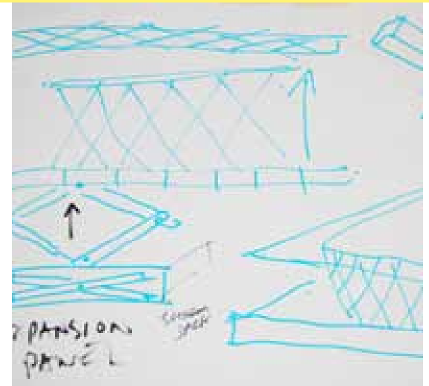


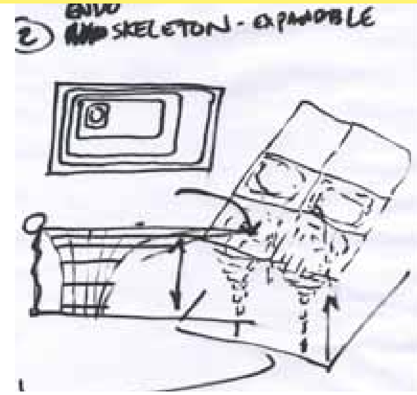


Fold-Out
This system would pack flat and include walls and floors that lift or spin into place on site.

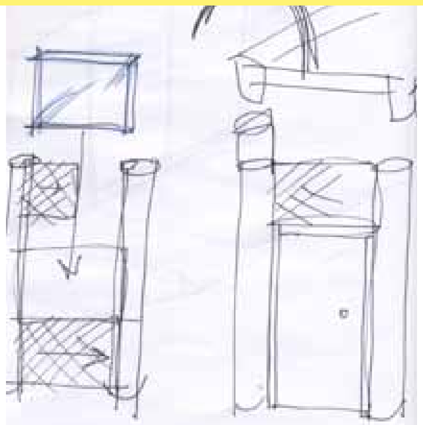
Spin-Out
This system would pack flat and include walls and floors that lift or spin into place on site.

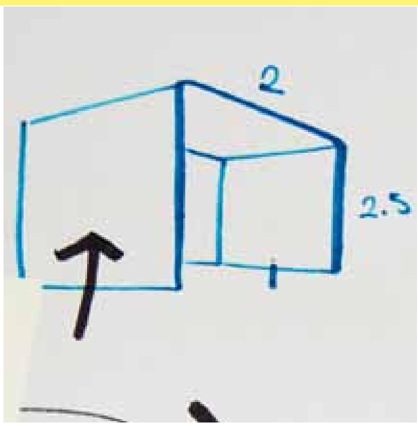






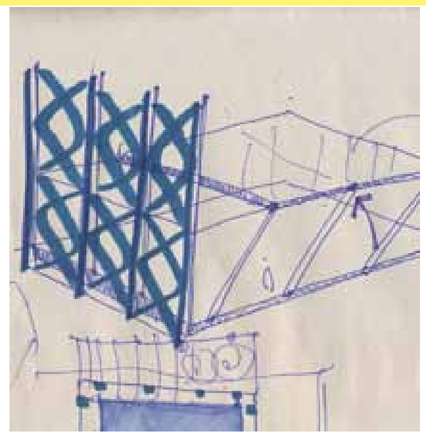
Accordion: This endo-skeleton (with a parametric paneled skin) could expand using a scissor jack, permitting modification of the home's footprint.

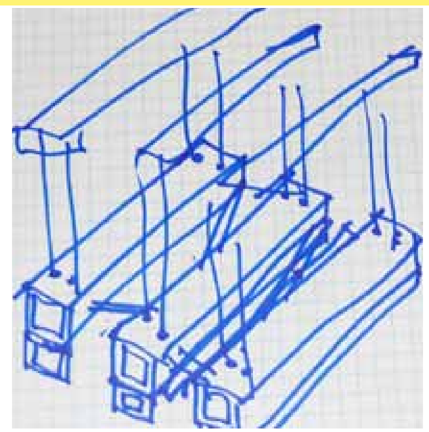


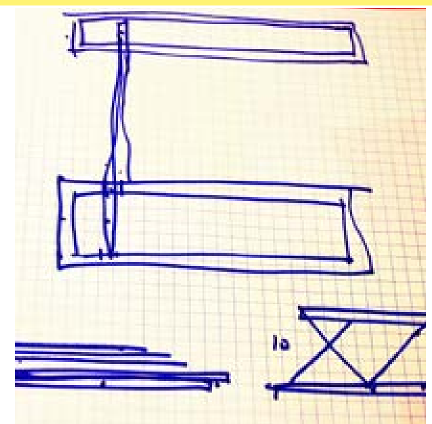


Ribbon: A retractable screen could pull out horizontally or vertically between structural posts to define the living space. This system would require technical development and is more appropriate for temporary spaces.

C-Connection
This system would pack flat and include walls and floors that lift or spin into place on site.







CHARRETTE PROCESS WORK

Typology Combinations | Systems

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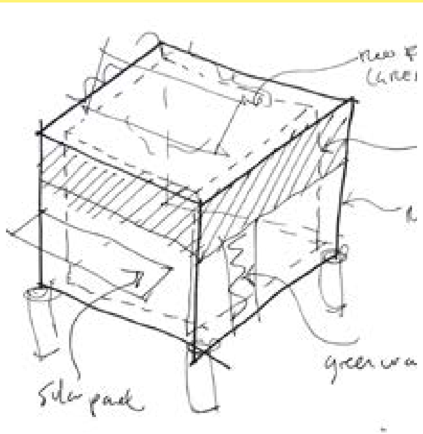
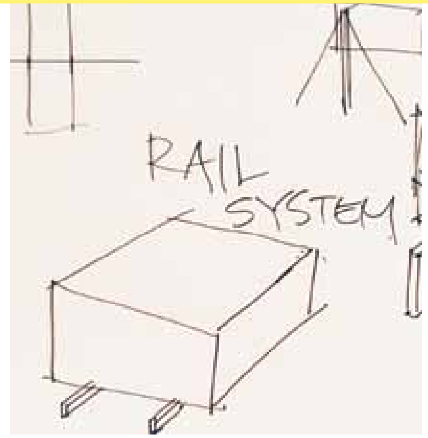
- Charrette Day 2
- Charrette Day 3
- Charrette Day 4
- Charrette Day 5

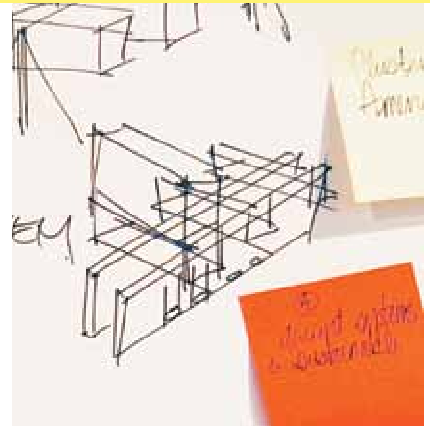


Super Structure: A ‘soft’ living space is protected by a resiliant outer shell, leaving an interstitial indoor/outdoor area.

In Costa Rica the core could be light, while in Southern Ontario it would be heavy.

The inner core could be constructed from cheaper materials however, there would be some degree of redundancy. Expandibility is limited.

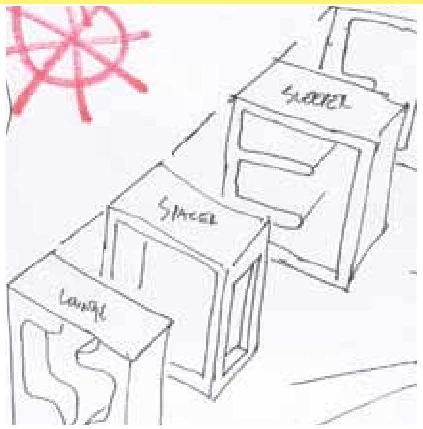




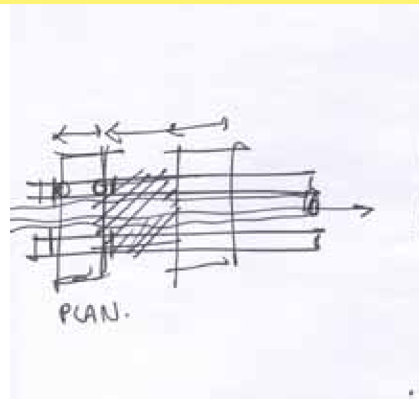
Clustered Amenities: Services such as water and energy are efficiently organized along a central core, that is shared between homes.

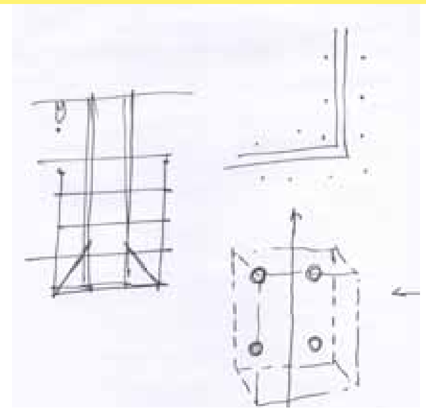
As a result, homes would be somewhat interdependant. Easy access to the core is critical for maintenance.

System could be analyzed for potential economies of scale.



Modules: Spaces would be efficiently organized according to function within premanufactured compartments.





CHARRETTE PROCESS WORK

Typology Combinations | Materials

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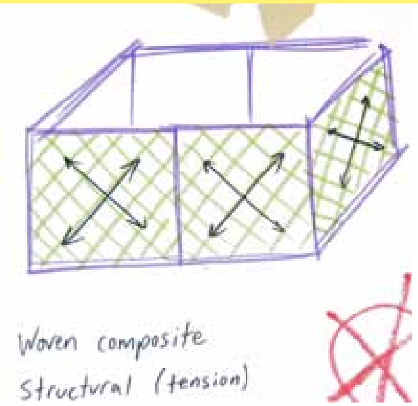
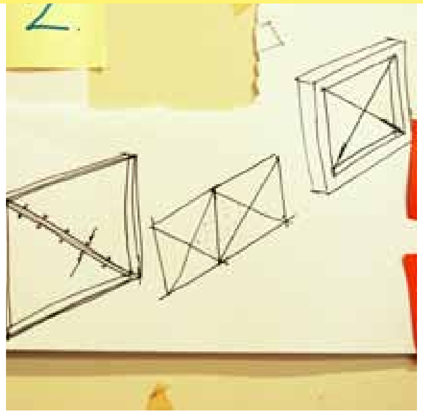
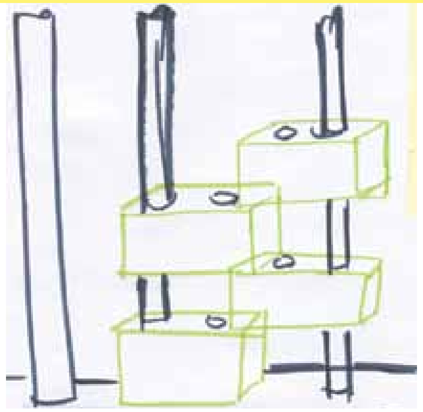
- Charrette Day 2
- Charrette Day 3
- Charrette Day 4
- Charrette Day 5



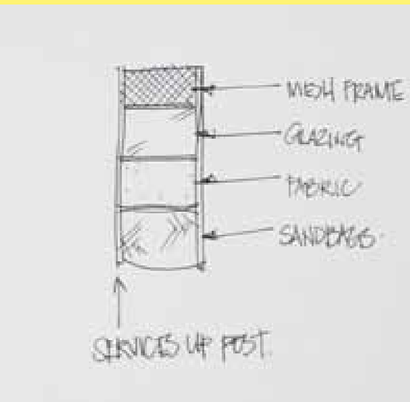


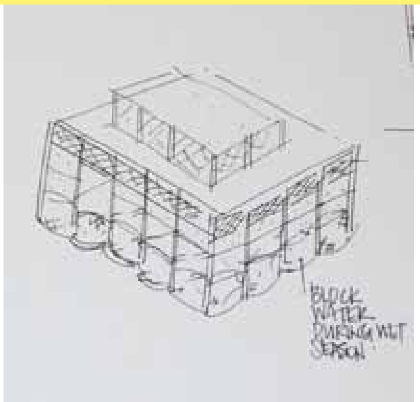


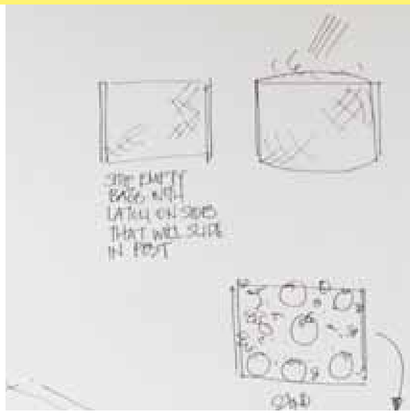
Woven Panel: Lightweight, structural panels could be constructed from a woven composite, such as glass or carbon fibre.

The panels could be developed to suit any climate. The system would require design development, although a less durable model could be constructed using plywood.

Stacked Components: Structural objects such as a cinder block or a sand bag could be stacked like bricks, and held in place using thin posts.







Infill: A prefabricated shell could be filled with local materials (such as sand), that provide both structure and insulation.

This multifunctional approach has the potential for innovation. For example, specialized bags with side latches could be prefabricated and filled on site.

The system also lends to supporting local economies, resulting in an inexpensive solution. Potential for modularity would need to be explored. The method is labour intensive.

2 DESIGN SCHEMES
Modular Grid | Structure

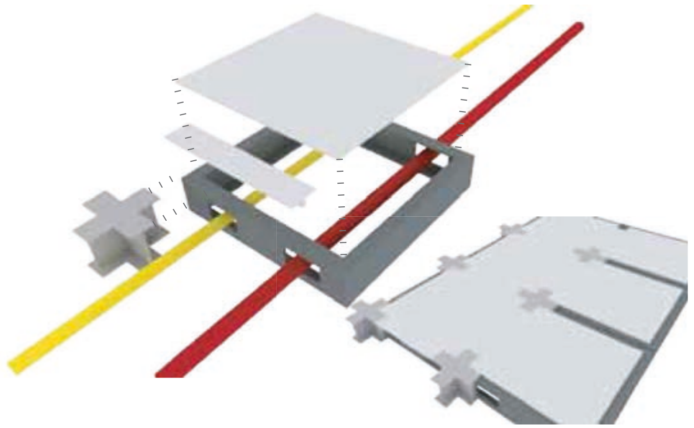
- Charrette Day 1
- Charrette Day 2
- Charrette Day 3
- Charrette Day 4
- Charrette Day 5

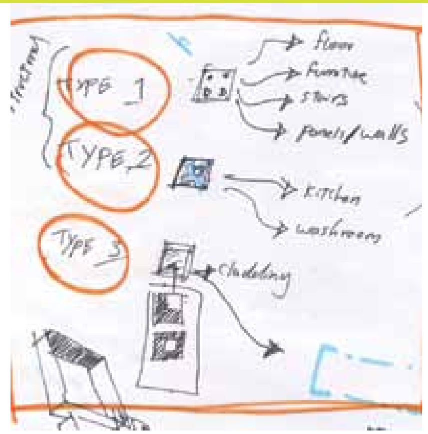
The team tried to push a simple vision to its limits: a waffle assembly panel that would be low weight and low volume, that could serve the function of floor, wall and ceiling assembly.

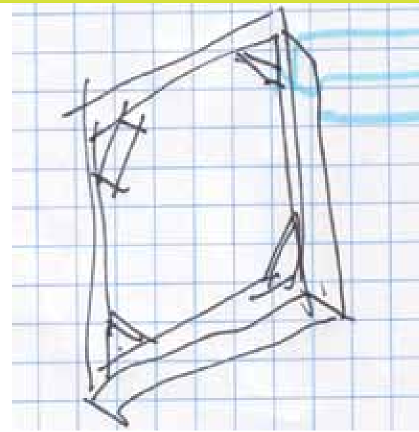
Modular Grid

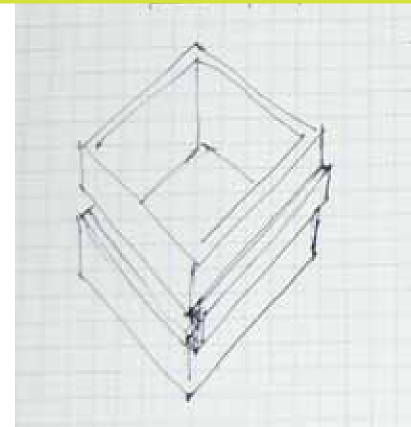
A modular component that could make any space

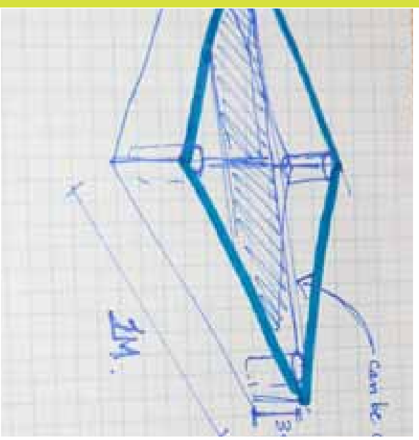
In this scheme, a standardized structural panel is designed to accept service systems through its interior space, resulting in an easy-to-assemble, flexible housing typology.



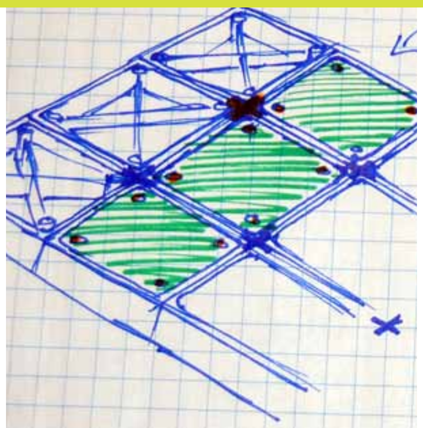


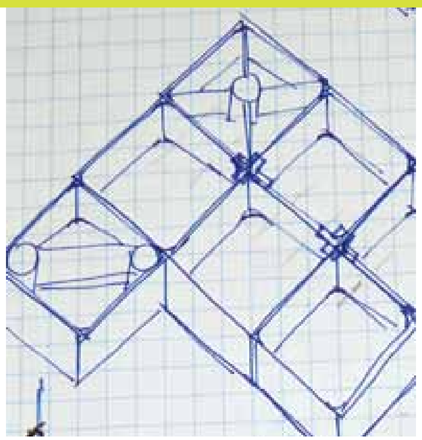




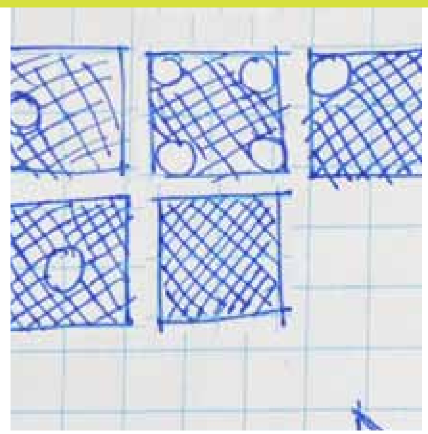


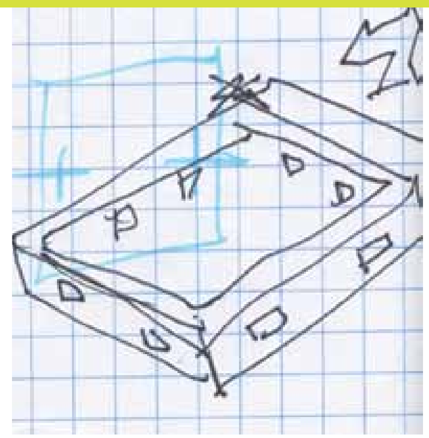
Panels could be a vacuum or waffle assembly.

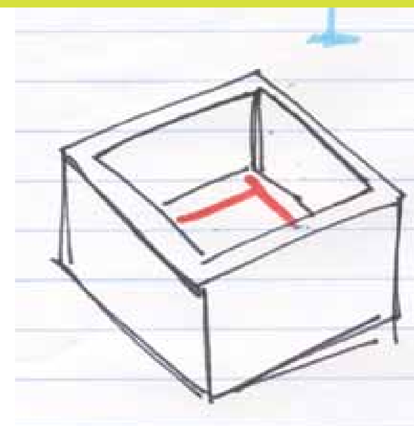




Panels could include a cross-brace in various formations, depending on their placement to accommodate for different loads in the floor, walls and ceiling.





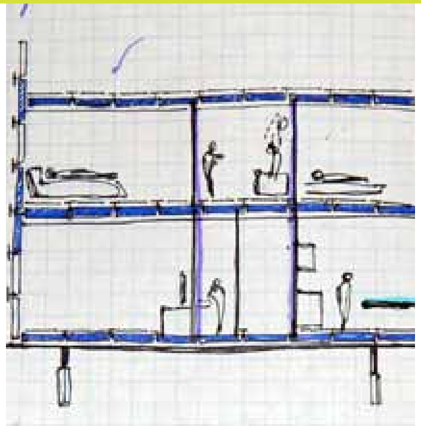
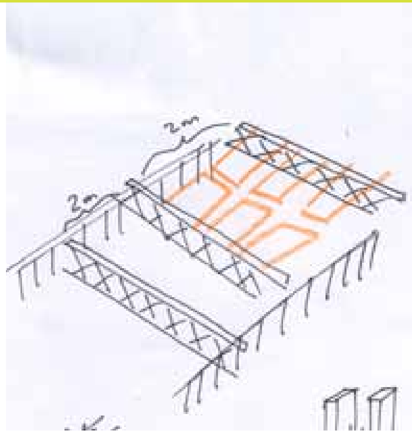


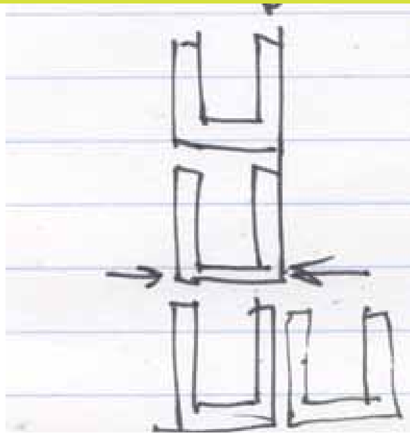
2 DESIGN SCHEMES

Modular Grid | Structure

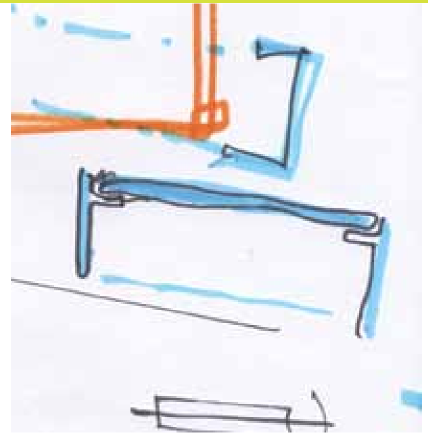
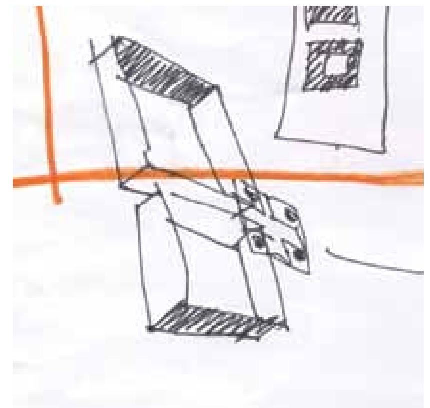
- Charrette Day 1
- Charrette Day 2
- Charrette Day 3
- Charrette Day 4
- Charrette Day 5

The parts would assemble and disassemble like a puzzle.

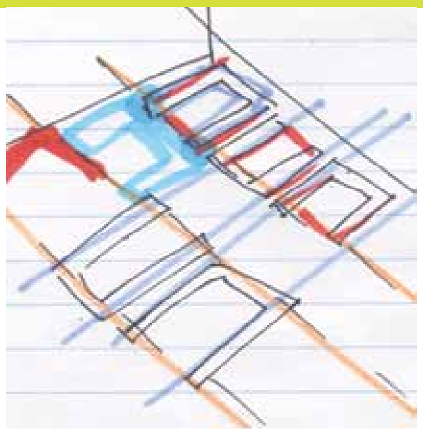
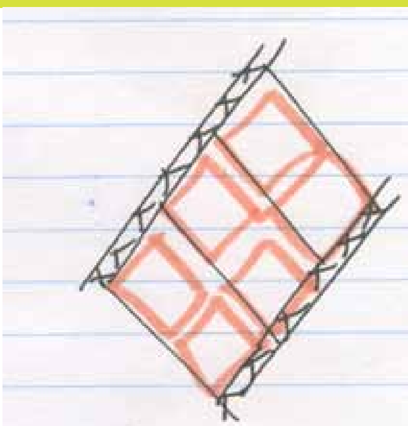
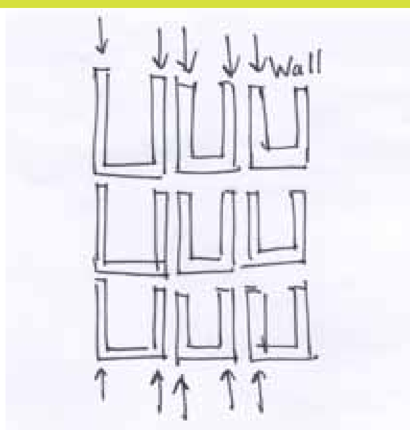



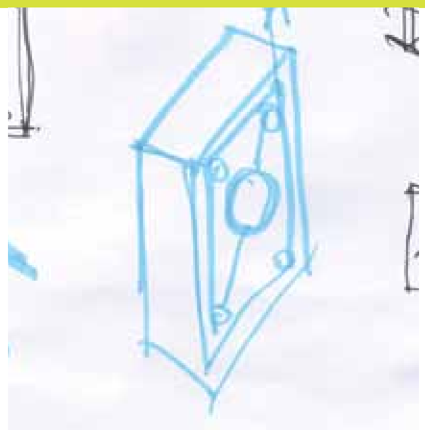
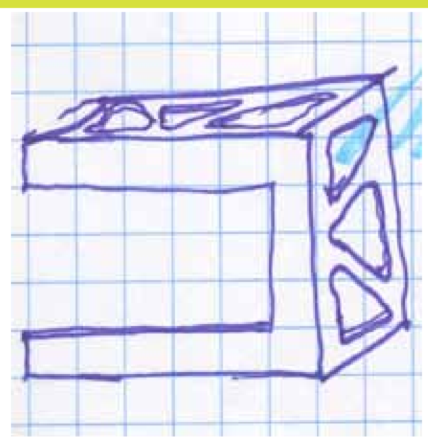
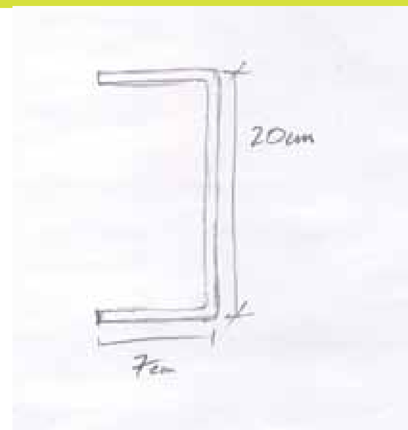


Panels could be used as floor, wall or ceiling assemblies.

Panels could nest together when shipped.

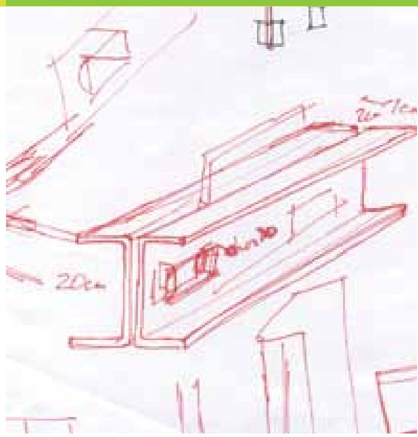
2 DESIGN SCHEMES

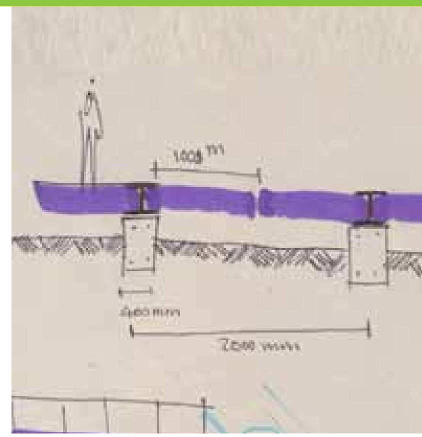
Modular Grid | Structure

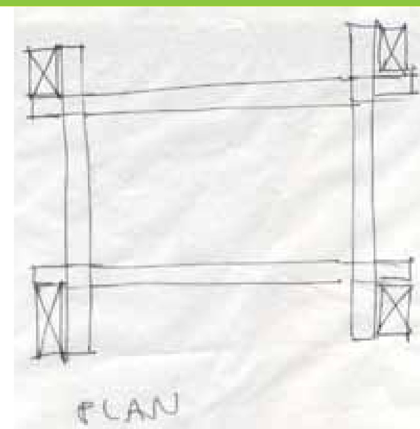
- Charrette Day 1
- Charrette Day 2
- Charrette Day 3
- Charrette Day 4
- Charrette Day 5

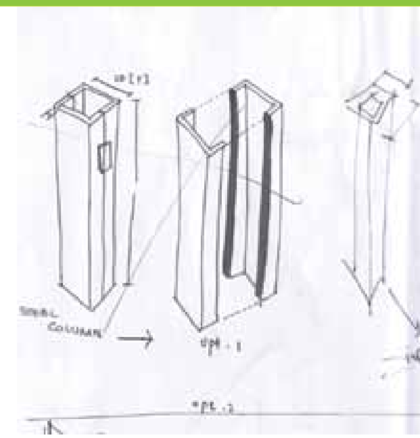
The team experimented with the placement of I-beams to act as a connecting point, and as structural columns.

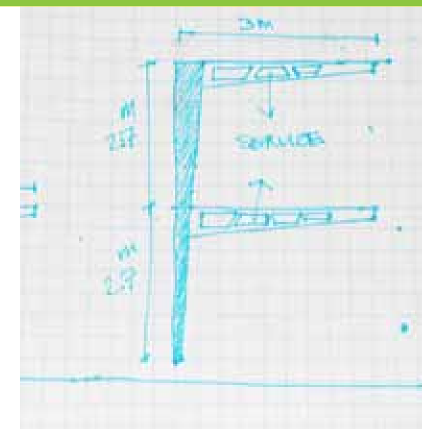
Panels could join at the corners with I-beams.

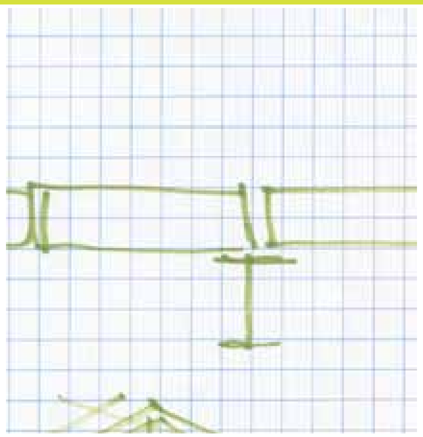




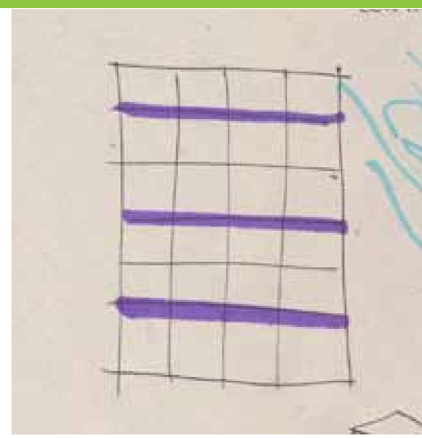




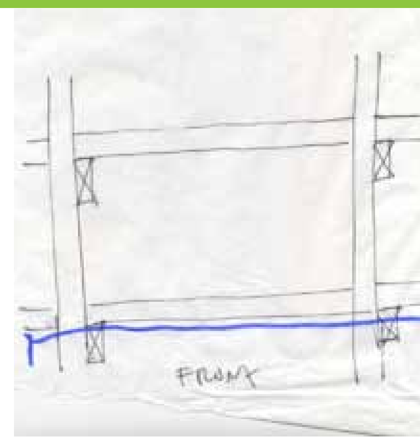


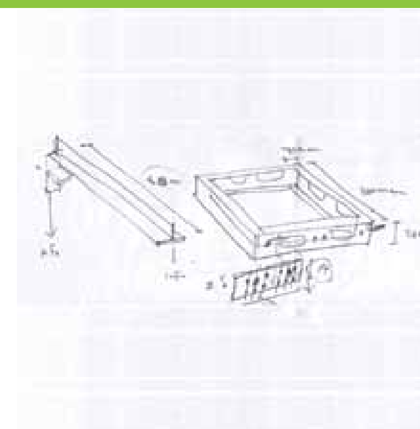


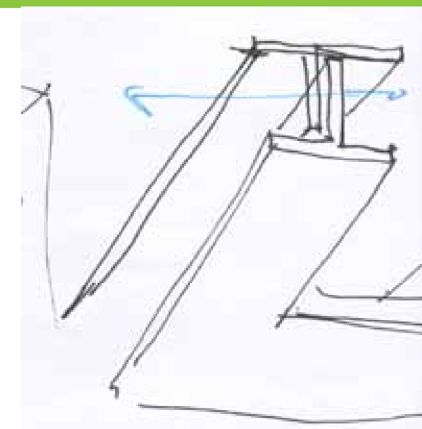
Panels could sit on top of, or sit within an I-beam, which would be 10cm wide at its base, with a 3cm channel.



I-beams would span across the short wall every 2m.



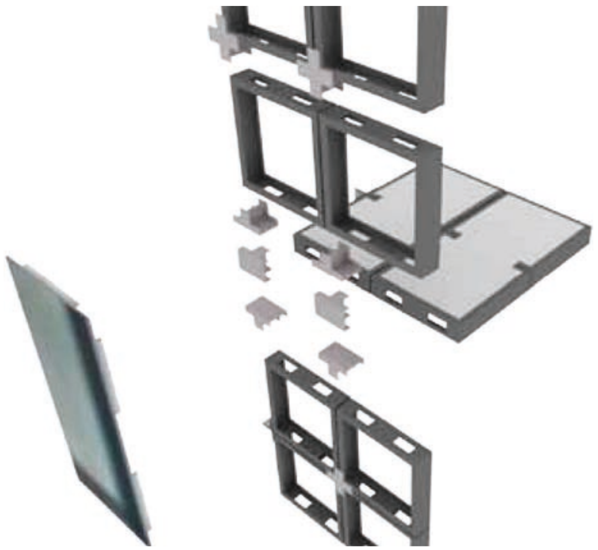


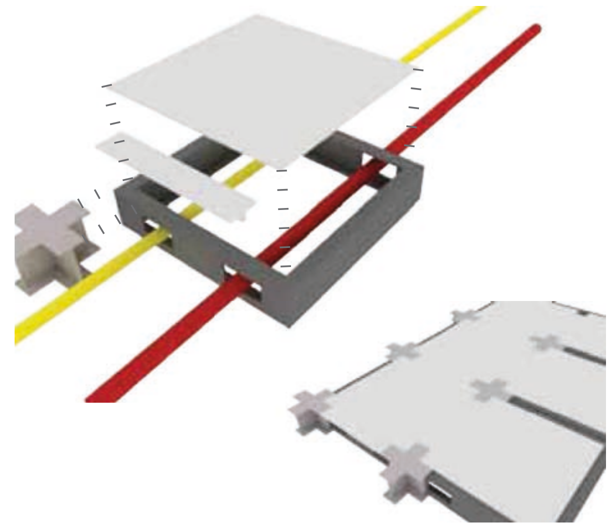


2 DESIGN SCHEMES
Modular Grid | Structure

- Charrette Day 1
- Charrette Day 2
- Charrette Day 3
- Charrette Day 4
- Charrette Day 5

On the third day, the team arrived at a square stud system that could be assembled in a factory as a closed component, or on site.

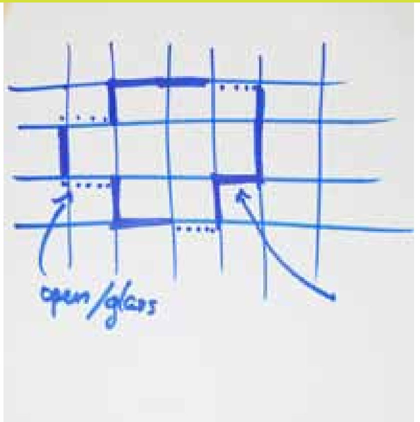




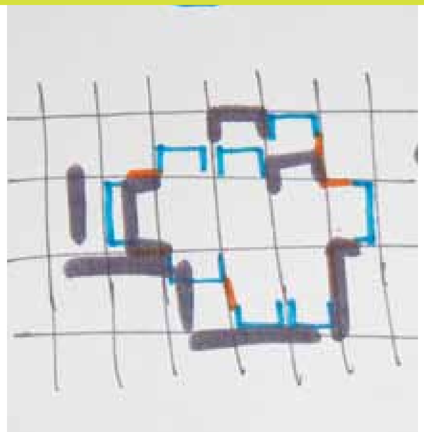
2 DESIGN SCHEMES
Modular Grid | Schematic

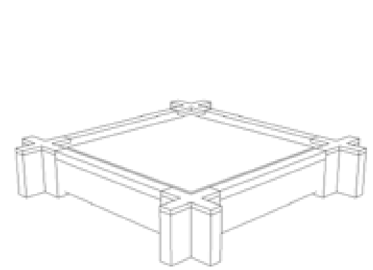
- Charrette Day 1
- Charrette Day 2
- Charrette Day 3
- Charrette Day 4
- Charrette Day 5

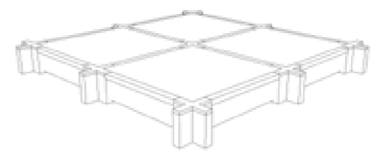
The schematic of the unit would be derived from a grid. This grid could combine to form a module of many dimensions, and then combine again to form a unit.

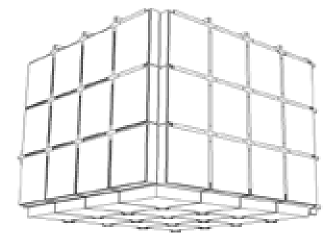


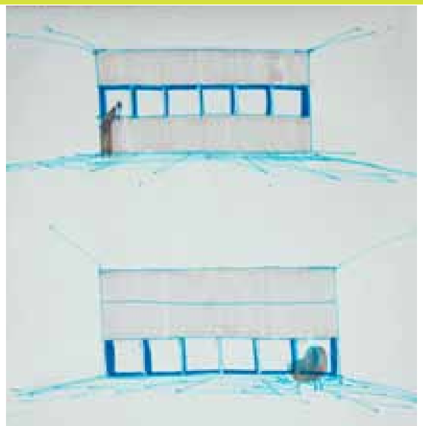
Standard sized panels could combine to form a grid.



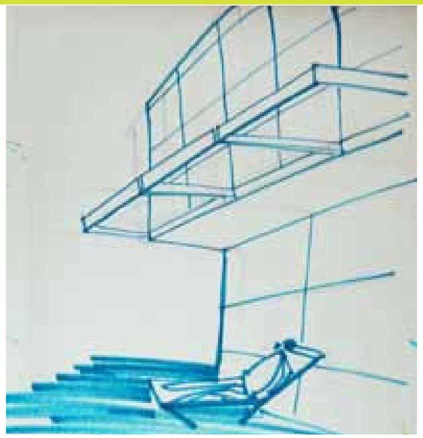




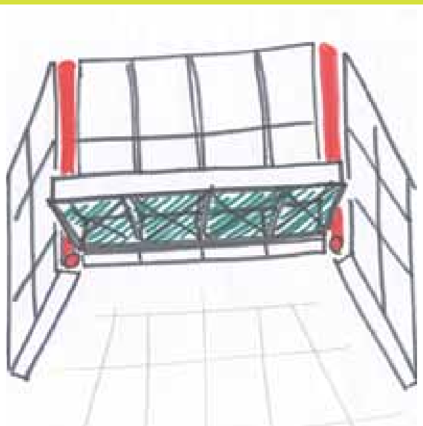


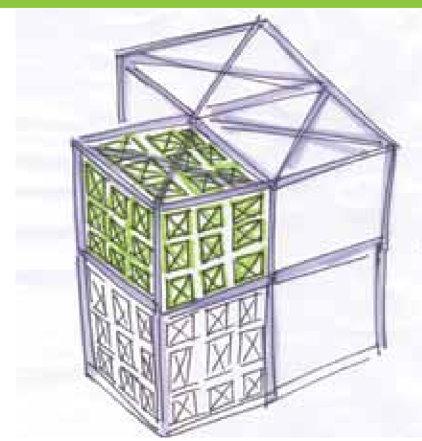


Panels could be configured to achieve various facades.

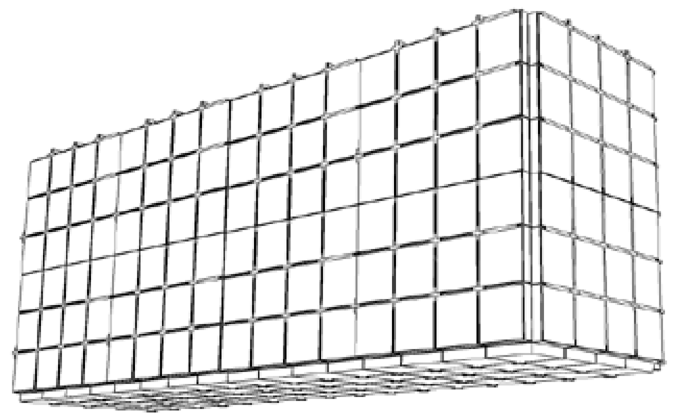


Panels could also function as an operable window or swivel to make an awning.





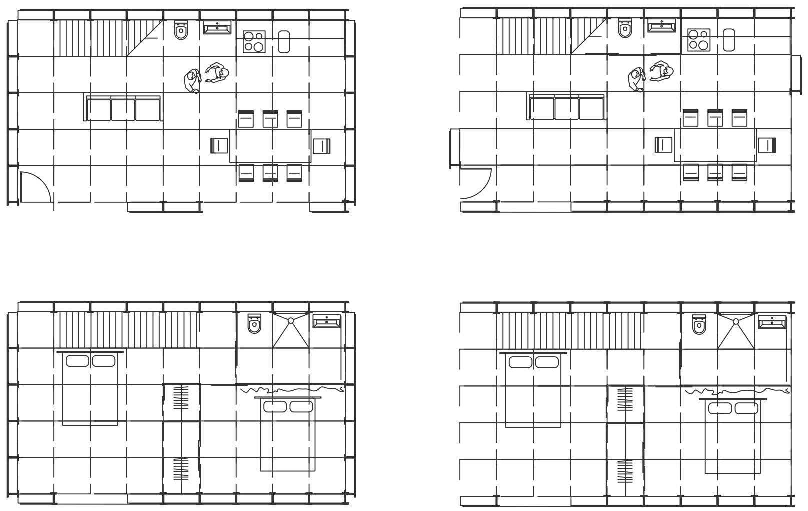
Panels would form modules, which could be combined to form a unit.



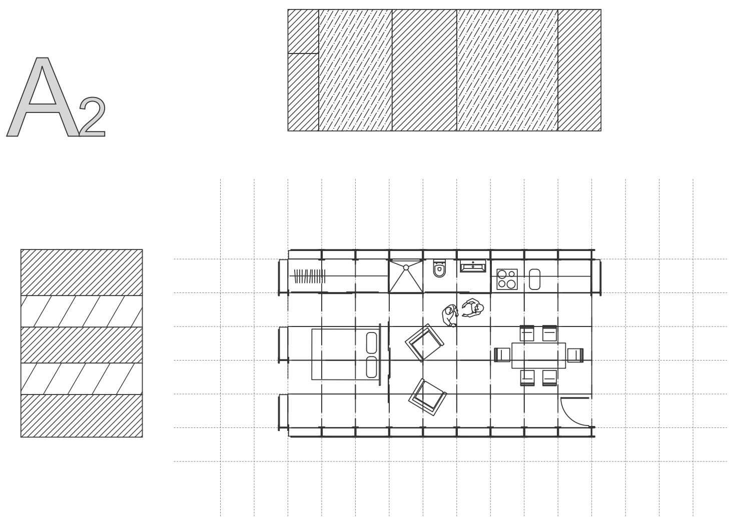
2 DESIGN SCHEMES

Modular Grid | Schematics

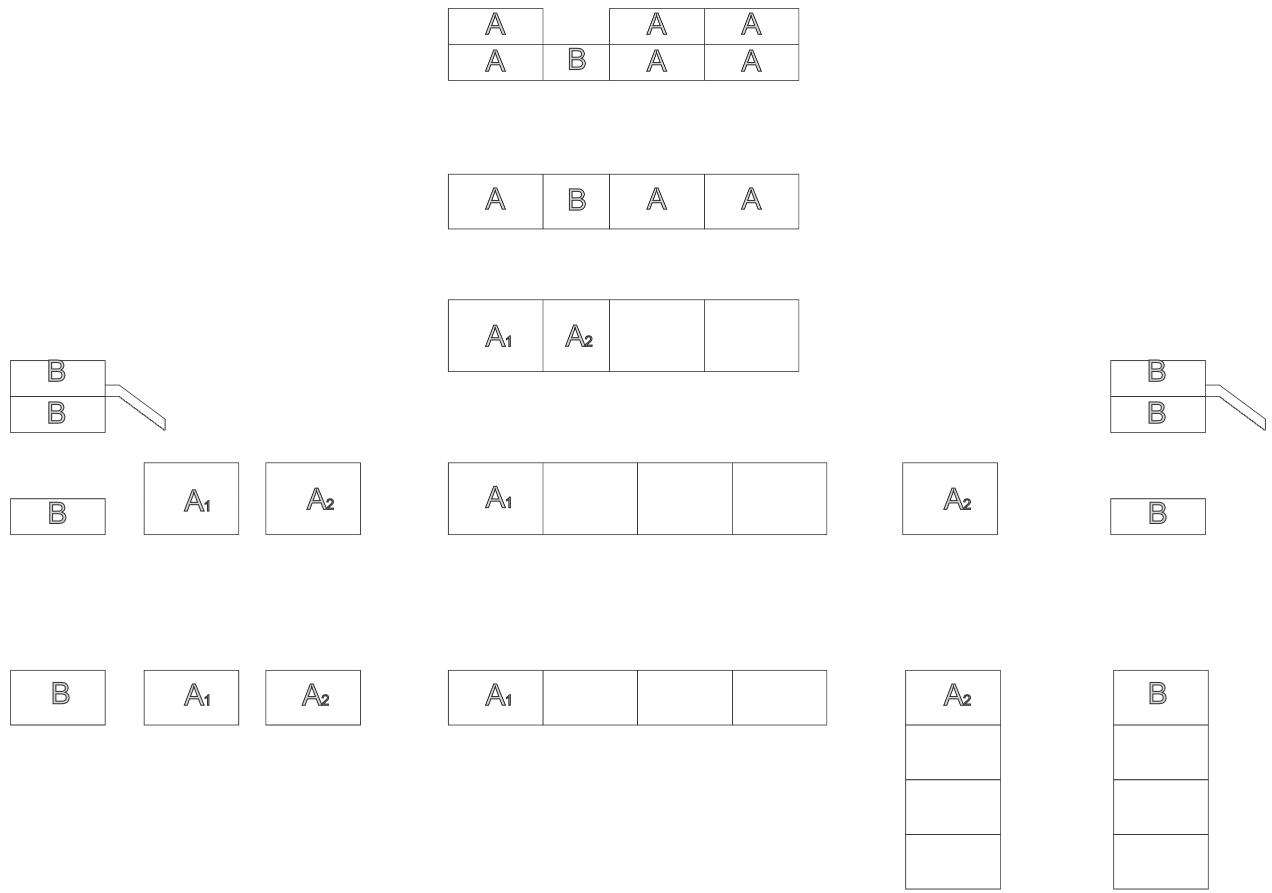
- Charrette Day 1
- Charrette Day 2
- Charrette Day 3
- Charrette Day 4
- Charrette Day 5



A_1 A_2



B

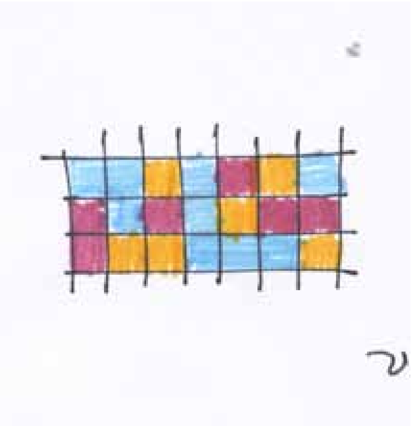


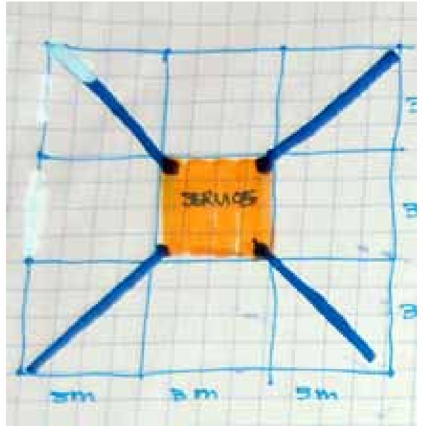
2 DESIGN SCHEMES

Modular Grid | Systems

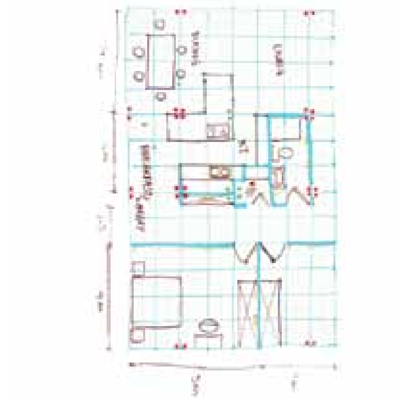
- Charrette Day 1
- Charrette Day 2
- Charrette Day 3
- Charrette Day 4
- Charrette Day 5

The flexibility of the schematic extends to the placement of its systems. The services could be placed at any point within the grid, and channelled through the square studs, as well as vertical columns.

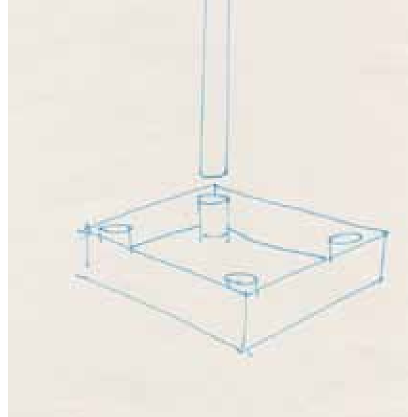




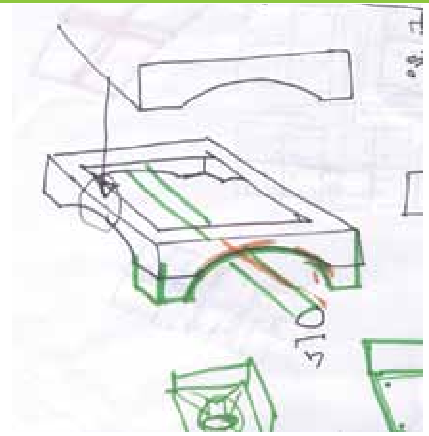
A service core could be placed at any point within the grid.



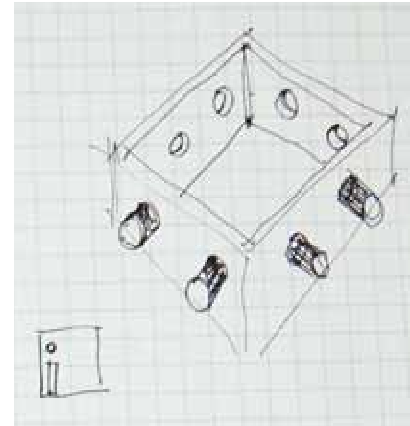
The modular grid would offer versatility for inhabitants in the floorplan.

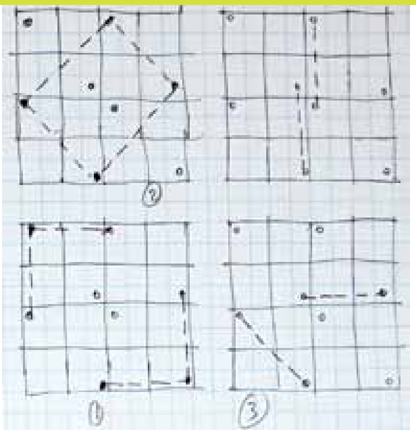


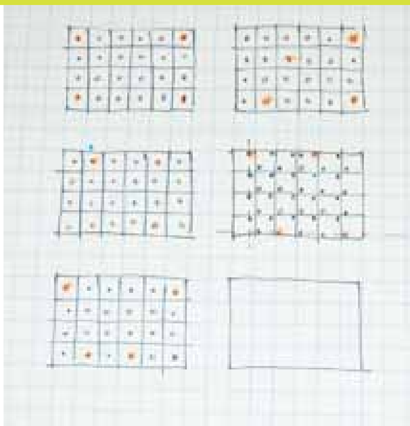
Vertical columns could also serve as studs for interior partitions.



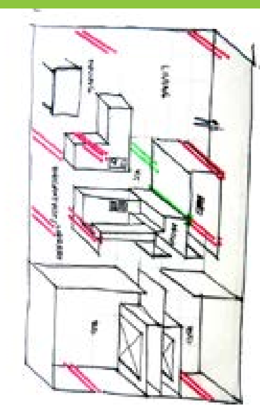
Service conduits could run through the panels.

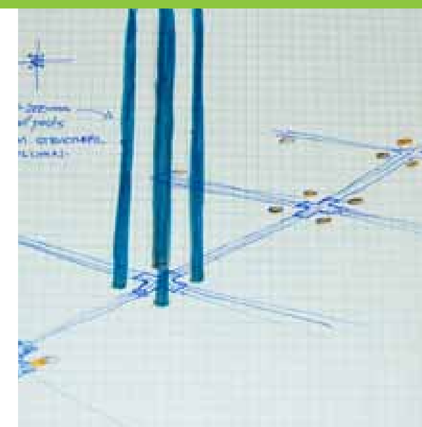




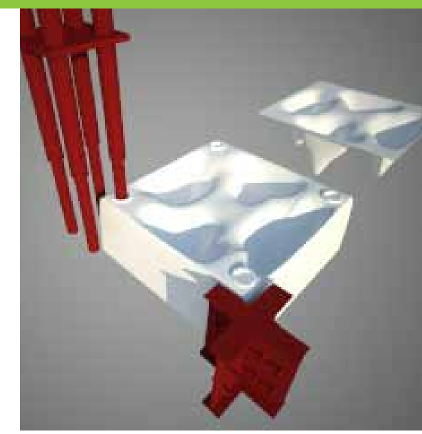


The floor system could operate like a peg board, into which columns, service shafts and wall partition posts could be dropped.





Four thin posts with a unified sheathing could fit in an opening at the panel's corners, forming a structural column.

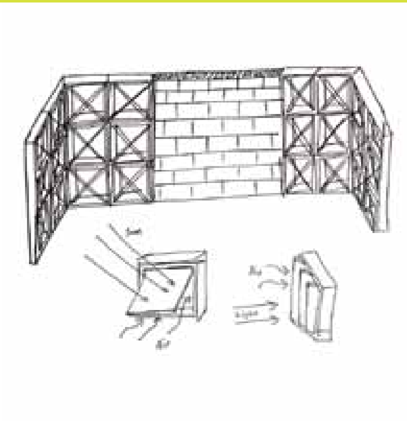
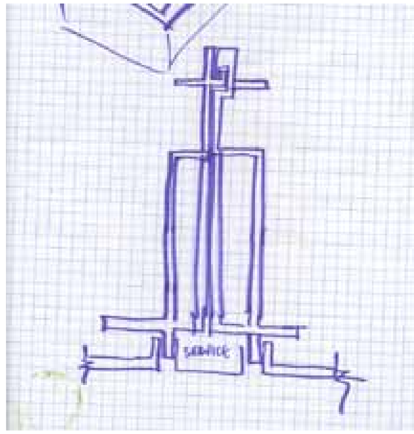
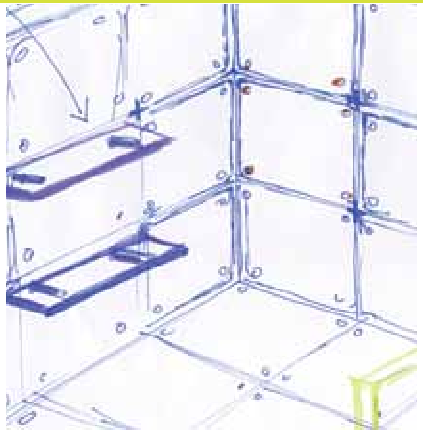


Hollow posts could act as both structural columns, service channels and wall partitions.

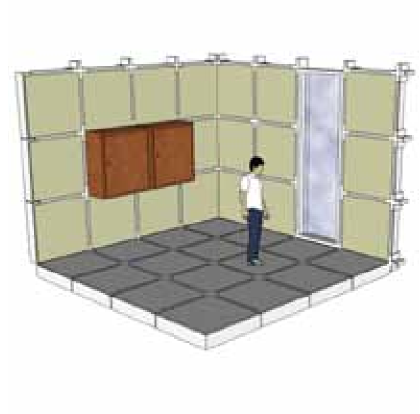
2 DESIGN SCHEMES
Modular Grid | Systems

- Charrette Day 1
- Charrette Day 2
- Charrette Day 3
- Charrette Day 4
- Charrette Day 5

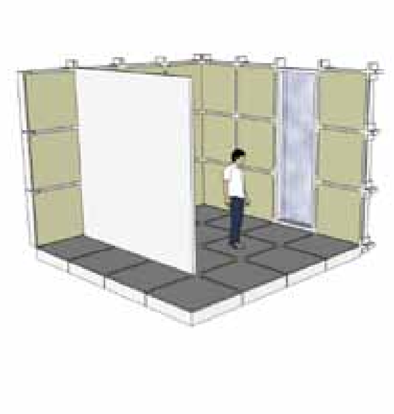
The system could function like a peg board that could accept services, fixtures and furniture.

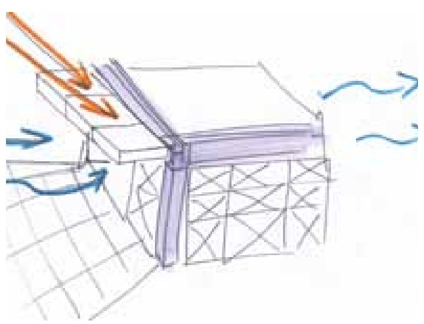
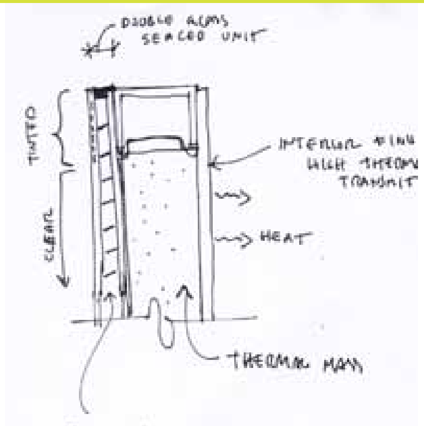
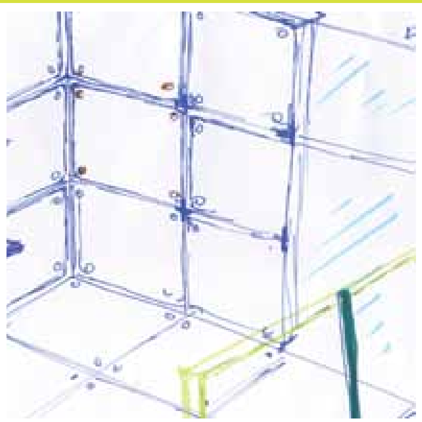
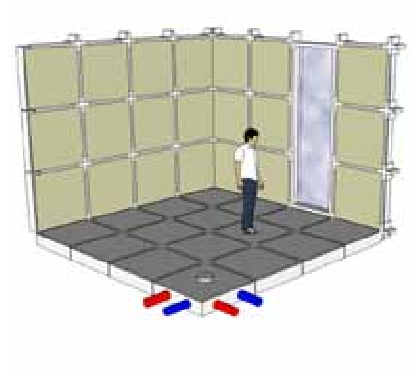
The gap remaining between the panels would form grooves that could accept removable partition walls. These could be reoriented by the inhabitant.



The peg board system on the wall could be used to hang cabinetry and fixtures

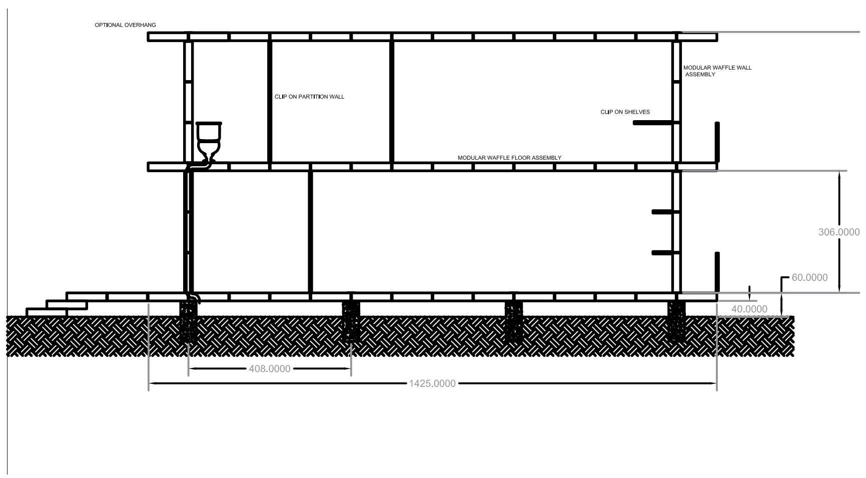


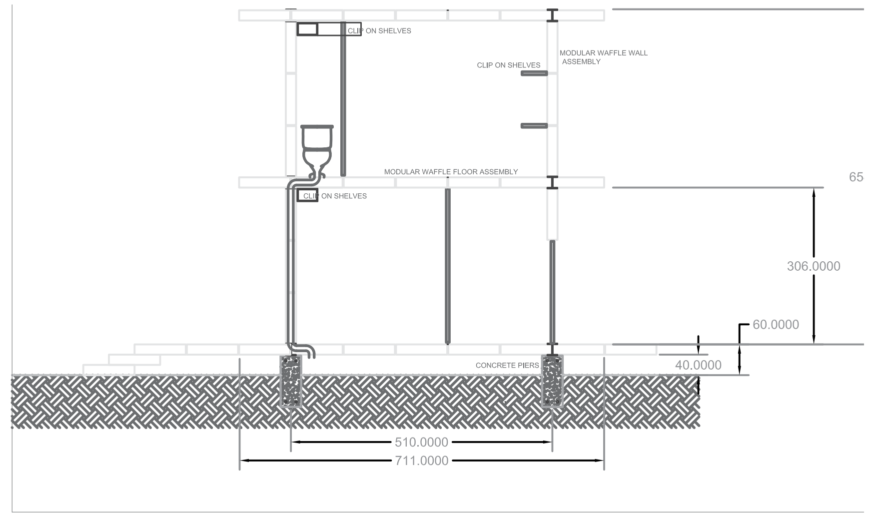
Void panels would create windows.

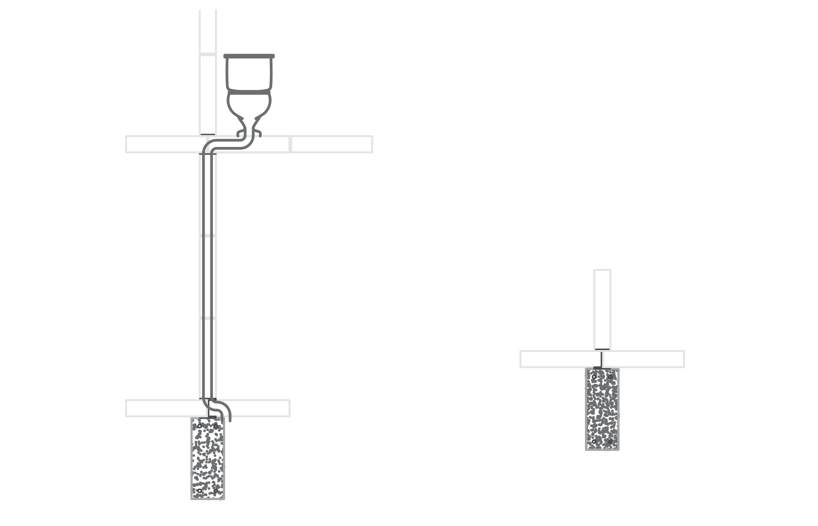





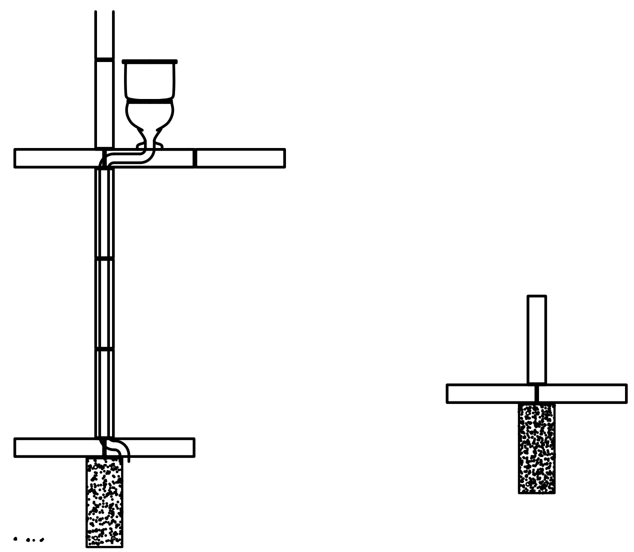
2 DESIGN SCHEMES

Modular Grid | Systems



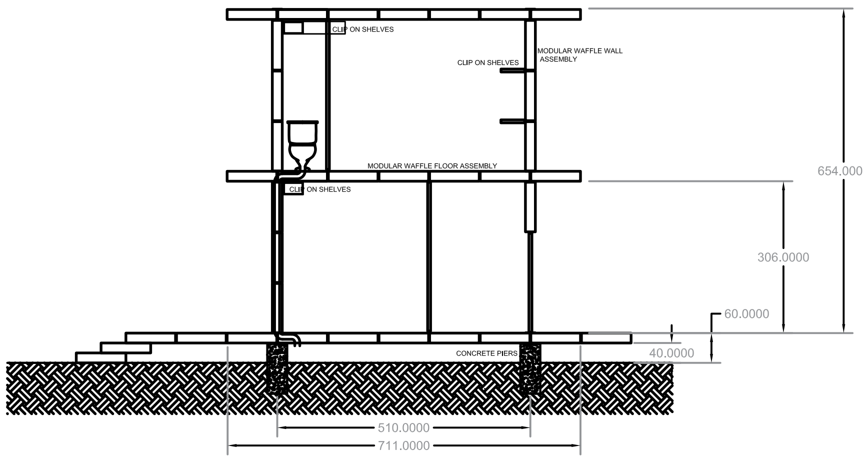


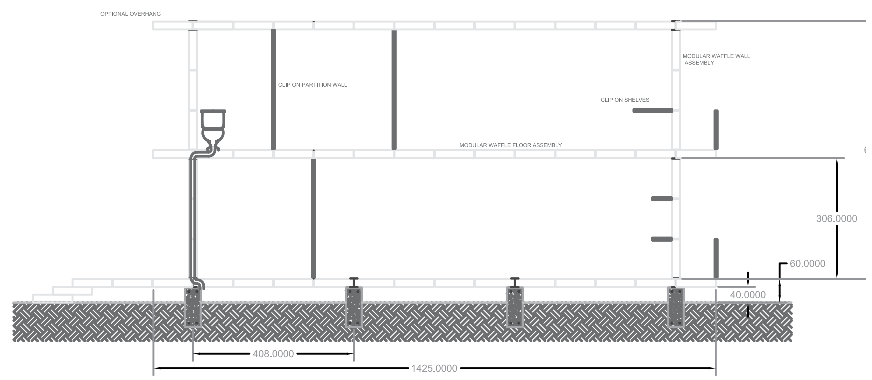




2 DESIGN SCHEMES

Spatial Frame | Systems



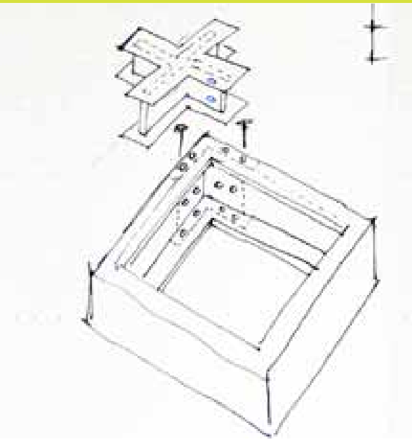


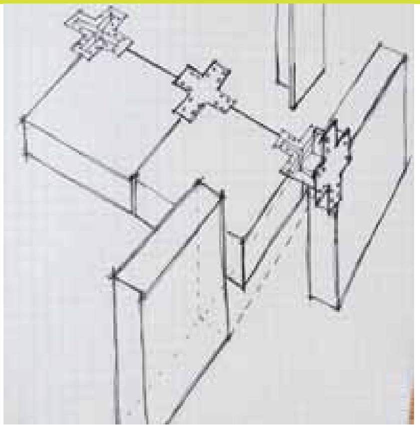
2 DESIGN SCHEMES

Modular Grid | Connections

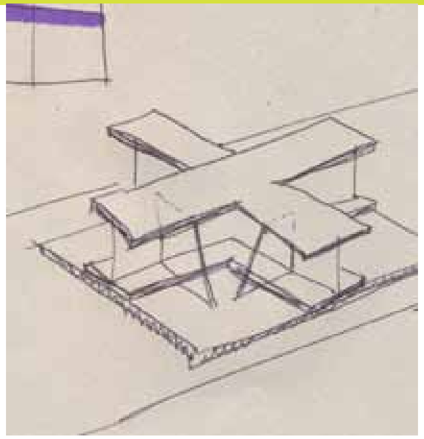
- Charrette Day 1
- Charrette Day 2
- Charrette Day 3
- Charrette Day 4
- Charrette Day 5

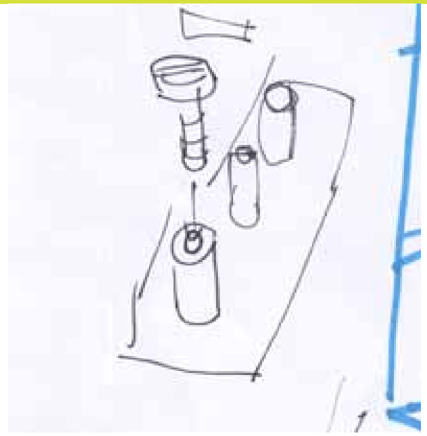
The joints are fundamental to the success of the modular grid scheme. As each one creates a potential point of weakness, their integrity is essential.

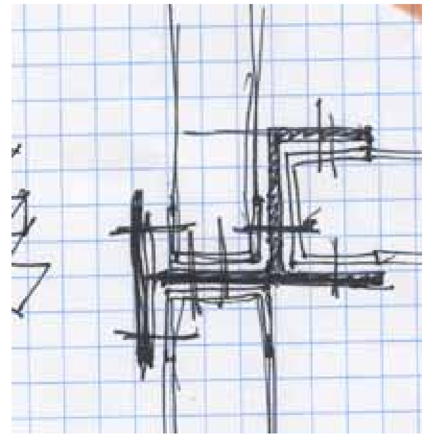


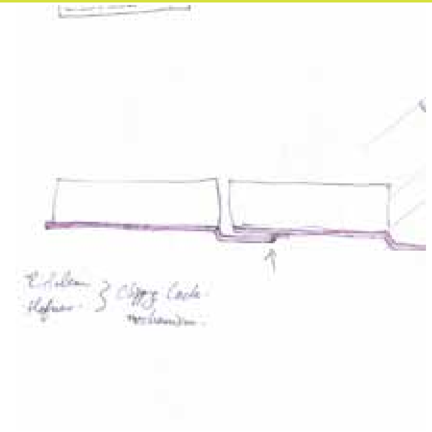


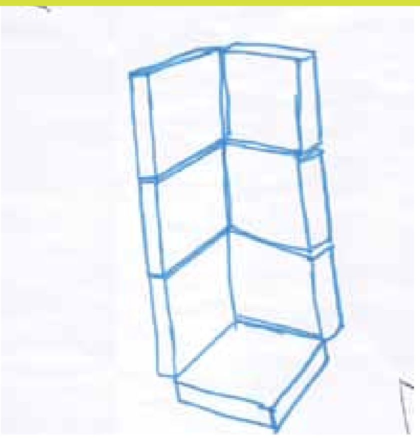
Panels could connect on both their perpendicular and parallel axis.

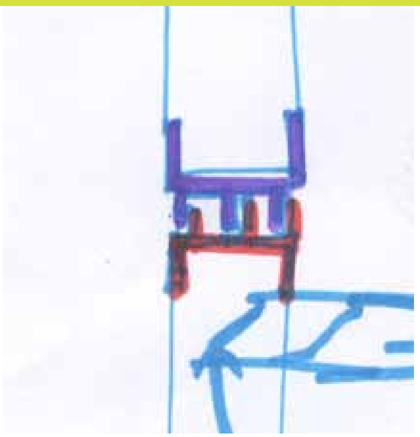


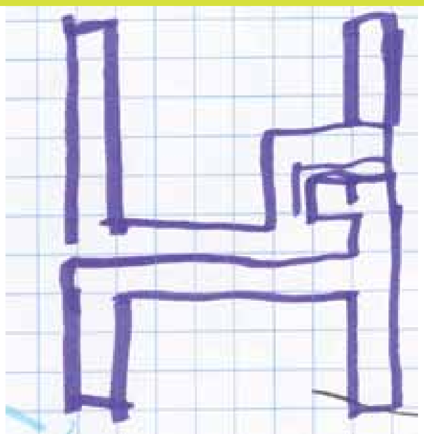


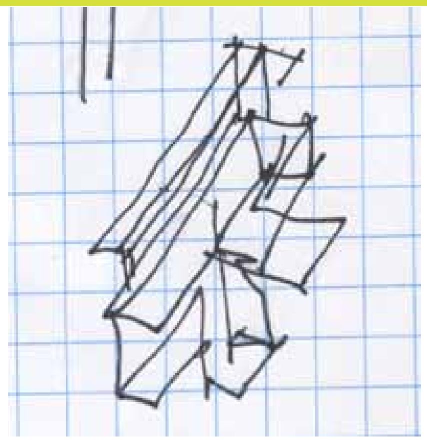


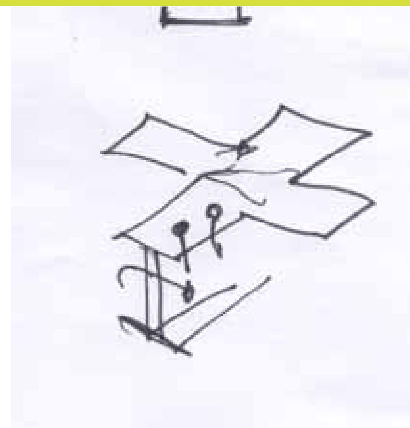










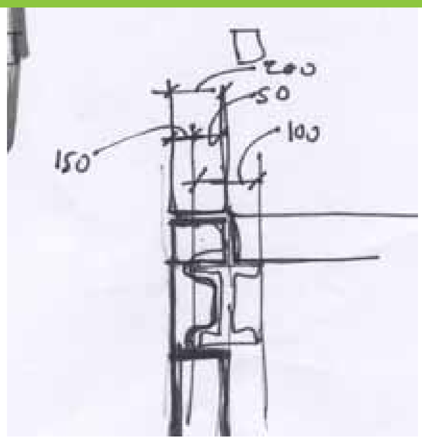


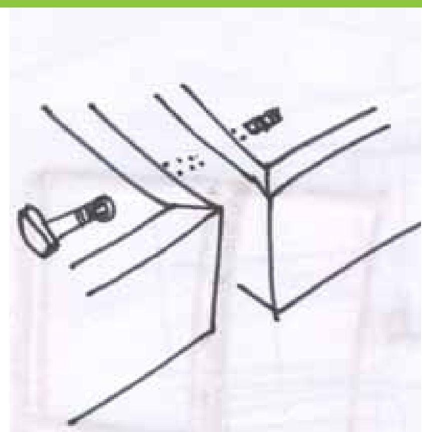
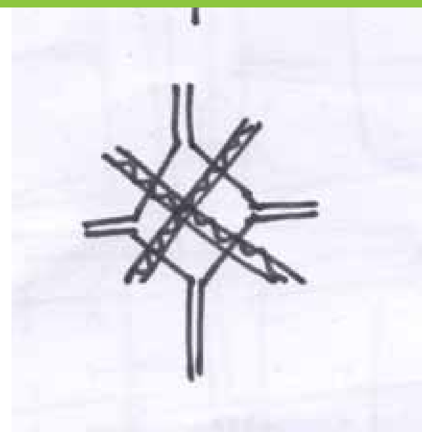
2 DESIGN SCHEMES

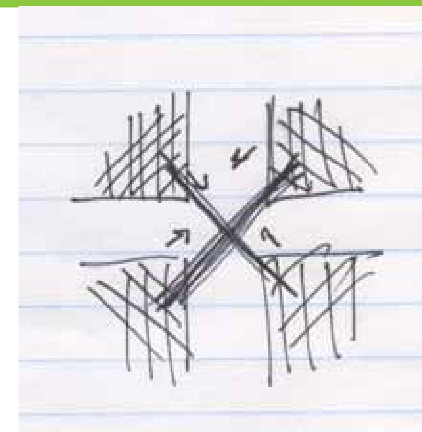
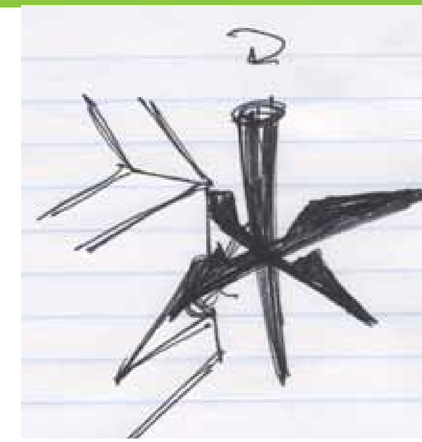
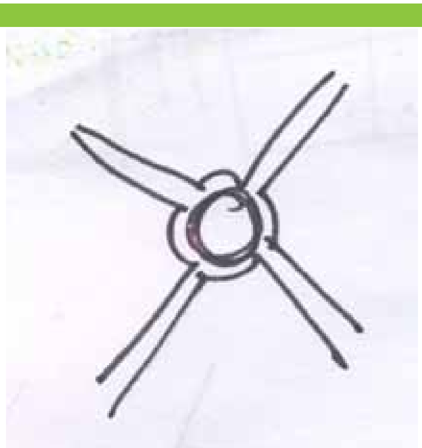
Modular Grid | Connections

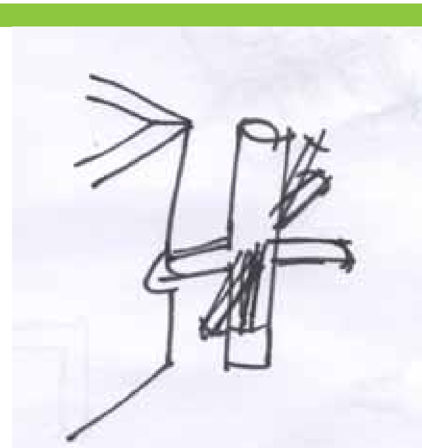
- Charrette Day 1
- Charrette Day 2
- Charrette Day 3
- Charrette Day 4
- Charrette Day 5

The team considered joints that could lock by virtue of how the pieces fit together.





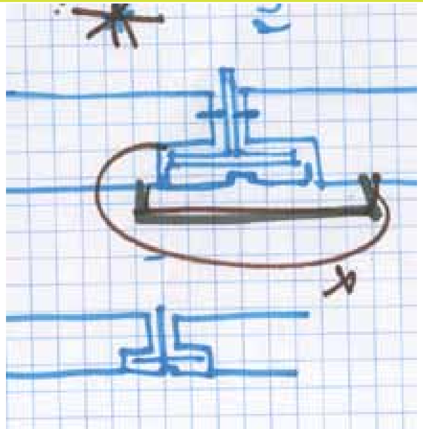
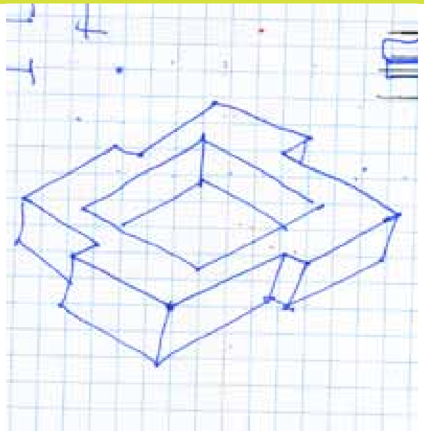
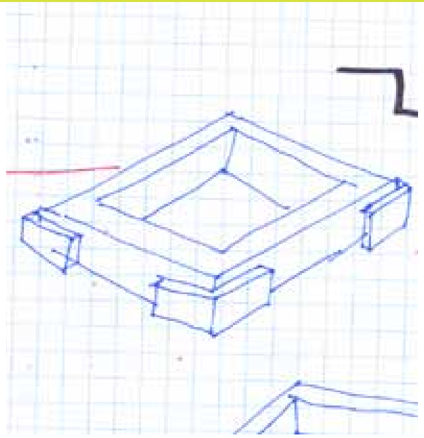
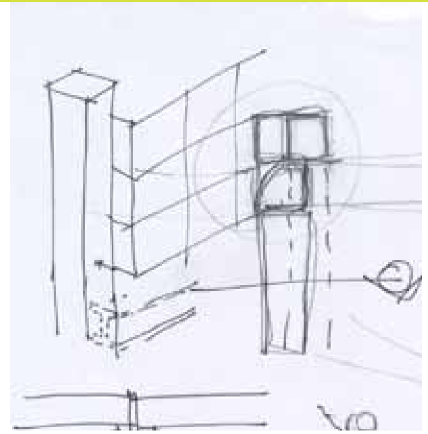
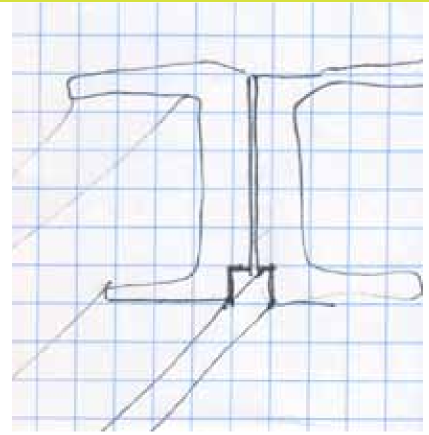
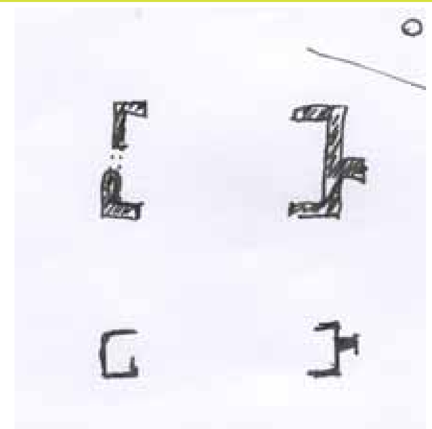
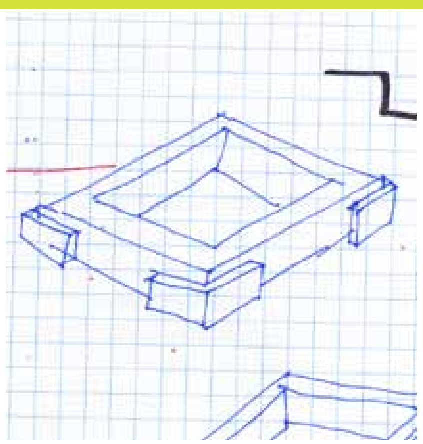
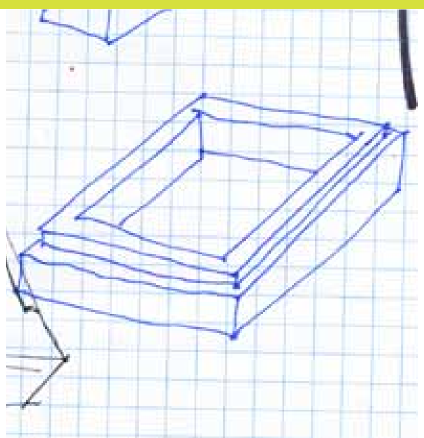
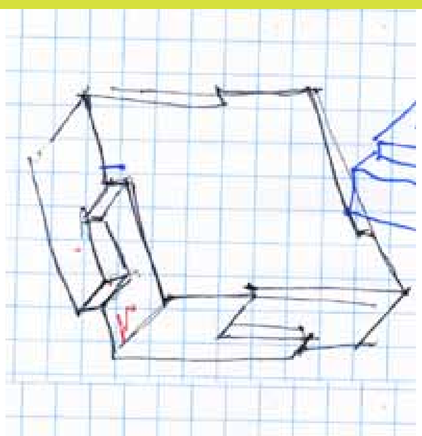
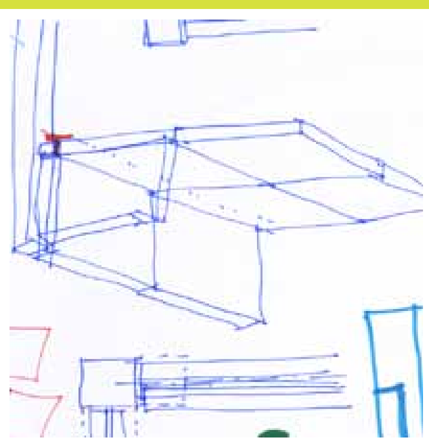
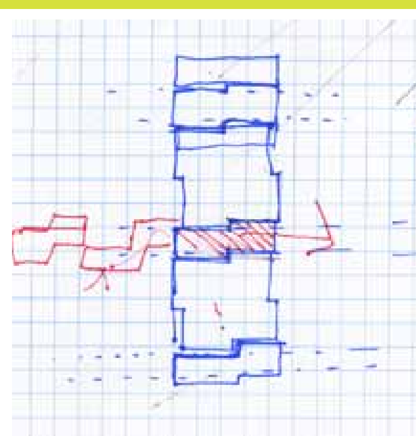
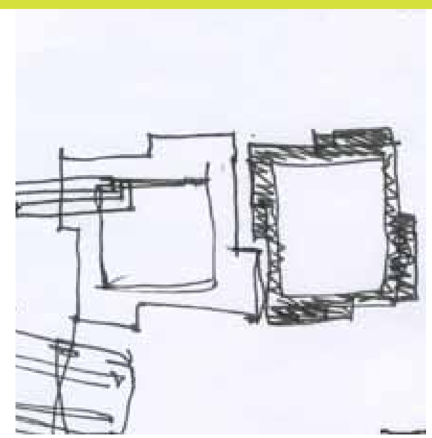


2 DESIGN SCHEMES

Modular Grid | Connections

- Charrette Day 1
- Charrette Day 2
- Charrette Day 3
- Charrette Day 4
- Charrette Day 5

In this regard, the team also considered how the square studs could be designed to connect at their four corners - thus contributing to the locking effect.

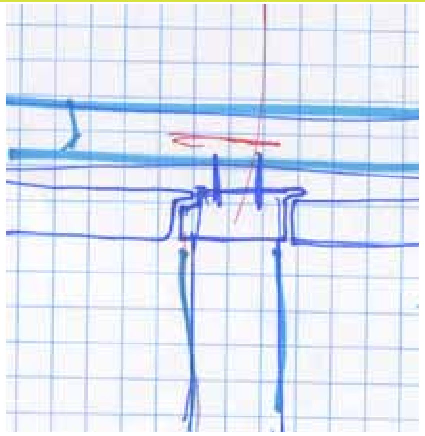
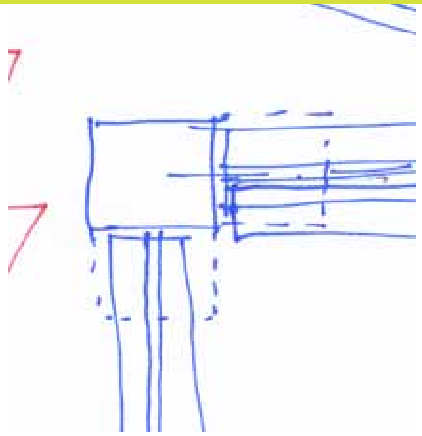
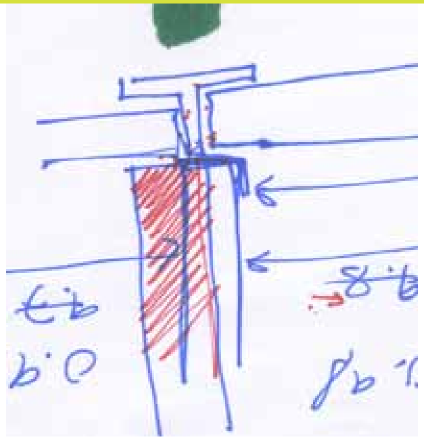
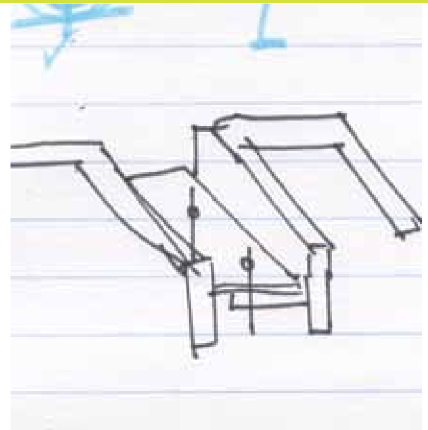













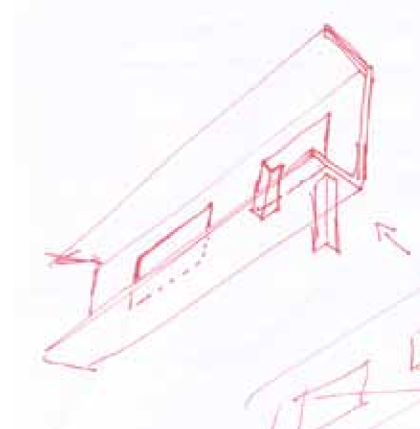
2 DESIGN SCHEMES

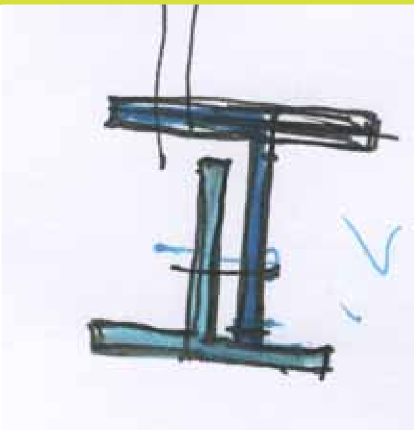
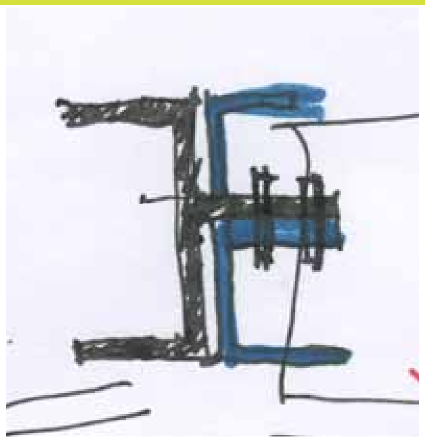
Modular Grid | Connections

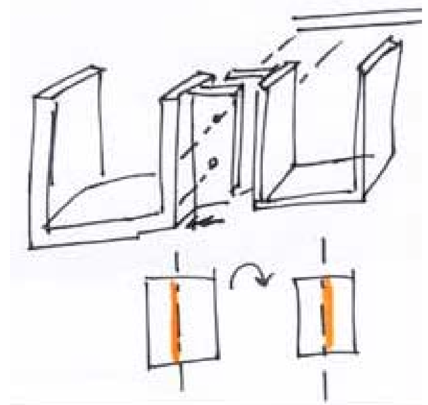
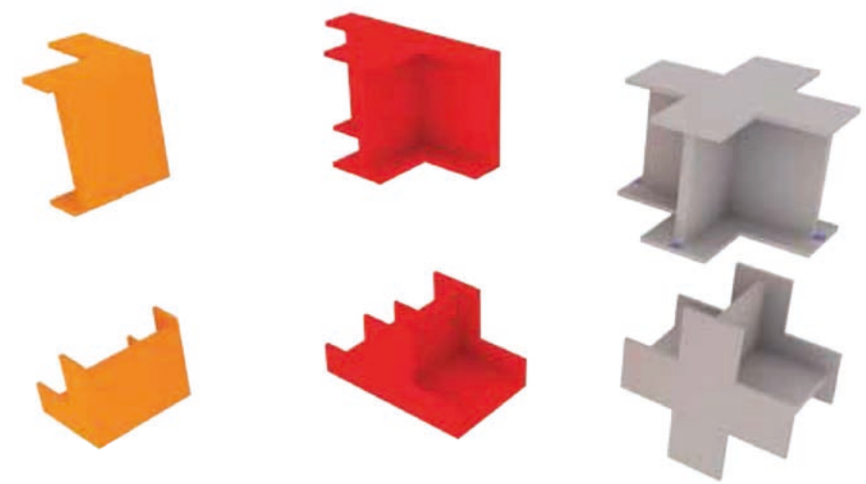
- Charrette Day 1
- Charrette Day 2
- Charrette Day 3
- Charrette Day 4
- Charrette Day 5

By the third day, the team arrived at a series of connection designs that would enclose each square stud on two sides.



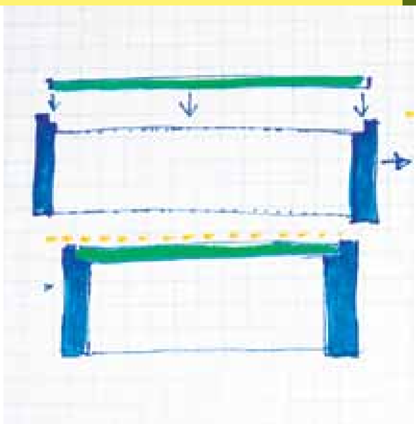
2 DESIGN SCHEMES

Modular Grid | Cladding and Infill

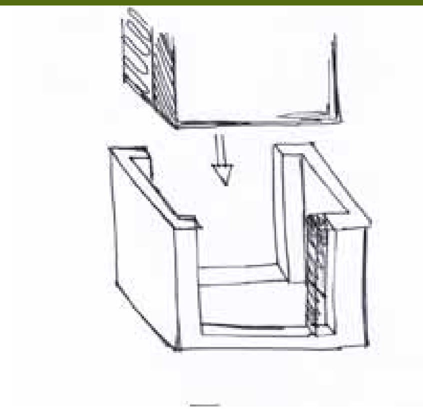
- Charrette Day 1
- Charrette Day 2
- Charrette Day 3
- Charrette Day 4
- Charrette Day 5

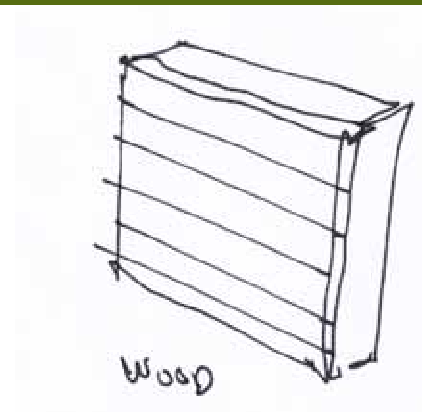
The team also considered how the stud's cladding could sit within or slide into its grooves.

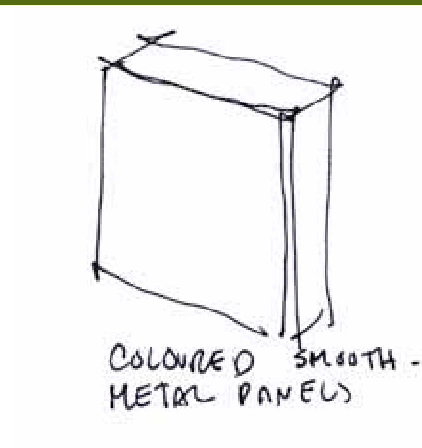
Insulation could comprise of fill using a local material, such as s and or straw.

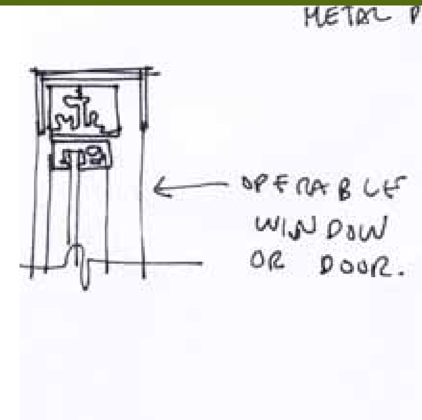


Southern Ontario could employ super insulated walls while Costa Rica would use a porous wall.

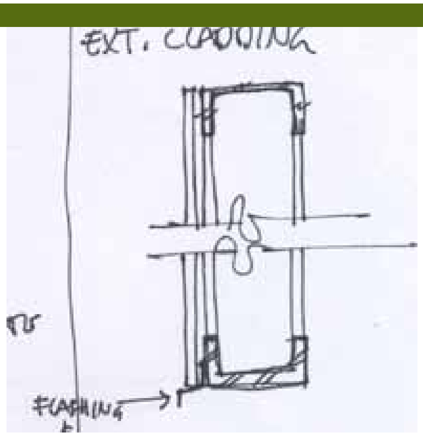


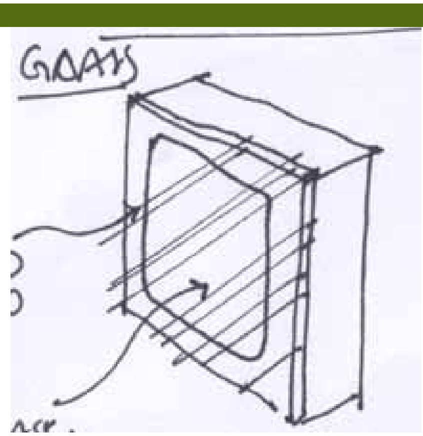


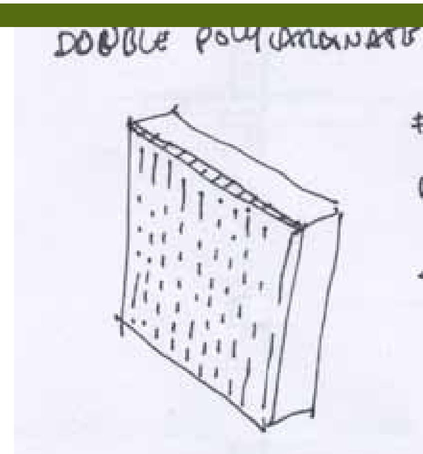


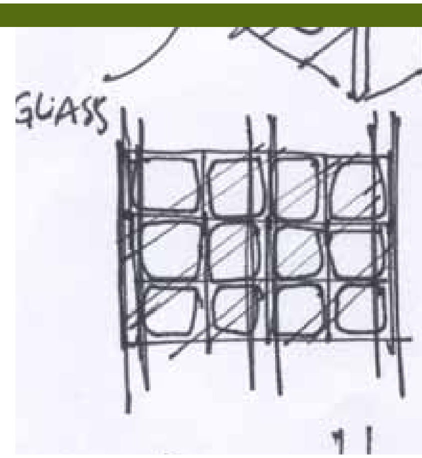


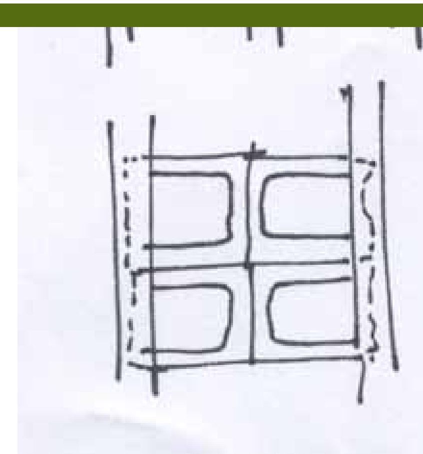
Panels could be sound dampened and finished on both side











Panels could possibility extend to hold a straw bale.

Glazing could exist in voids.

2 DESIGN SCHEMES

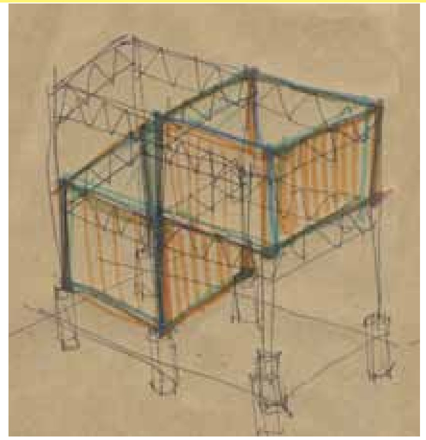
Spatial Frame | Structure

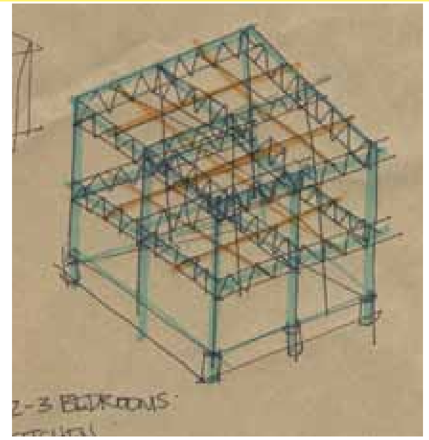
- Charrette Day 1
- Charrette Day 2
- Charrette Day 3
- Charrette Day 4
- Charrette Day 5

Spatial Frame

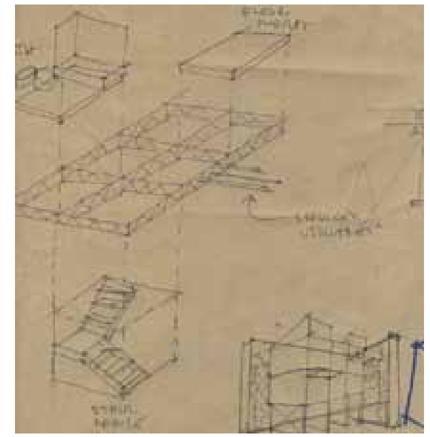
A frame that creates space and hangs a skin and facade

The spatial frame is a variation of the super structure typology. Conventional structural members would come together as repeated forms, with possibility for spatial variation give it modular flexibility for both floor and walls. Its double envelope helps achieve passive heating, cooling and ventilation. The system would ideally incorporate low-tech materials and simple connections to simplify the construction process.

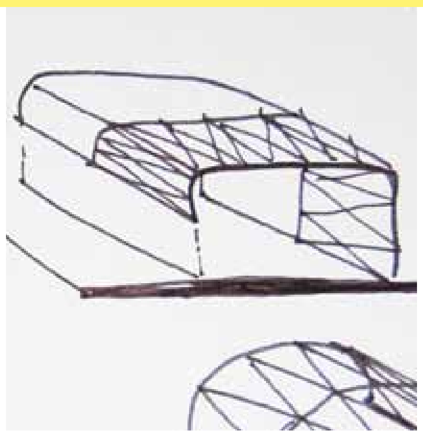




Modularity: In this way, units could slide in and out of the super structure like dresser drawers within a multi-unit complex. Void space could be used as common areas.



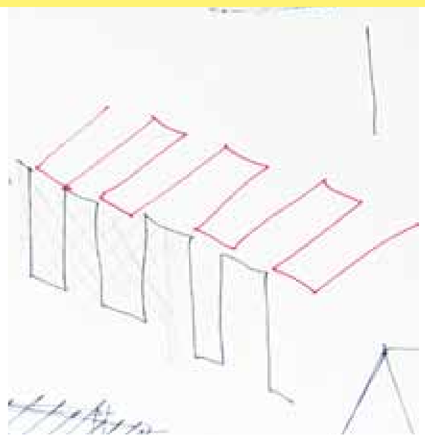
Similarly, modular components of each unit, such as the stairwells, could slide into a frame within the sub structure.

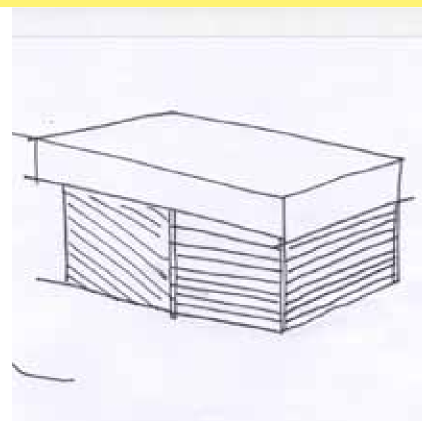


Super Structure: The development of the spatial frame concept was derived from the ‘House in a House’ scheme.

The team experimented with developing a secondary structure that could house a living space.

The two frames, exterior and interior, would work as a unit, although could be structurally independant.





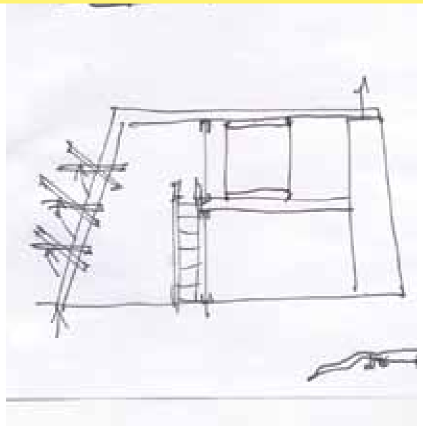
As well, the entire structure could collapse for shipping and unfold on site, using a dovetail connection.

2 DESIGN SCHEMES

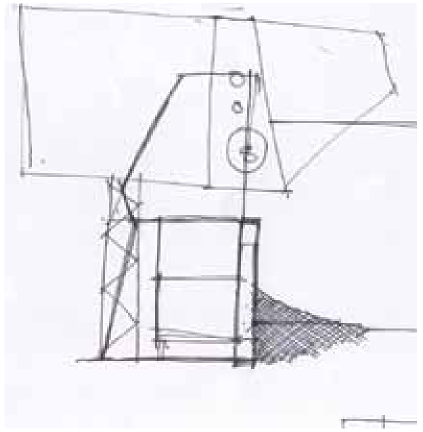
Spatial Frame | Structure

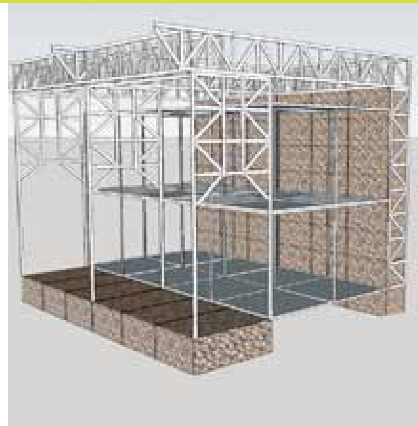
- Charrette Day 1
- Charrette Day 2
- Charrette Day 3
- Charrette Day 4
- Charrette Day 5

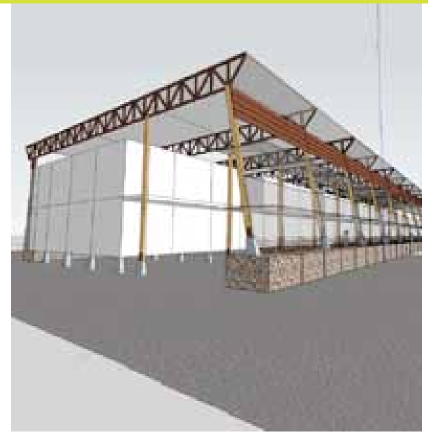
A truss system was explored for roof, wall and floor assemblies.

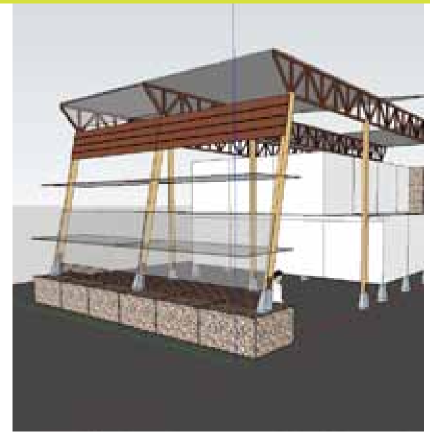


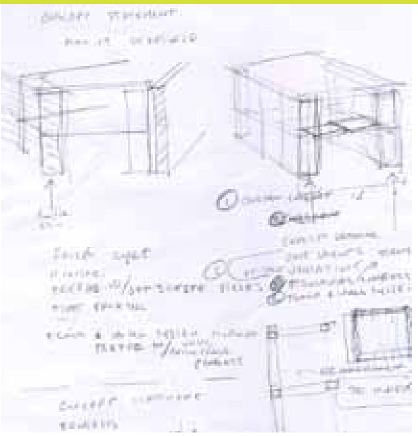
Truss Walkway: This drawing invstigates using a truss column to create an exterior shared hallway.

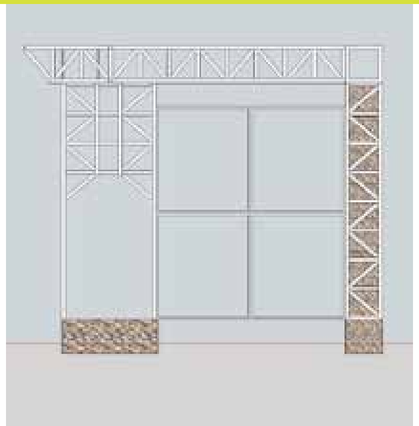




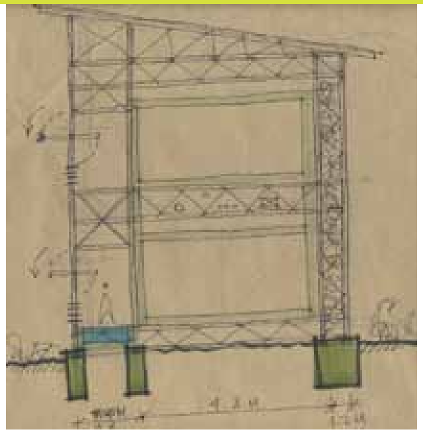




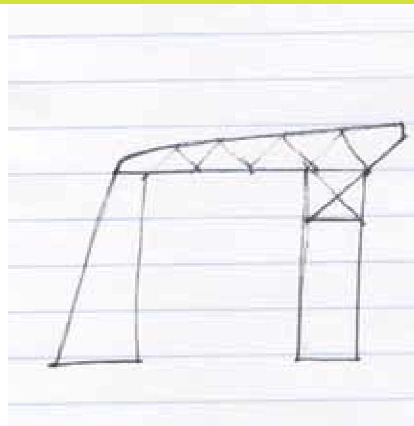


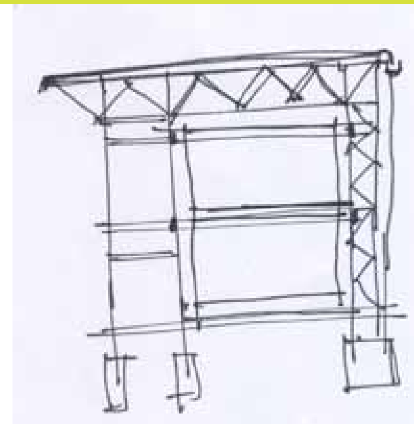


Truss Structure: In this design, the truss is explored as a roof, wall and floor assembly option.



Interior units could hang from the truss super structure using brackets.





2 DESIGN SCHEMES

Spatial Frame | Structure

- Charrette Day 1
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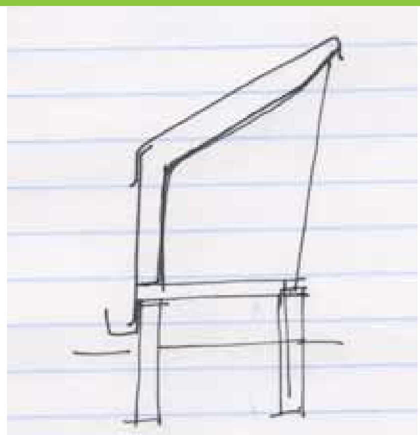
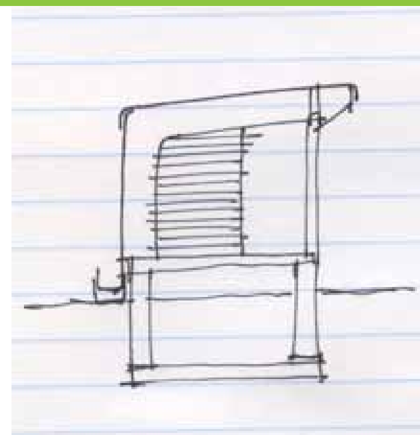
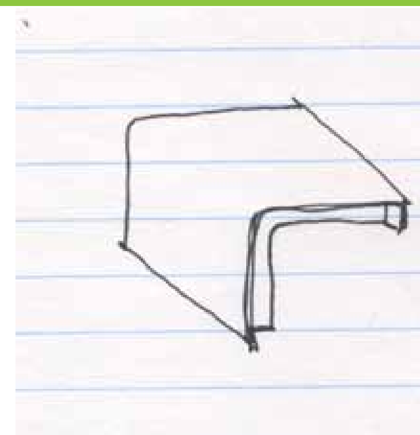
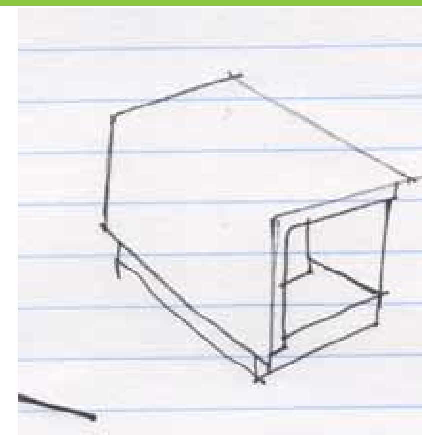
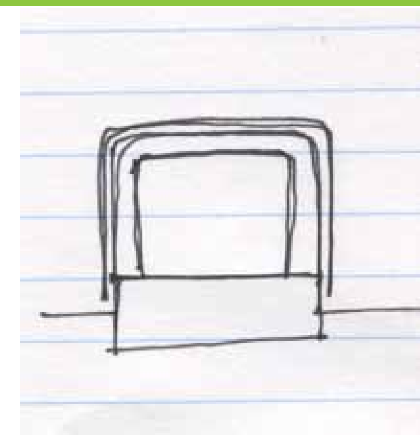
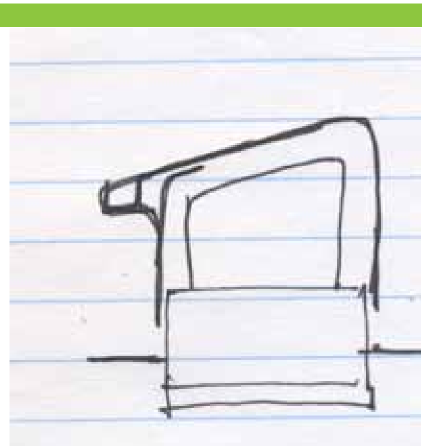
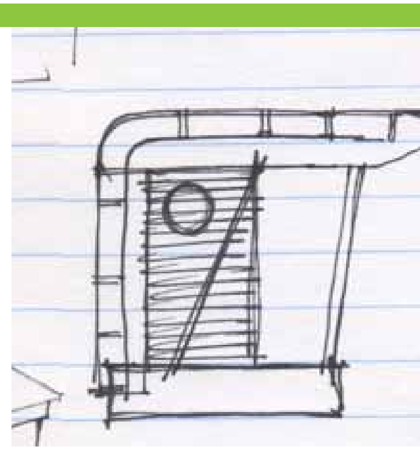
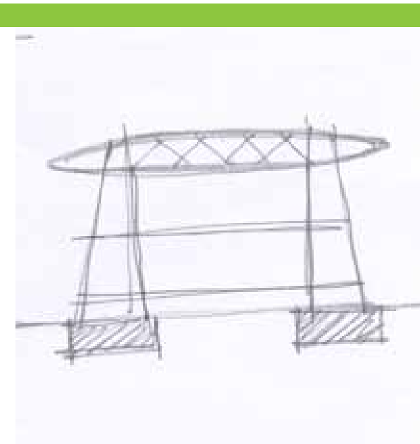
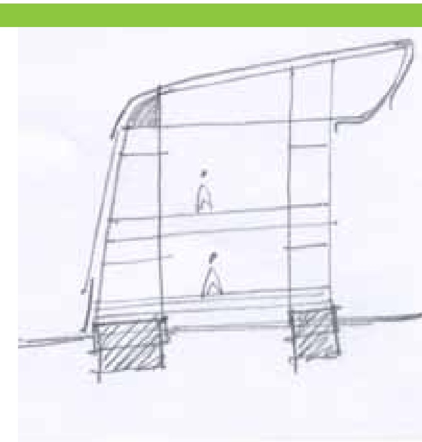


Profile: Different profiles could be tested for performance in strength, weight, material reduction and aerodynamics.

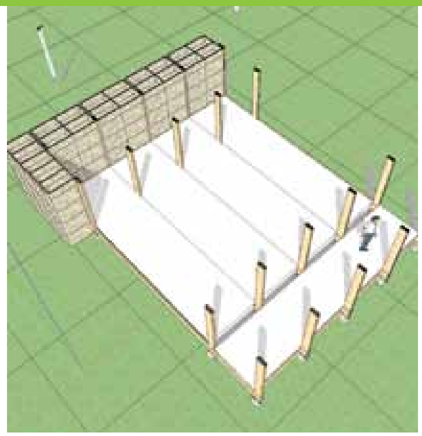

Fabrication: Diverting from standard truss goemetry would require customized manufacturing.

2 DESIGN SCHEMES

Spatial Frame | Structure

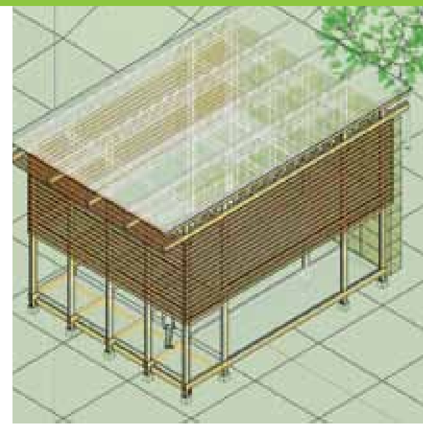
- Charrette Day 1
- Charrette Day 2
- Charrette Day 3
- Charrette Day 4
- Charrette Day 5

By the third day, the integration of the truss was minimalized, and simplified to a post and beam scheme.

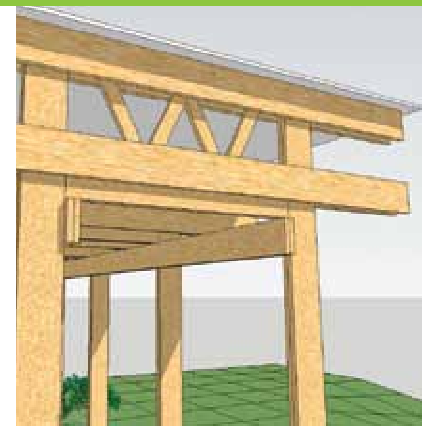


Design Development: In the third day of the charrette, the team simplified the super structure concept by reducing the amount of material used.

The design evolved from a truss-based super structure, to a post and beam frame that could accept any kind of cladding.



Fabrication: This spatial frame could be fabricated using primarily nominal lumber, which would be cheap and available in both regions.



The lumber members would be connected using primarily bolted lap joints with steel brackets and joist hangers.

Foundation: Using a pier foundation would reduce the amount of concrete (compared to slab construction).

Systems: Wooden slats of the outer shell would aid with ventilation while also preventing heat gain from sunlight.

Using nominal lumber would also permt on-site fabrication using a supervised, unskilled labour force.

Comparatively, using steel structural members would likely require premanufactuing off site.

The lumber members could be laminated 2x10" beams.

Dimensions: In this design, the spatial frame is proposed in a 1:5:1 ratio - where the first 4' areas forms a shared corridor, the second 20' serves as private living space, and the last 4' as a service corridor for utilities (water, heating and cooling).

2 DESIGN SCHEMES

Spatial Frame | Structure

- Charrette Day 1
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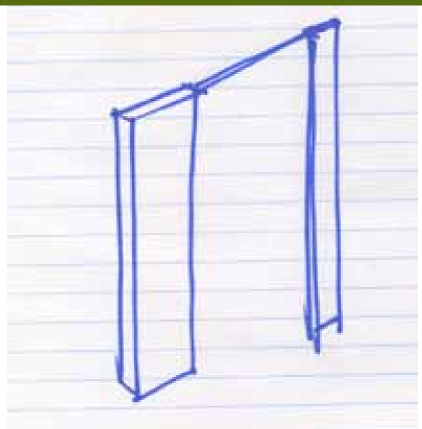
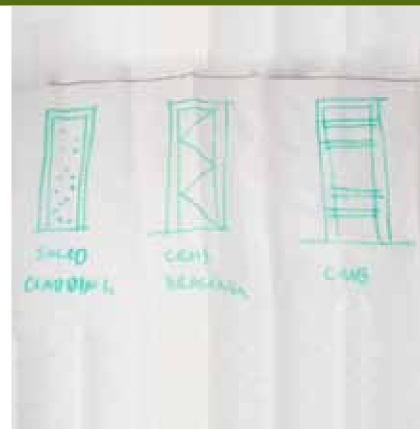
This scheme was further simplified on the fourth day, to a crib system that inherently provides a double skin or double envelope.

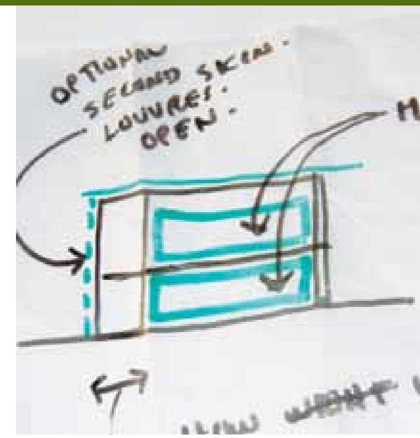


Design Development: On the fourth day, following the second review, the team proceede to integrate the post and beam frame with the modular grid.

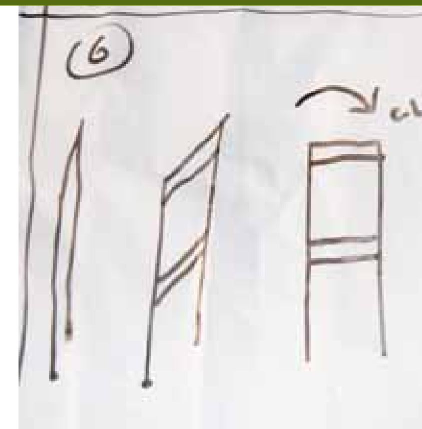
The spatial frame was developed as another modular component - the elements of which would include dimensioned structural members.



The structure's basic elements could comprise of solid members, truss members or crib members.

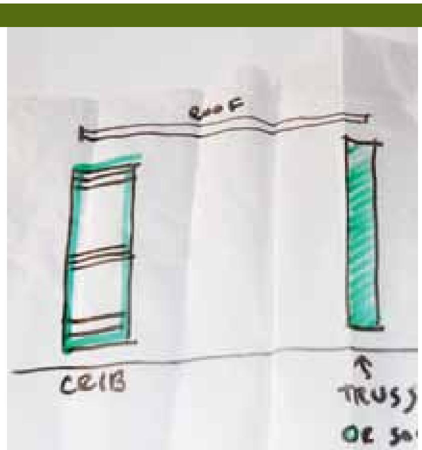


The corridor could be left open, with wooden slats or a green wall for partial protection; or, could be closed with a second skin, such as operable windows.



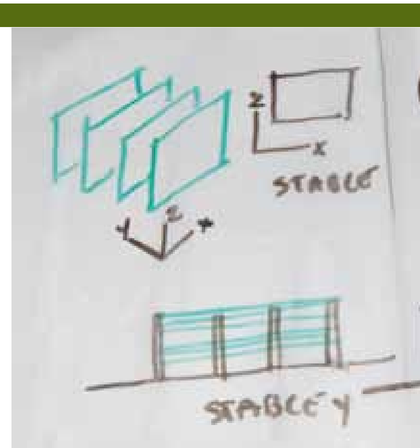
The structural members could be preattached and click into place on site.

Or, the components could be attached individually on site.

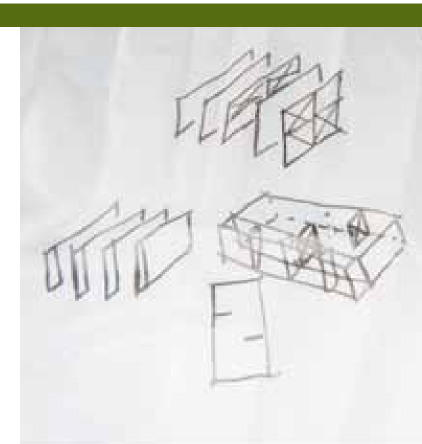


The structure's front element could comprise of a crib component, while the back could comprise of a truss structure.

When aligned in parallel, a living space is defined, with a corridor at the front, and space for a gabion wall or air pocket at the back. Inherent in this is a double skin.



The final result would be a double envelope or double skin structure, that comprises of multiple crib components placed incrementally.



2 DESIGN SCHEMES
Spatial Frame | Structure

- Charrette Day 1
- Charrette Day 2
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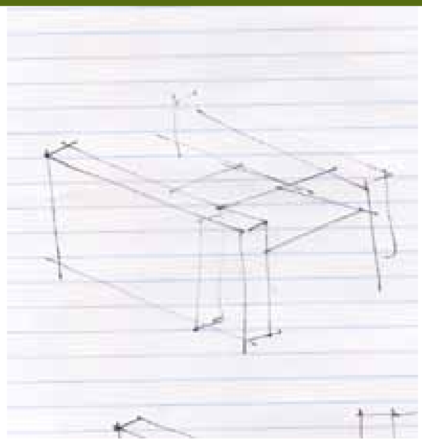
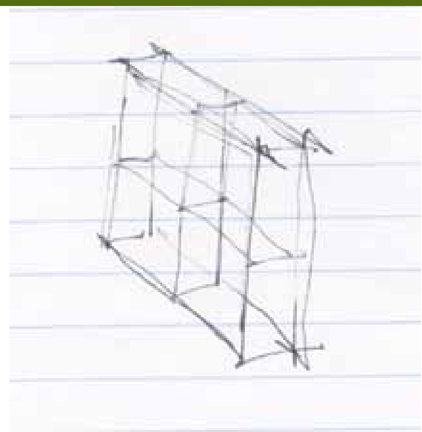
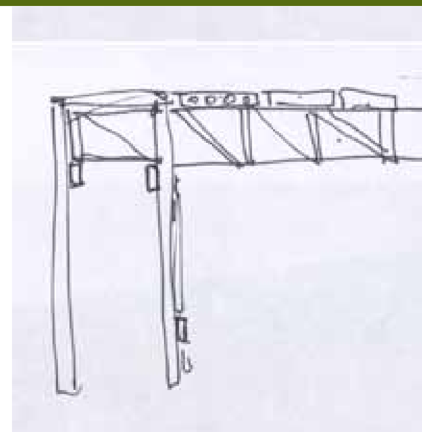
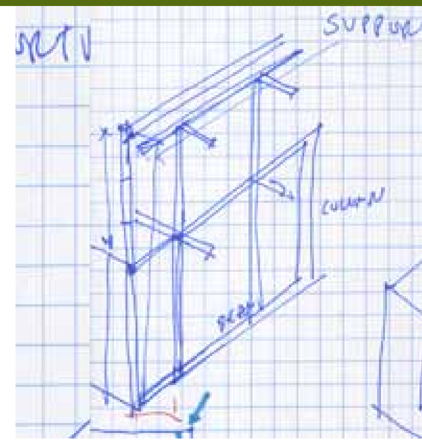
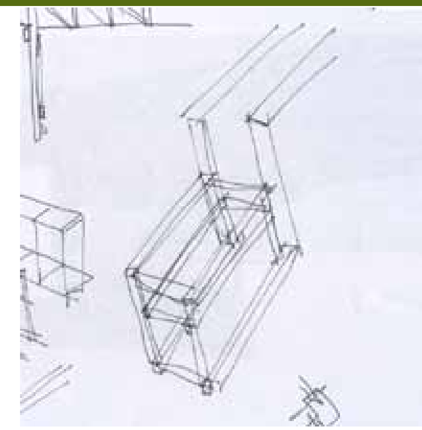
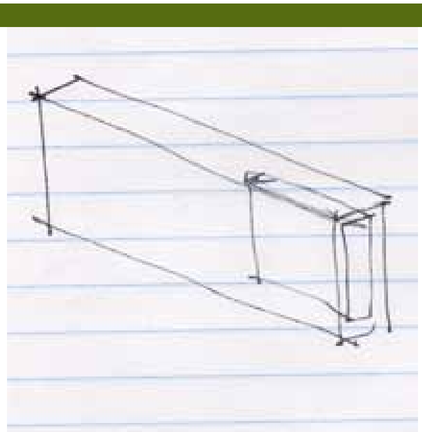
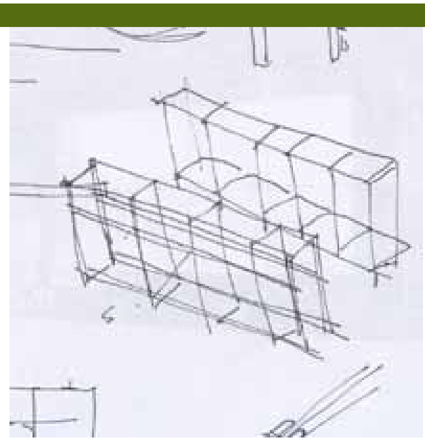
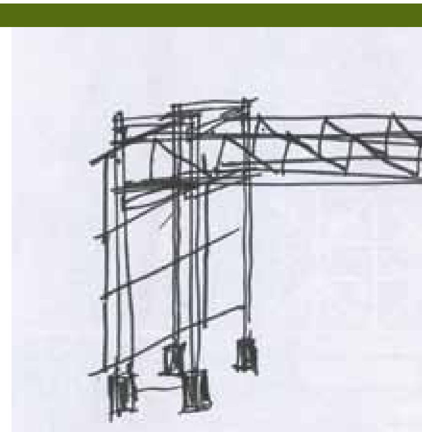
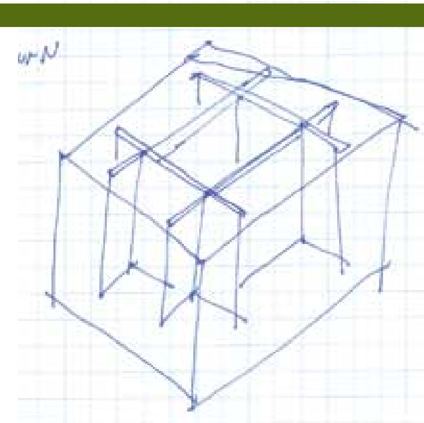
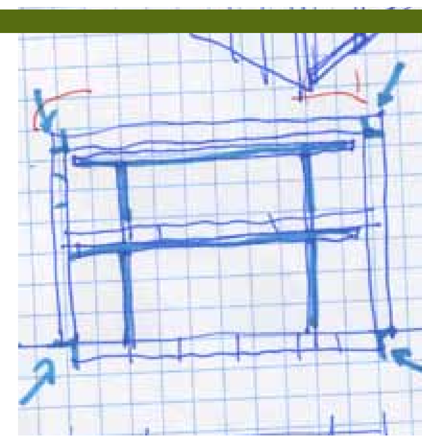
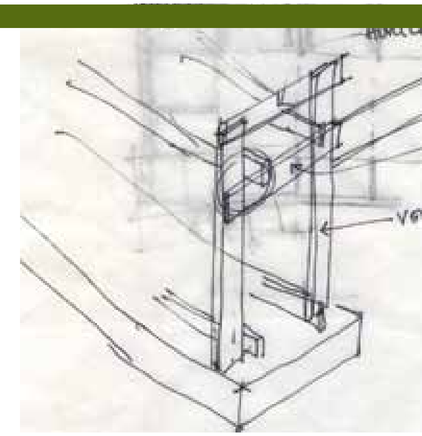
- Charrette Day 5

2 DESIGN SCHEMES

Spatial Frame | Structure

- Charrette Day 1
- Charrette Day 2
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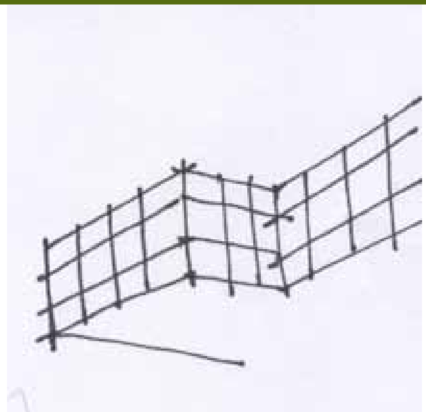
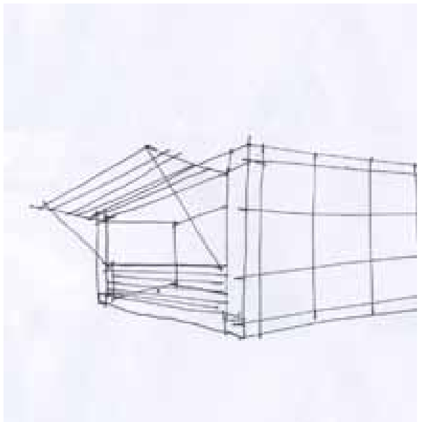
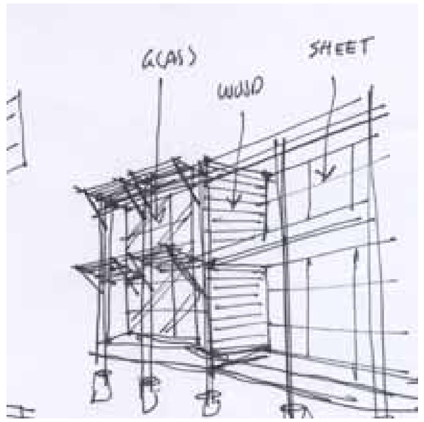
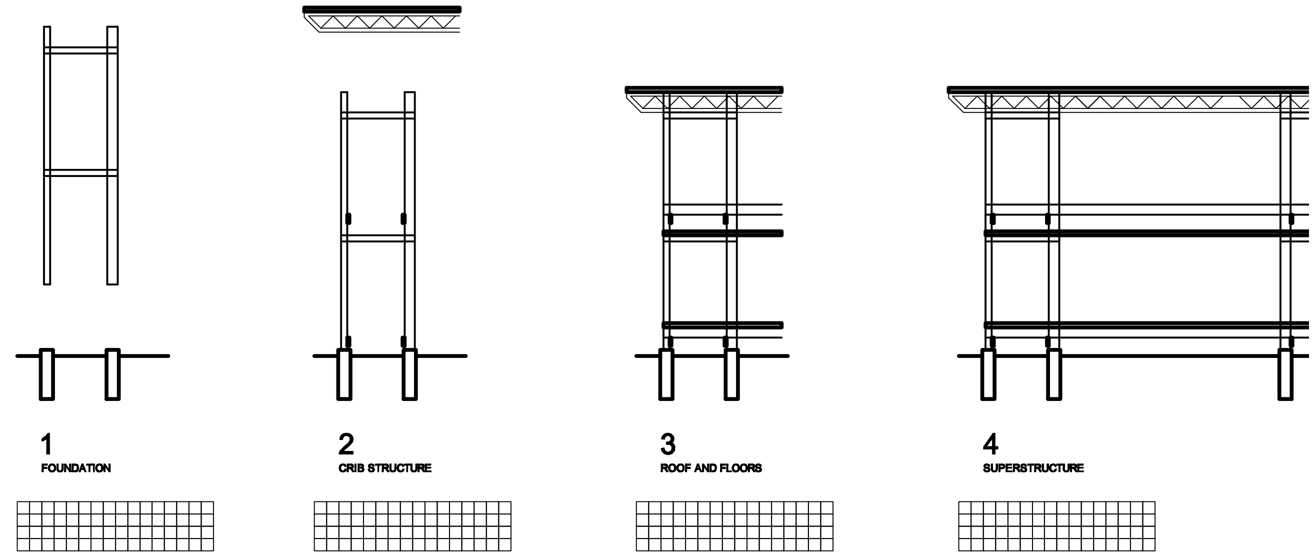
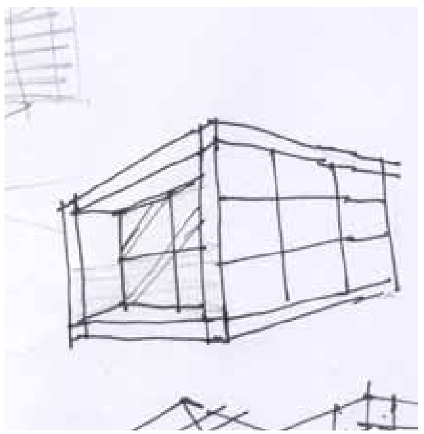


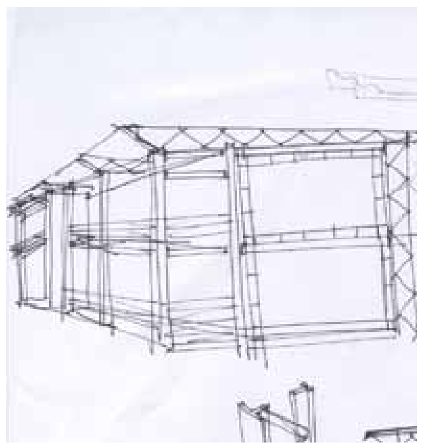


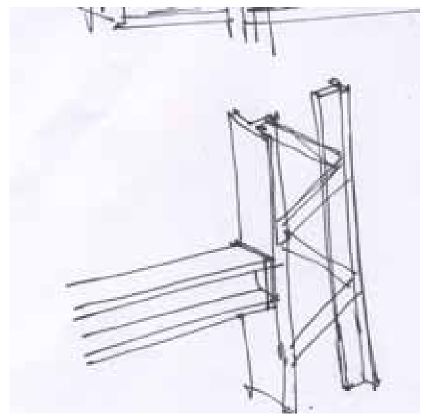


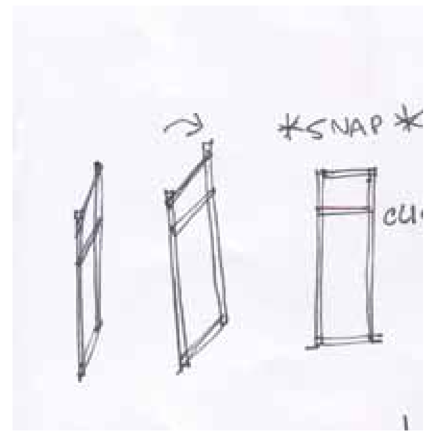


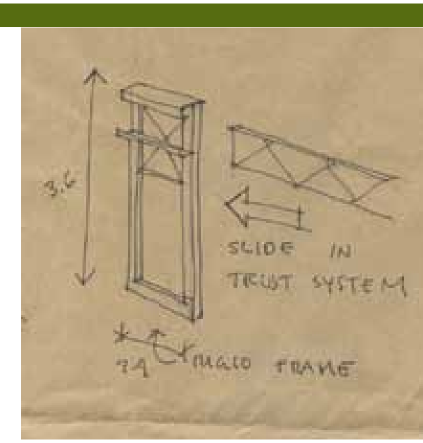
The structural crib would offer rigidity











2 DESIGN SCHEMES

Spatial Frame | Schematics

- Charrette Day 1
- Charrette Day 2
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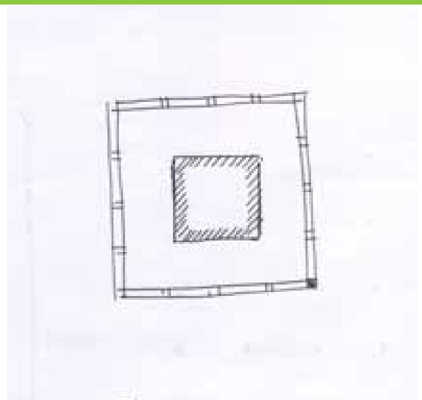
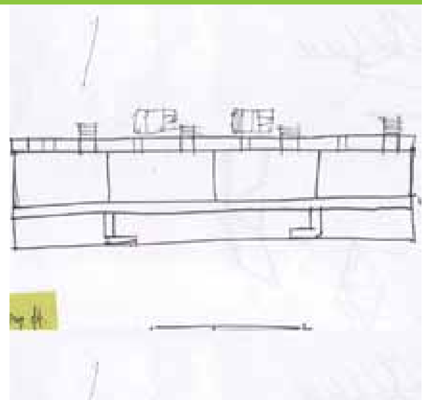
This spatial frame structure was well suited to vertical expansion.

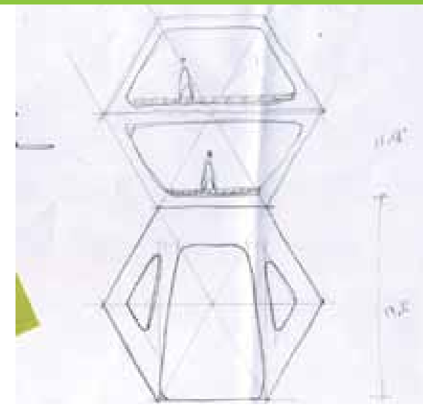


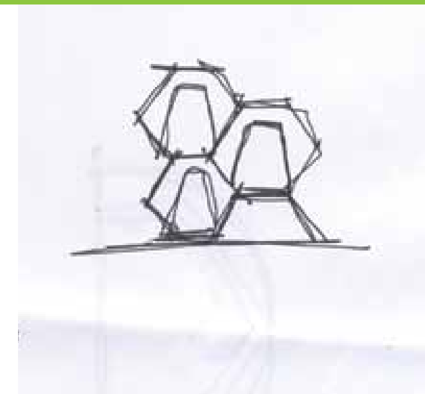
House in House: From the ‘House in a House’ scheme naturally follows the creation of private, semi private and public space.



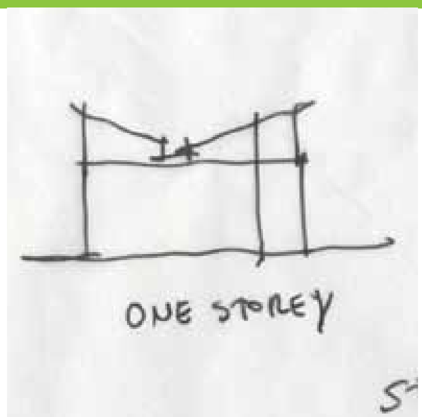
Site Clustering: In this schematic, the semi-private space is clustered as a walkway on one end, while parking and utilities are grouped on the other.

Alternatively, angled units that are cut on a 45 degree angle could serve as shared spaces, such as laundry; and, also permit a curved site plan.

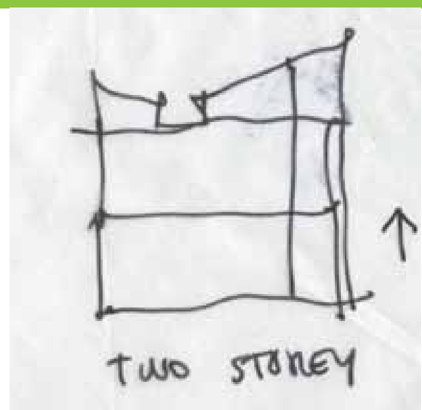




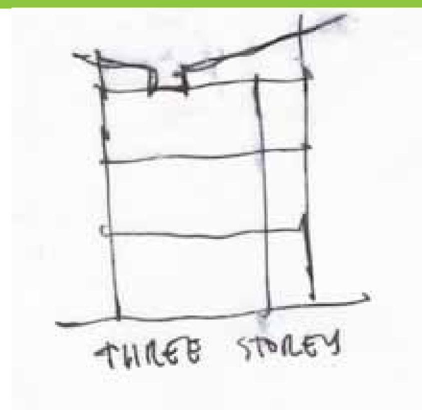
Alternatively, the hexagon is another efficient structural form that also lends well to stacking.



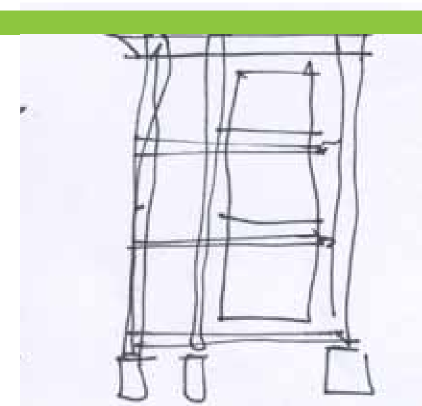
Stacking: If the interior modules were structurally indepedent from the frame, the complex could grow in vertial increments over time.



New storeys could be added simply by raising and removing the super strcuture’s roof.



The super structure would expand vertically, and the new units could be attached using brackets.



2 DESIGN SCHEMES
Spatial Frame | Schematics

- Charrette Day 1
- Charrette Day 2
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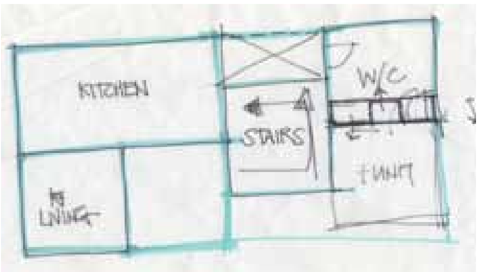
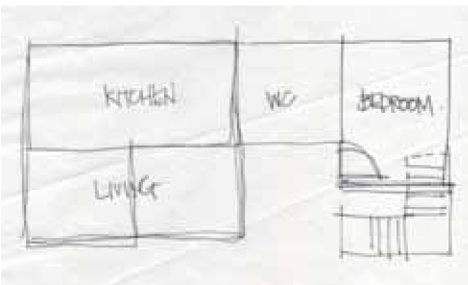
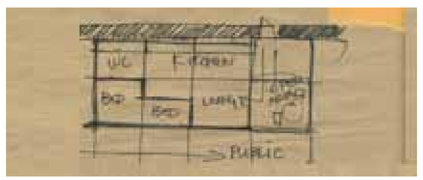
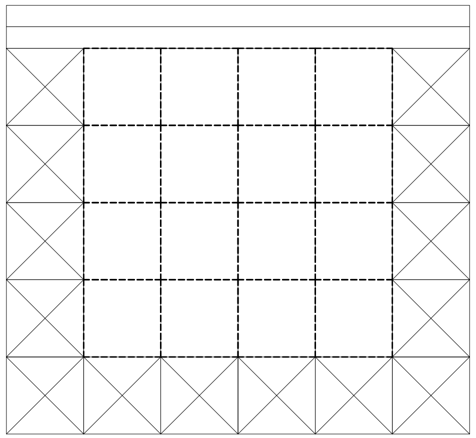
- Charrette Day 5

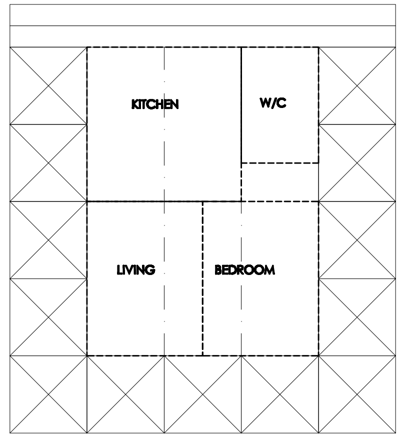
It could also follow a grid-based floorplan.



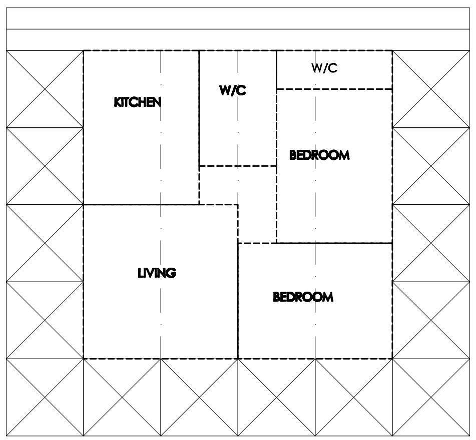




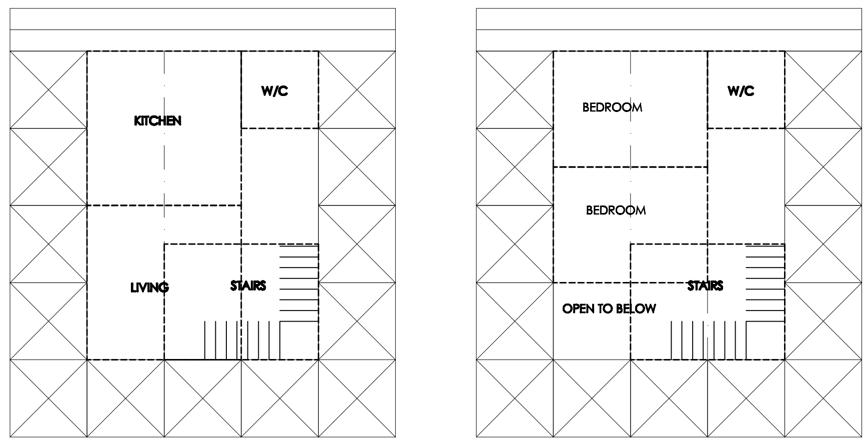




1 Bedroom, Single Storey



2 Bedroom, Single Storey



2 Bedroom, Double Storey

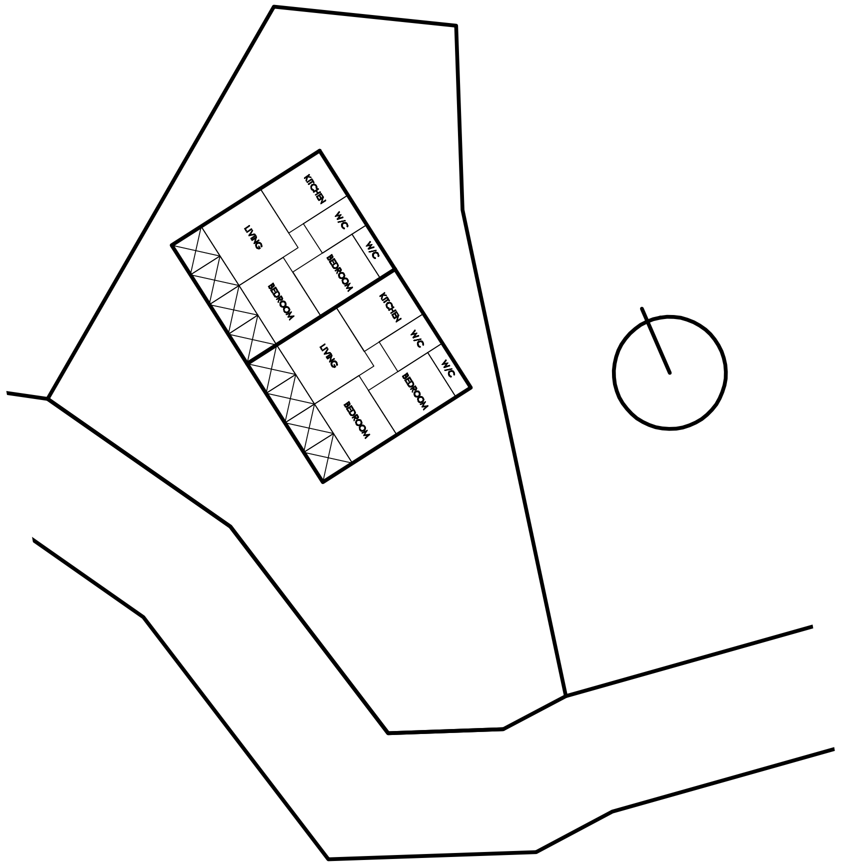
Unit Plans: The unit floorplans could also be derived from a geometric grid (this drawing uses a 2x2m base unit). In these drawings the division lines represent how the space could be organized by function within a primarily open concept plan (the lines are not intended to indicate walls, necessarily).

Services: The focus of this schematic exploration was mainly to group the wet services along one wall.

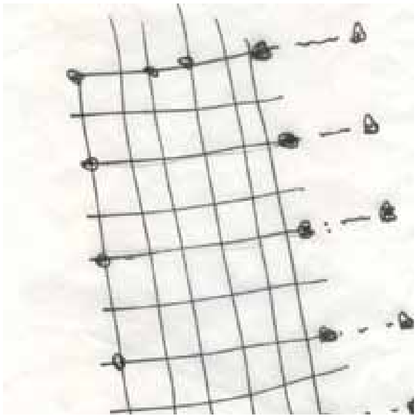
2 DESIGN SCHEMES

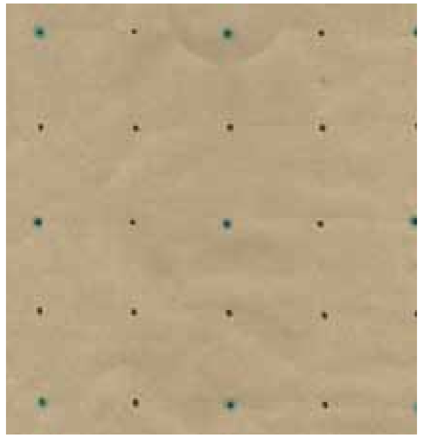
Spatial Frame | Schematics

- Charrette Day 1
- Charrette Day 2
- Charrette Day 3
- Charrette Day 4
- Charrette Day 5



Site Plan: Units are clusterd here on the Guanacaste site with their service walls running along the back.



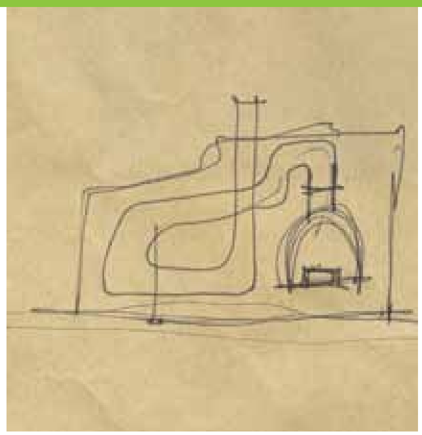


Unit Plan: On the fourth day of the charrette, the team revised the frame sys-tem to fit within the same dimensions as the modular grid. The team began with the dimension of 5x10m.

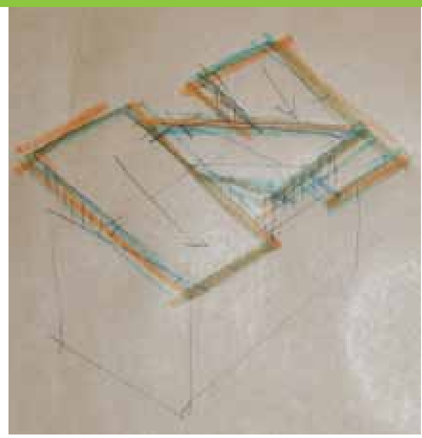
2 DESIGN SCHEMES

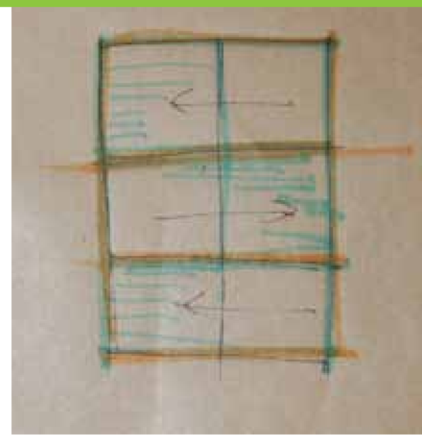
Spatial Frame | Systems

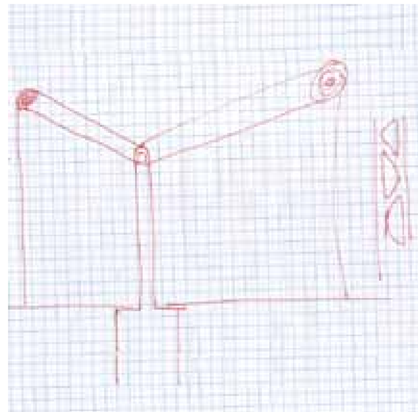
- Charrette Day 1
- Charrette Day 2
- Charrette Day 3
- Charrette Day 4
- Charrette Day 5

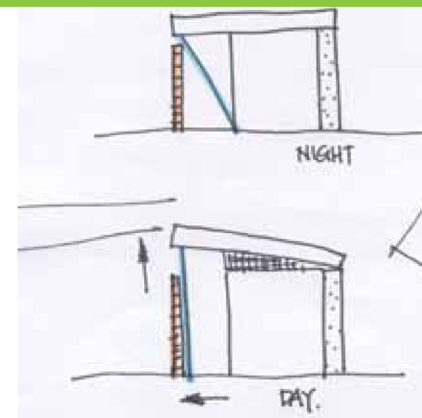


Masonry Heater: Masonry heaters are highly efficent stone fireplaces that use thermal mass to retain and emit heat for long periods of time.

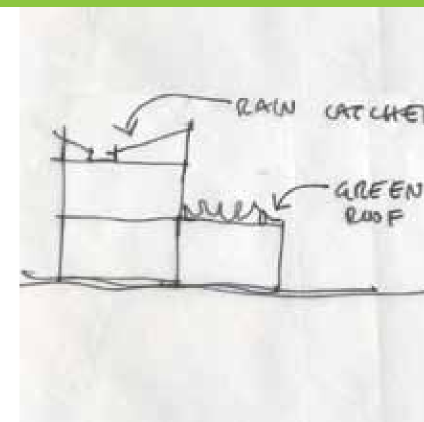






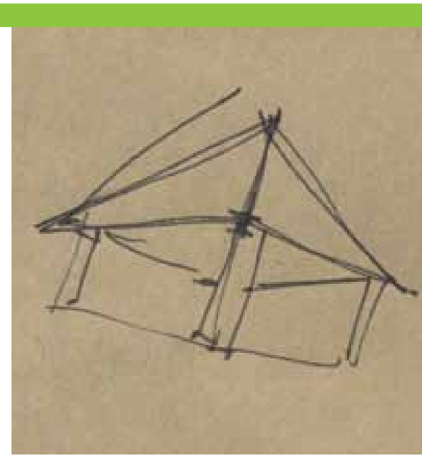


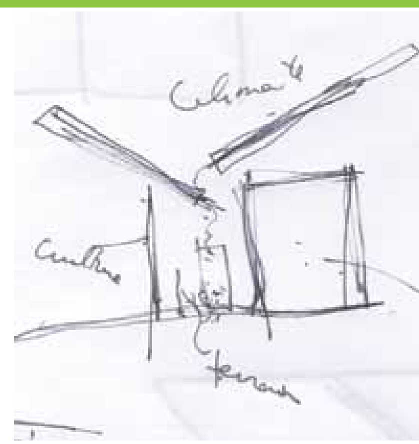
Roof: The roof could be raised and lowered daily or seasonally, to suit the desired ventilation strategy, and to keep out mosquitos.

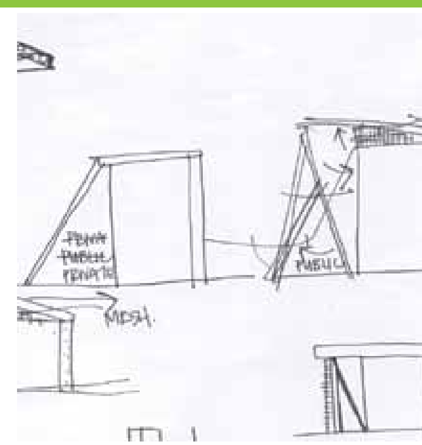


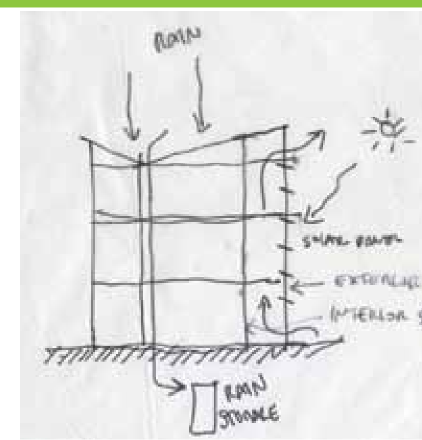
Water Collection: The roof could be angled to catch rainwater.

The water could be directed into an indoor cistern.





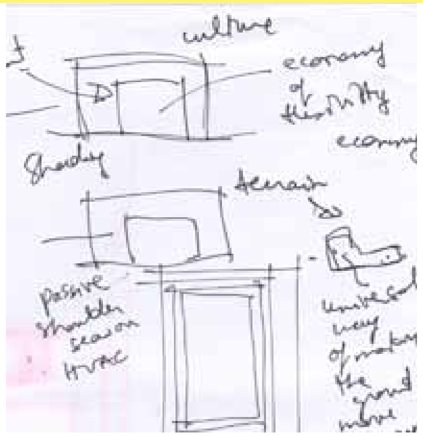




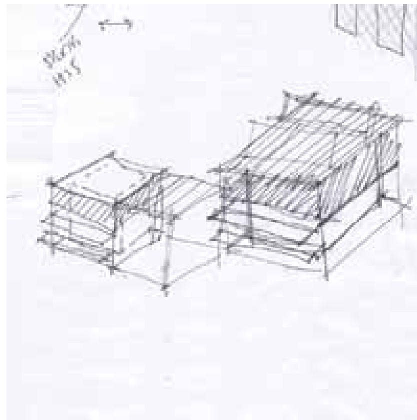
2 DESIGN SCHEMES

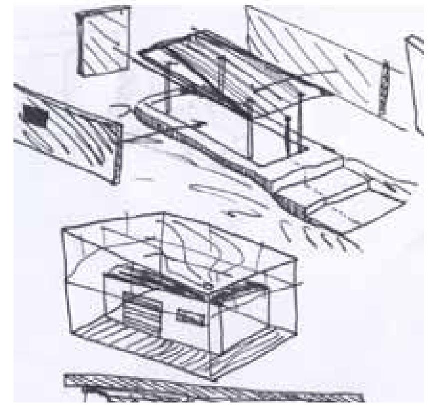
Spatial Frame | Systems

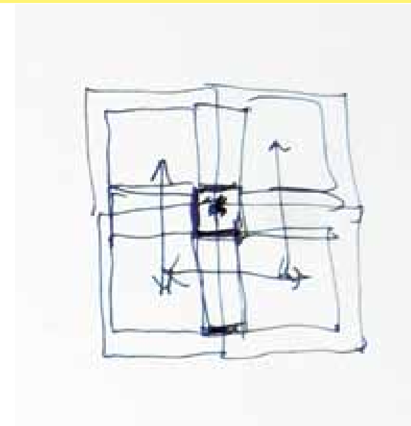
- Charrette Day 1
- Charrette Day 2
- Charrette Day 3
- Charrette Day 4
- Charrette Day 5

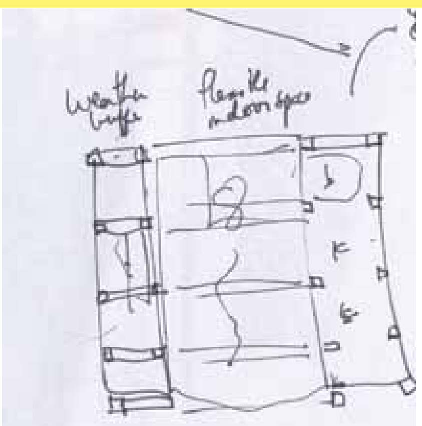


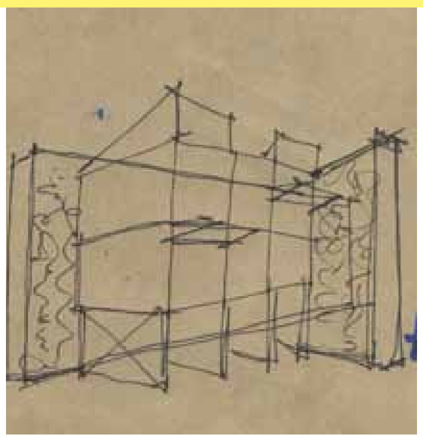
The gabion wall could be site specific and would add a social element to the design. it would also add thermal mass.



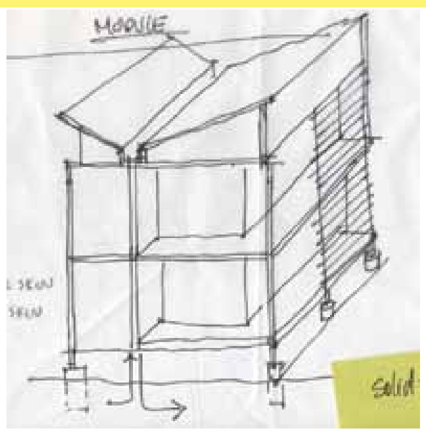




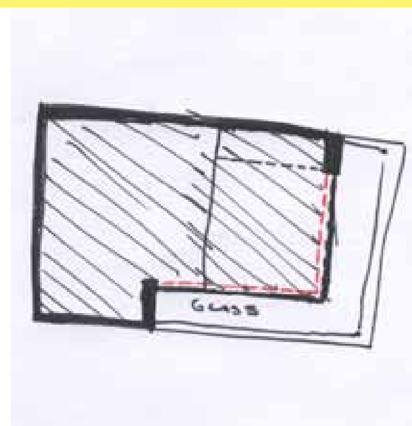


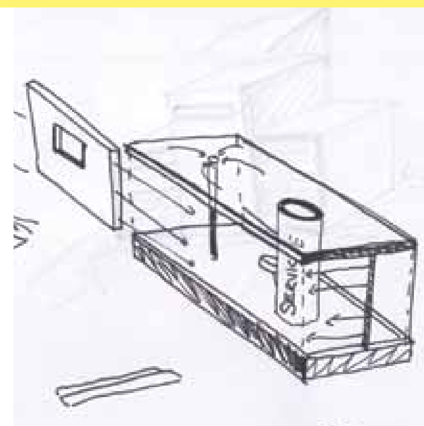


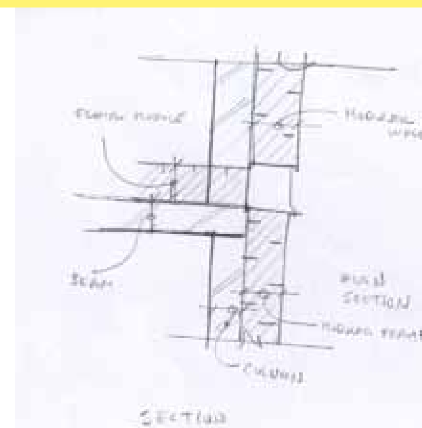
Passive Heating: A green wall or earth wall could be placed along the back and side of the unit to act as a thermal mass.



Passive Cooling: Exterior wood slats could assist with air flow, while pre-venting heat gain from sunlight.



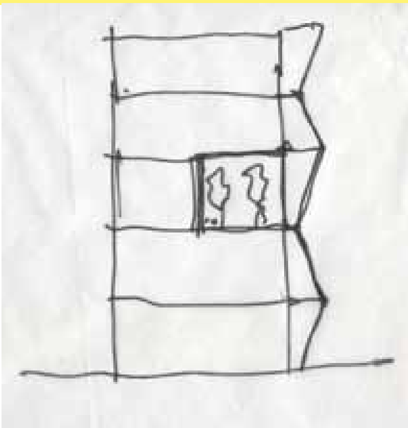


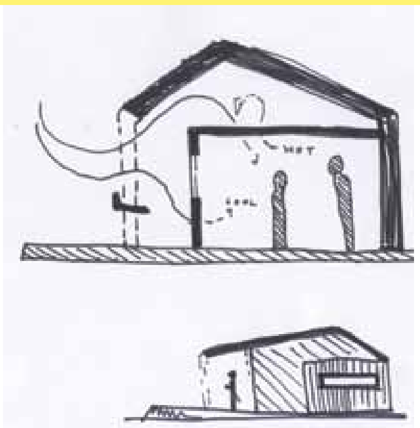


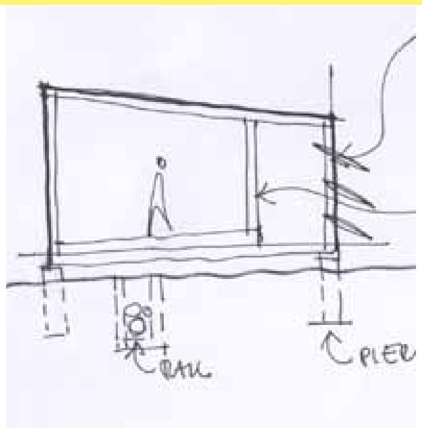
2 DESIGN SCHEMES

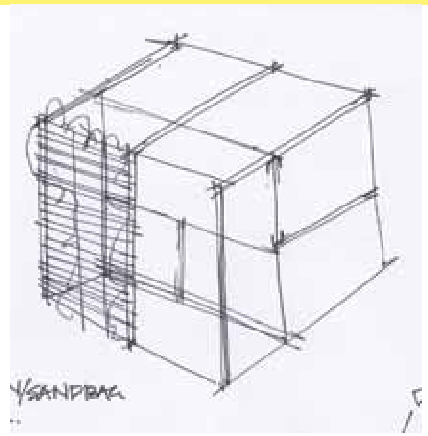
Spatial Frame | Systems

- Charrette Day 1
- Charrette Day 2
- Charrette Day 3
- Charrette Day 4
- Charrette Day 5

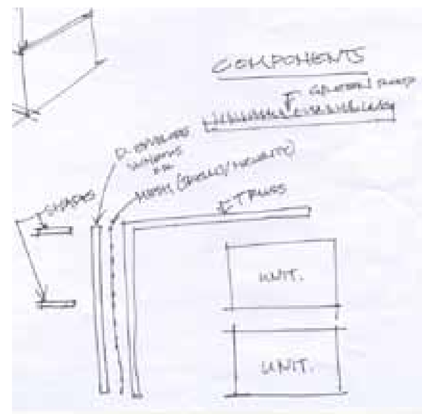




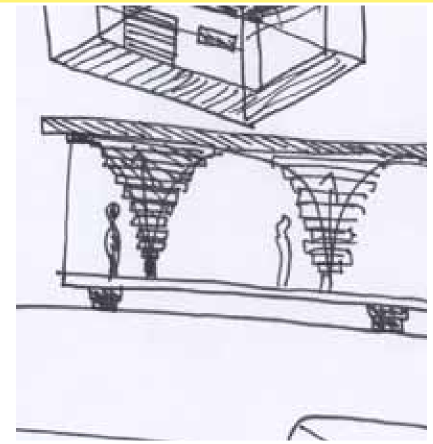


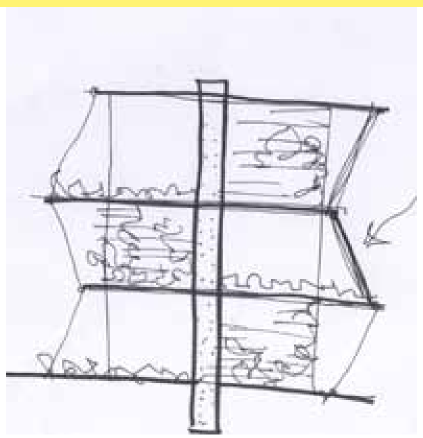


Passive Cooling: Use of a lattice structure in Costa Rica could turn the front facade into a living wall.

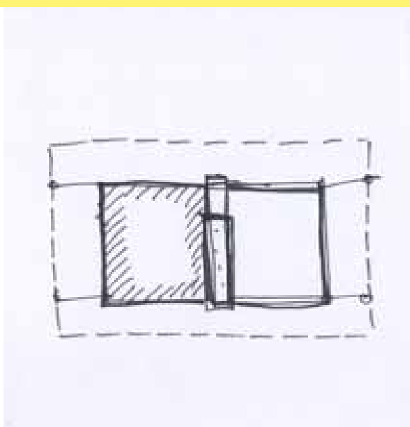


Together, the complete system could include a super structure, modular living units, shades, louvres, a green roof and a lattice.

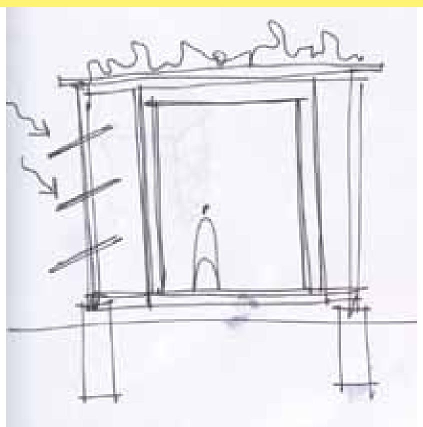


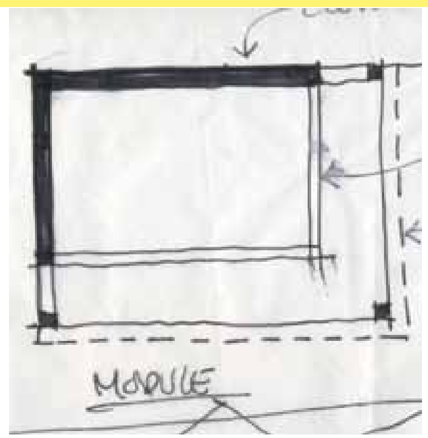


Units could be stacked around a central core.

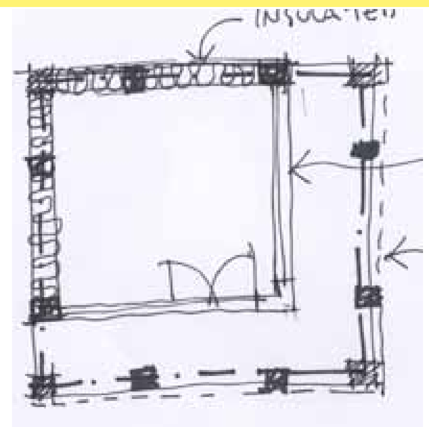


Within each unit, the side that is op-posite to the core could form a patio or balcony space.

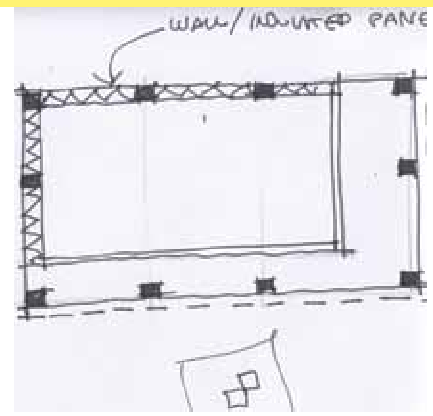




Passive Heating: A curtain wall in front could increase sun exposure in the winter months.



Wrapping the curtain wall around the end units would produce an extra semi-private space that could be used as one unit’s patio, adjacent to the public corridor.



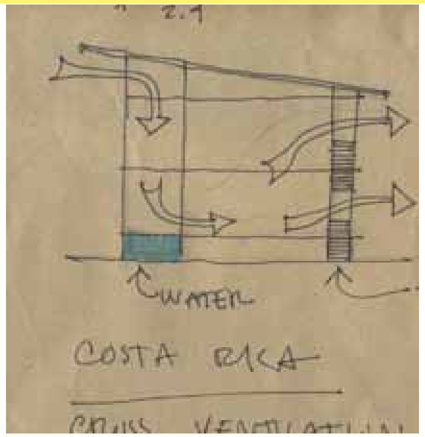
Alternatively, all units could be wrapped with this extra exterior patio.

2 DESIGN SCHEMES

Spatial Frame | Systems

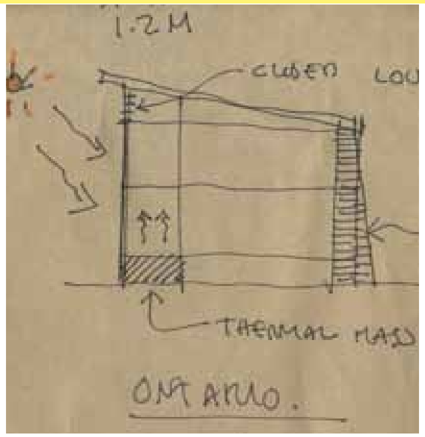
- Charrette Day 1
- Charrette Day 2
- Charrette Day 3
- Charrette Day 4
- Charrette Day 5

Site work should be limited to foundations and connections to services.

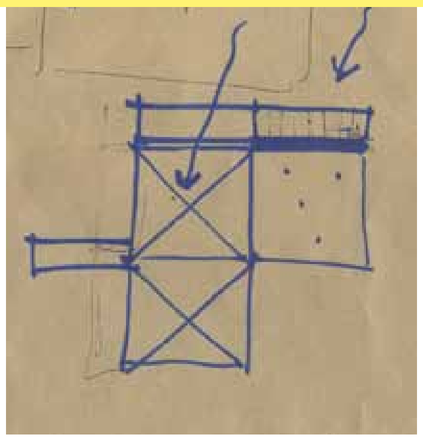


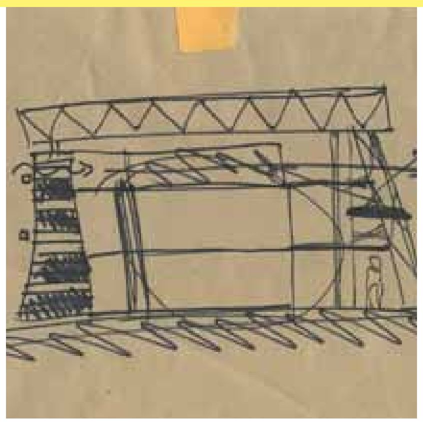
Passive Cooling: In Costa Rica, a water pool could be placed under the walkway to cool water passing through the Gabion wall.

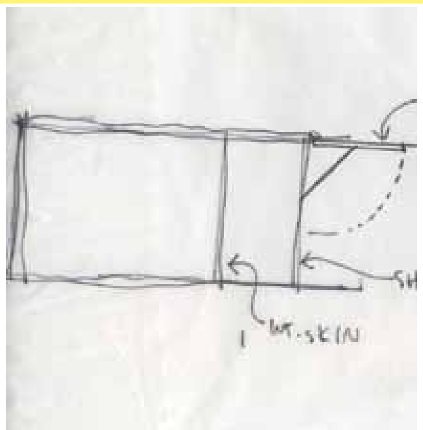
Plant material could also cool and filter the air as it passes through.

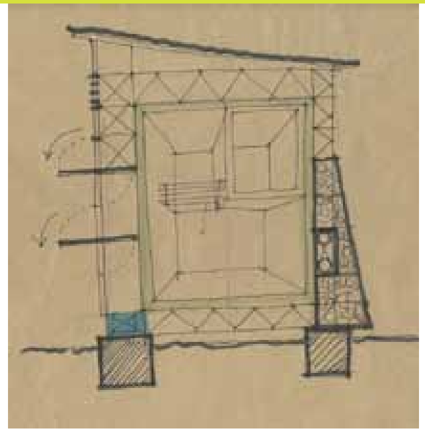


Passive Heating: The gabion wall would also act as a thermal mass to absorb heat from the sun in the Southern Ontario winter.

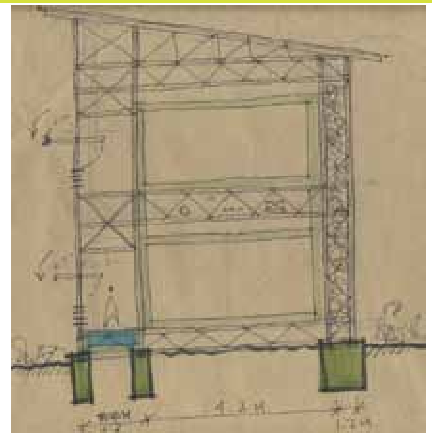




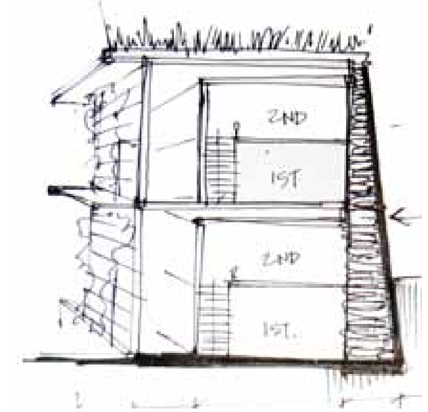




A canopy of louvres could be used to manage ventilation and sun exposure.

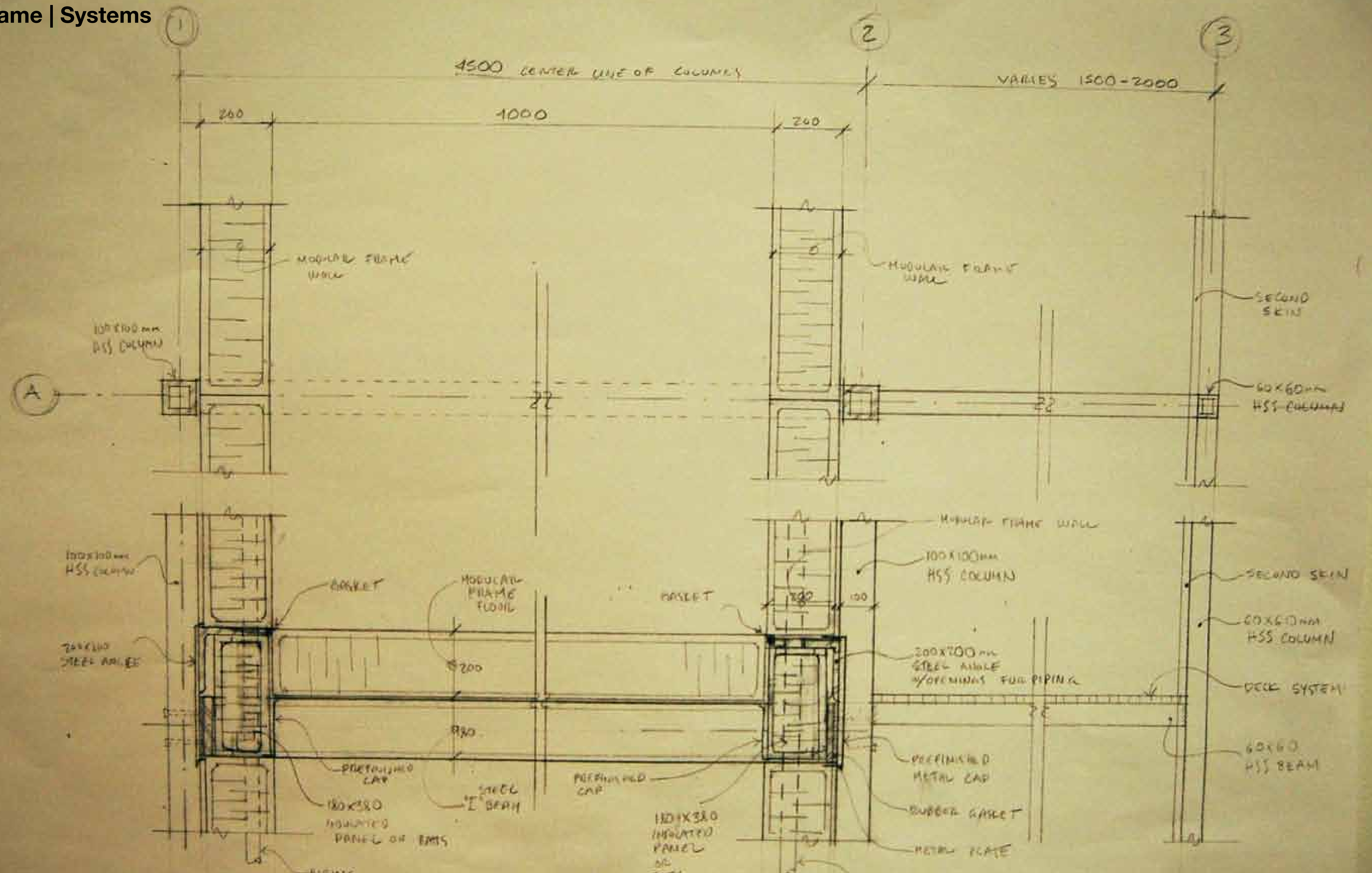


The double skin would act as a weather buffer.



2 DESIGN SCHEMES

Spatial Frame | Systems



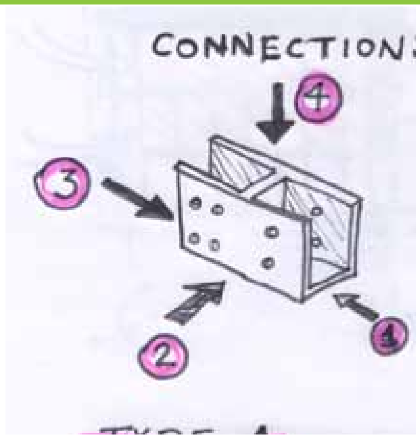
2 DESIGN SCHEMES

Spatial Frame | Connections

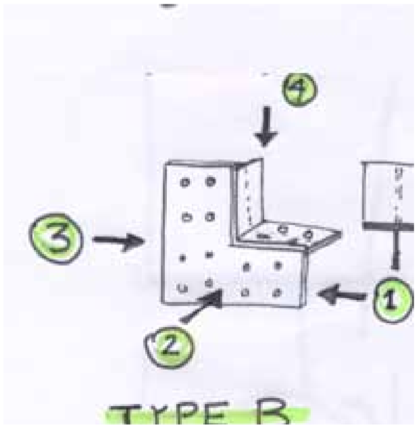
- Charrette Day 1
- Charrette Day 2
- Charrette Day 3
- Charrette Day 4
- Charrette Day 5

These connections are based on the concept of a beam splice – a device used in when two shorter steel members are joined. Connecting two steel members using a gusset plate, a splice plate and bolts is a common practice that is widely accepted in the steel industry. These connections are typically designed to withstand a force of approximately 100 kilopounds (100,000 lbs).

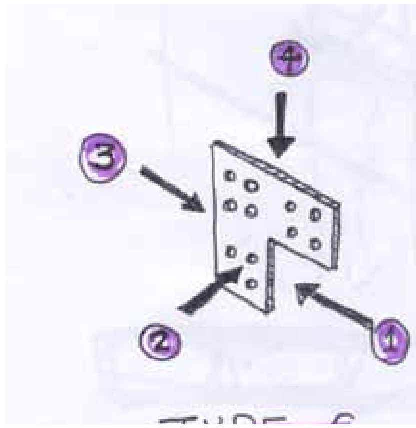
There are a number of forces (stresses) (and safety factors) that could act on the splice, including: material dead loads, live loads 40 lbs/sq ft and environmental factors, such as wind.



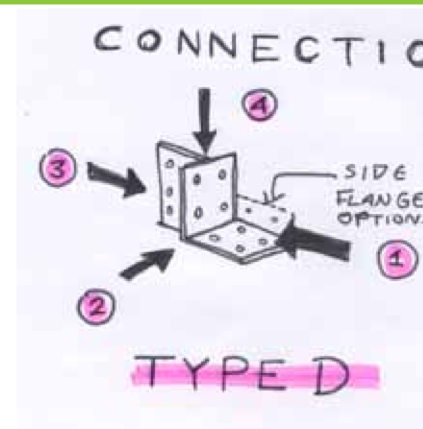
Connections, Type A: Connections could be modified on site as needed.



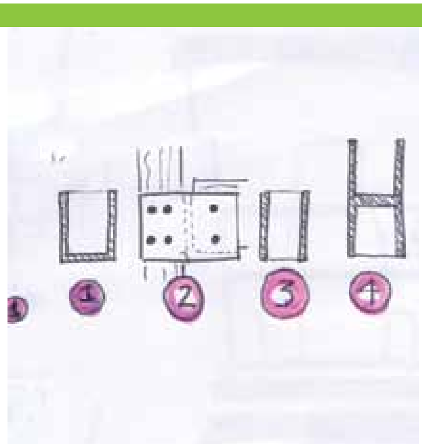
Connections, Type B: This type of connection would require a bolt/screw template.



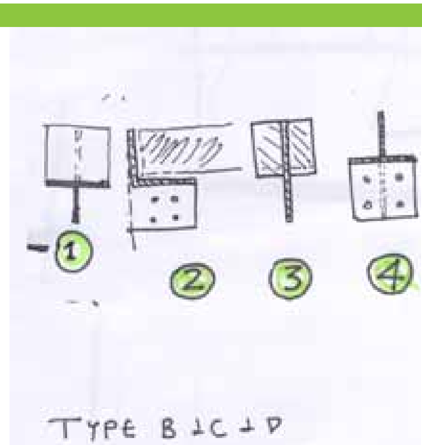
Connections, Type C: This type of connection would require a bolt/screw template.



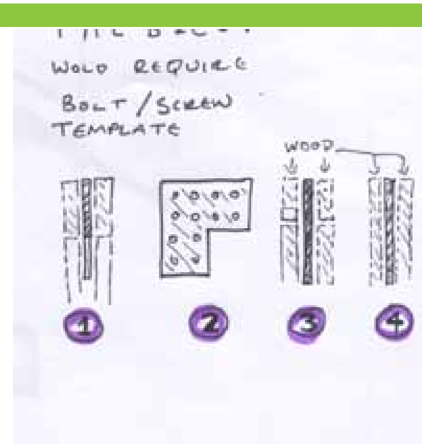
Connections, Type D: This type of connection would require a bolt/screw template.



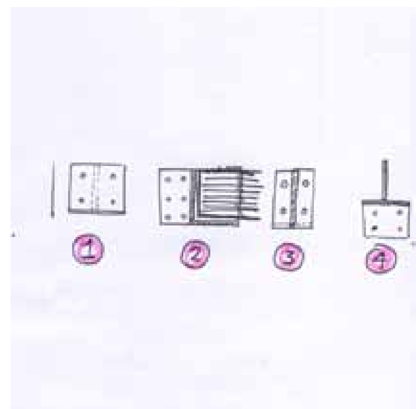
Connections, Type A



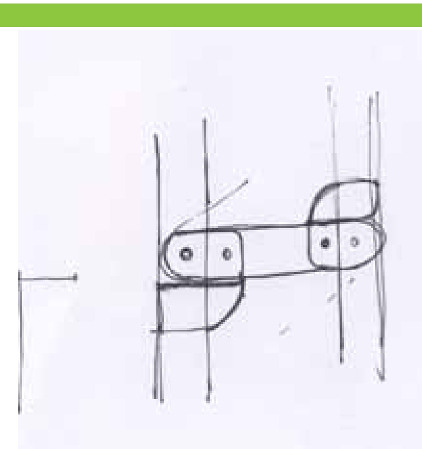
Connections, Type B

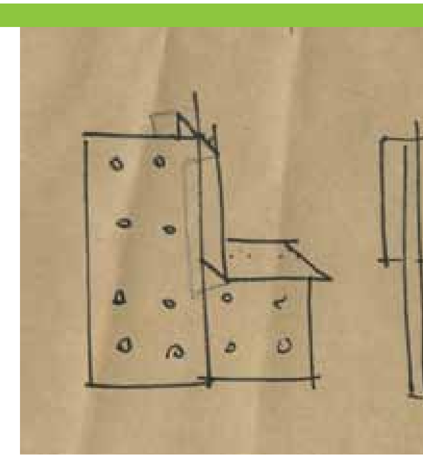


Connections, Type C



Connections, Type D





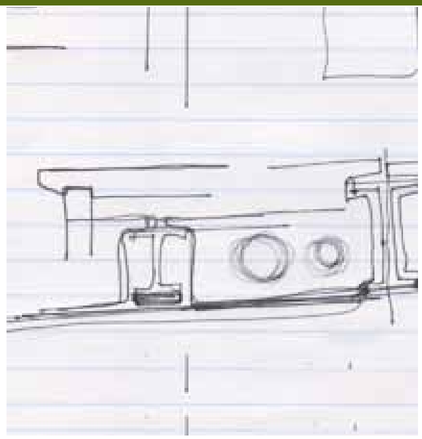
All connections represented here are intended for post and beam construction with nominal lumber or LVLs. Likely they would be steel.

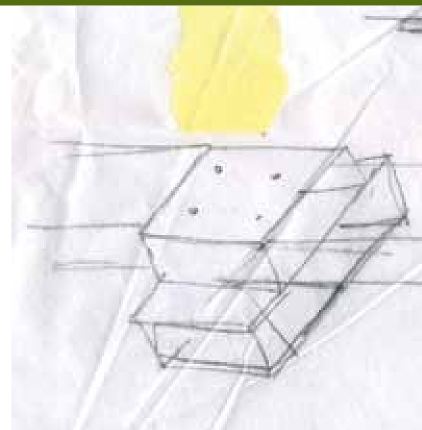
2 DESIGN SCHEMES

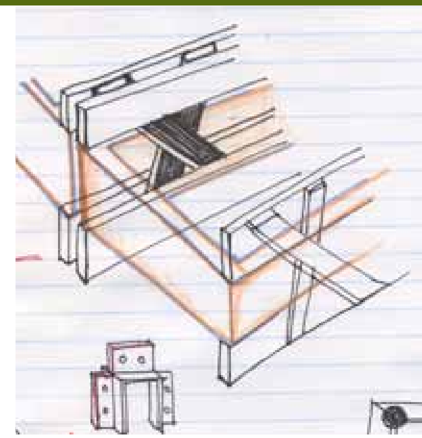
Spatial Frame | Connections

- Charrette Day 1
- Charrette Day 2
- Charrette Day 3
- Charrette Day 4
- Charrette Day 5

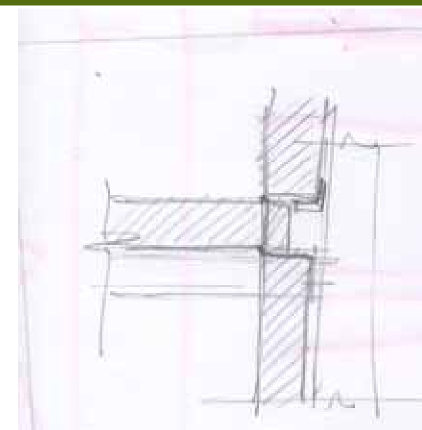
These forces will impact the design of the system in the following aspects: the depth of the member, the thickness of the gusset plate, the number of bolts (as a cross-sectional area), and the spacing of the bolts in the plate.

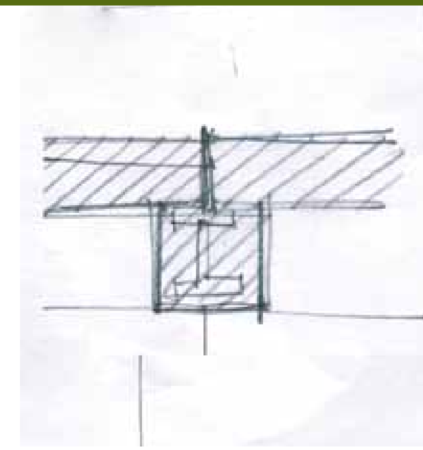




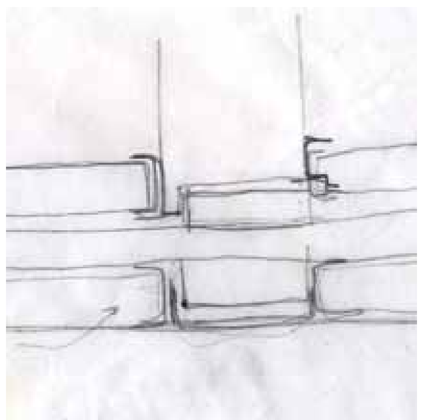


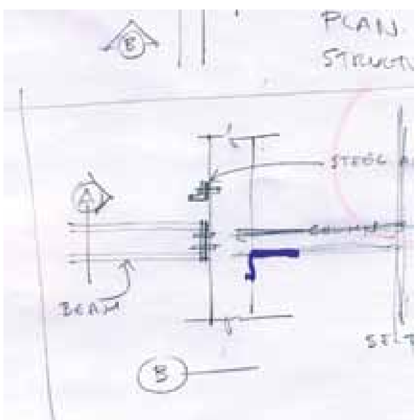
Panels could slot into a prefacbricated truss.

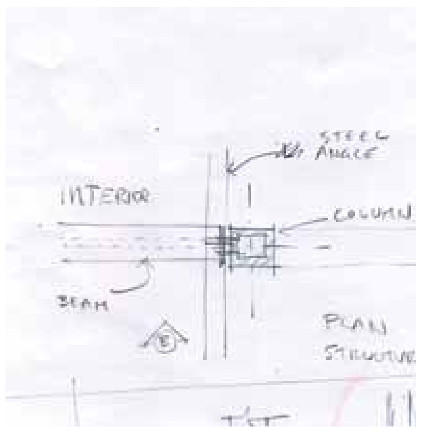


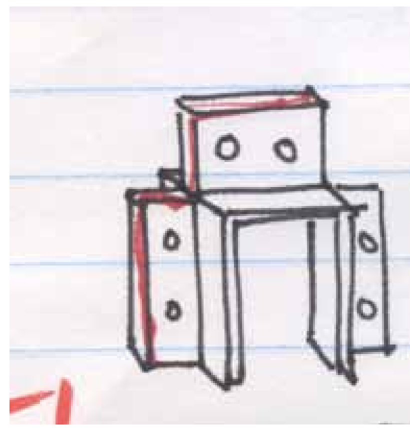


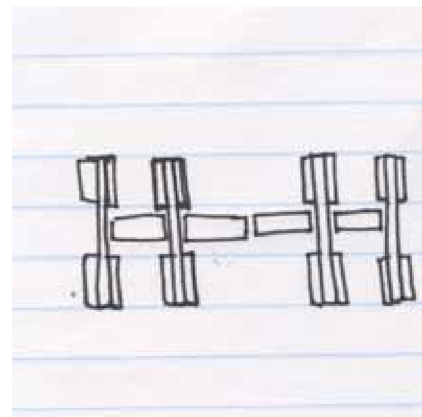
The steel I beam could be encased to look like a wood truss.

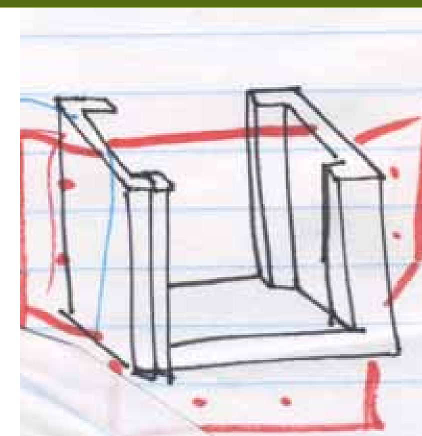












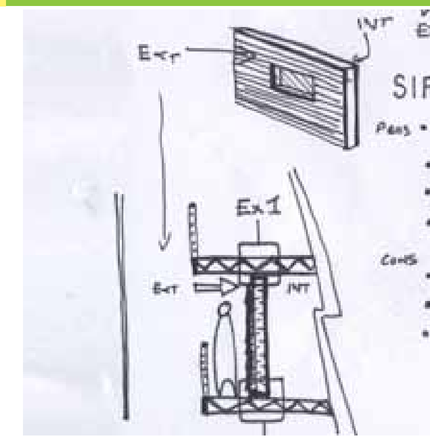
2 DESIGN SCHEMES

Spatial Frame | Cladding and Infill

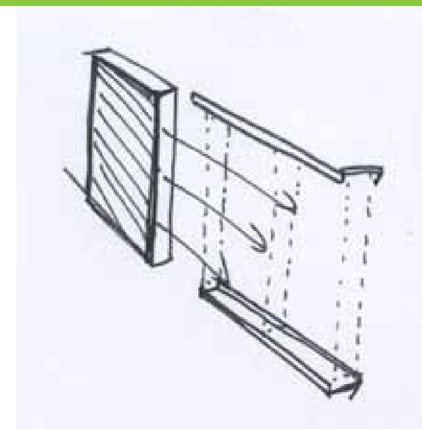
- Charrette Day 1
- Charrette Day 2
- Charrette Day 3
- Charrette Day 4
- Charrette Day 5

Finishing: The exterior skin would be interchangeable, and could therefore synchronize with a passive systems design strategy for each individual site.

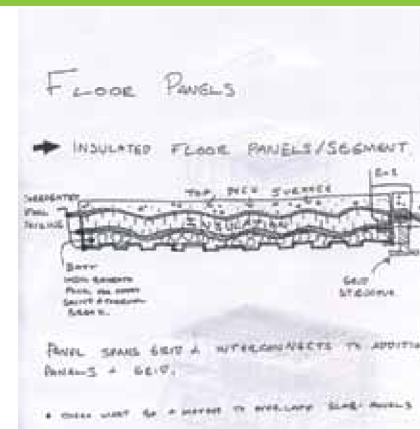
Finishing: Exterior and interior walls could be solid or soft (glazed, translucent) For example, a soft exterior shell could include sheathing rigid frames in fabric.



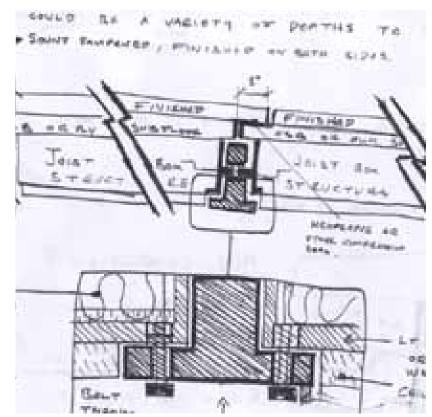
Wall Section: The house within a house schematic can lend itself to using either a hard exerior with a soft core, or a soft exterior with a hard core.



Interior Partitions: Interior partitions ould slide into a C-Channel. (interior partitions)

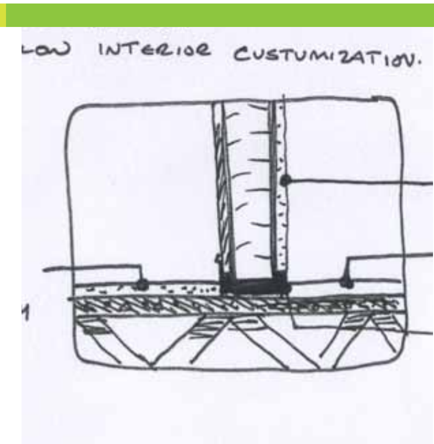


Floor Section, Southern Ontario

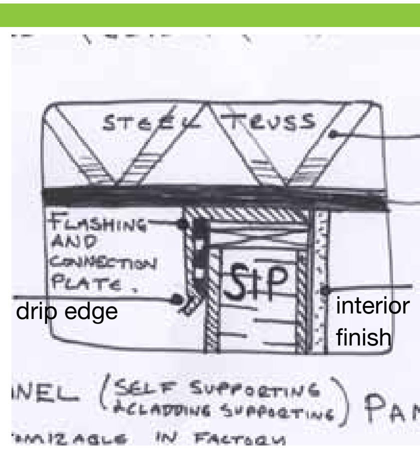


Floor Section, Costa Rica

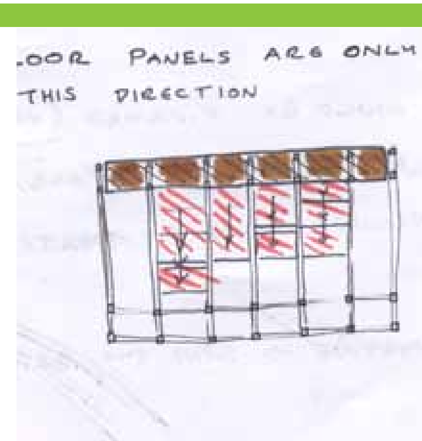
Finishing: Exterior and interior walls could be solid or soft (glazed, translucent)

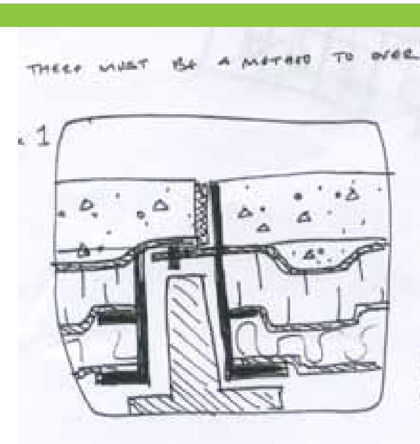


Wall Section

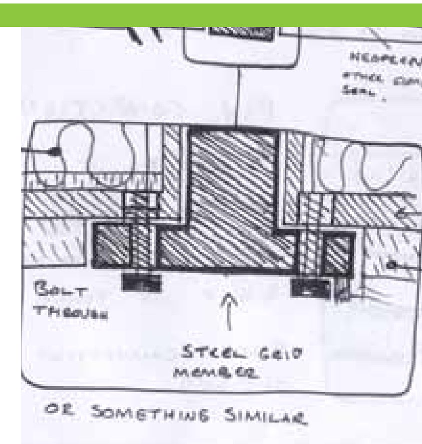


Wall Section: This drawing evaluates the use of a strucutural insulated panel (SIP) as the wall section. (See comparative notes in Section 6.0)





Floor Section, Southern Ontario: Slab panels could overlap.



Floor Section, Costa Rica

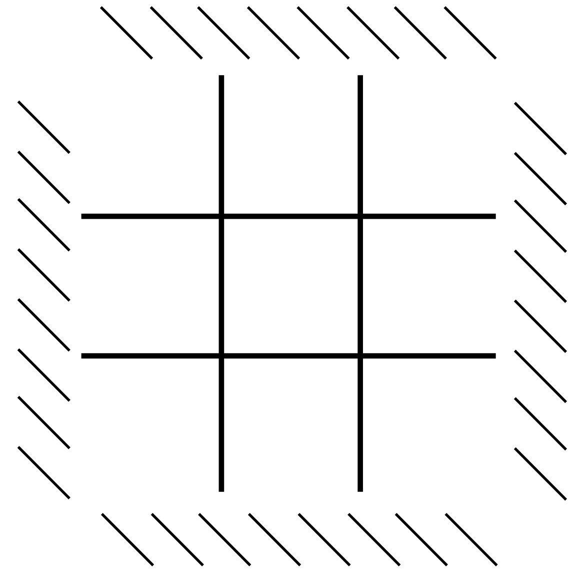
4.0

Modular Housing System: The Open Lattice

The Open Lattice System is designed to combine the virtues of premanufactured, modular housing with those of fine home building.

On the premanufactured side, its structure would comprise of a set of lightweight, dimensioned components that combine to form the basic framework for a living space. This could be easily multiplied in serial production, joined and stacked to arrive at many multi-storey, multi-unit complexes.

On the finer side, this framework could also integrate with cladding and environmental systems of many varieties — resulting in site-sensitive systems design, and a user-sensitive facade and interior. The relatively small size of the structural components also allows for a range of floorplan configurations.



The Open Lattice System is designed for easy shipping and installation however, its primary benefit is that it drastically reduces the need for on-site measurements and calculations by trades people. By working with a limited variety of prefabricated dimensional components, site installation is as easy as counting to 10!

THE OPEN LATTICE

Construction System | Structural Components

The Open Lattice System would comprise of three main structural components: the square stud, a modular frame and connections.

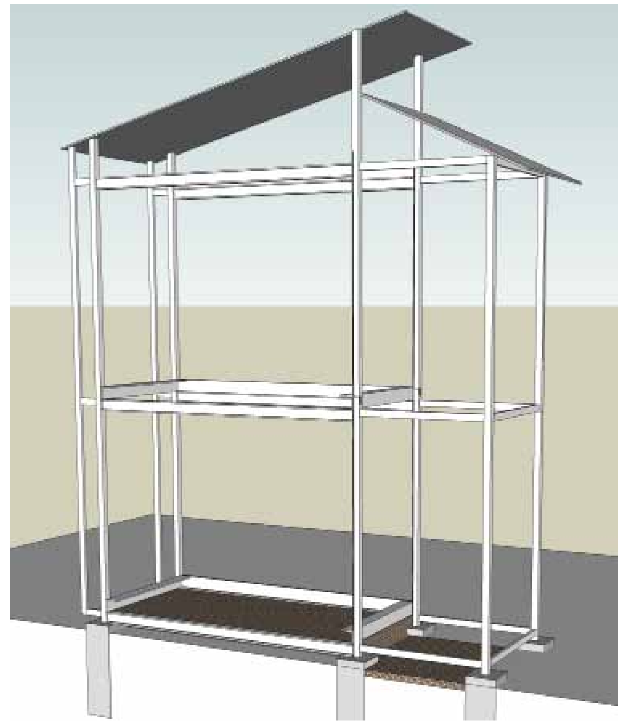
These components could be viewed as the 'fixed' or 'universal' elements of the design, as they could likely be repeated with similar materials and dimensions in multiple site applications.

The Square Stud
The square stud would be a strong, light-weight and versatile component that could be used to create wall, floor, ceiling and roof assemblies.

This drawing represents a 1x1m panel. This dimension, when multiplied, can result in the ideal proportion for a door frame (1x2m) or ceiling height (3m).

This dimension would also make the component easy to ship and handle without requiring special equipment.

The square studs could connect along their ends to result in floorplates or wall sections of varied sizes. Since floor, roof and ceiling panels typically undergo different types of routine stresses, the studs and their connections may require slightly different engineering for each application.



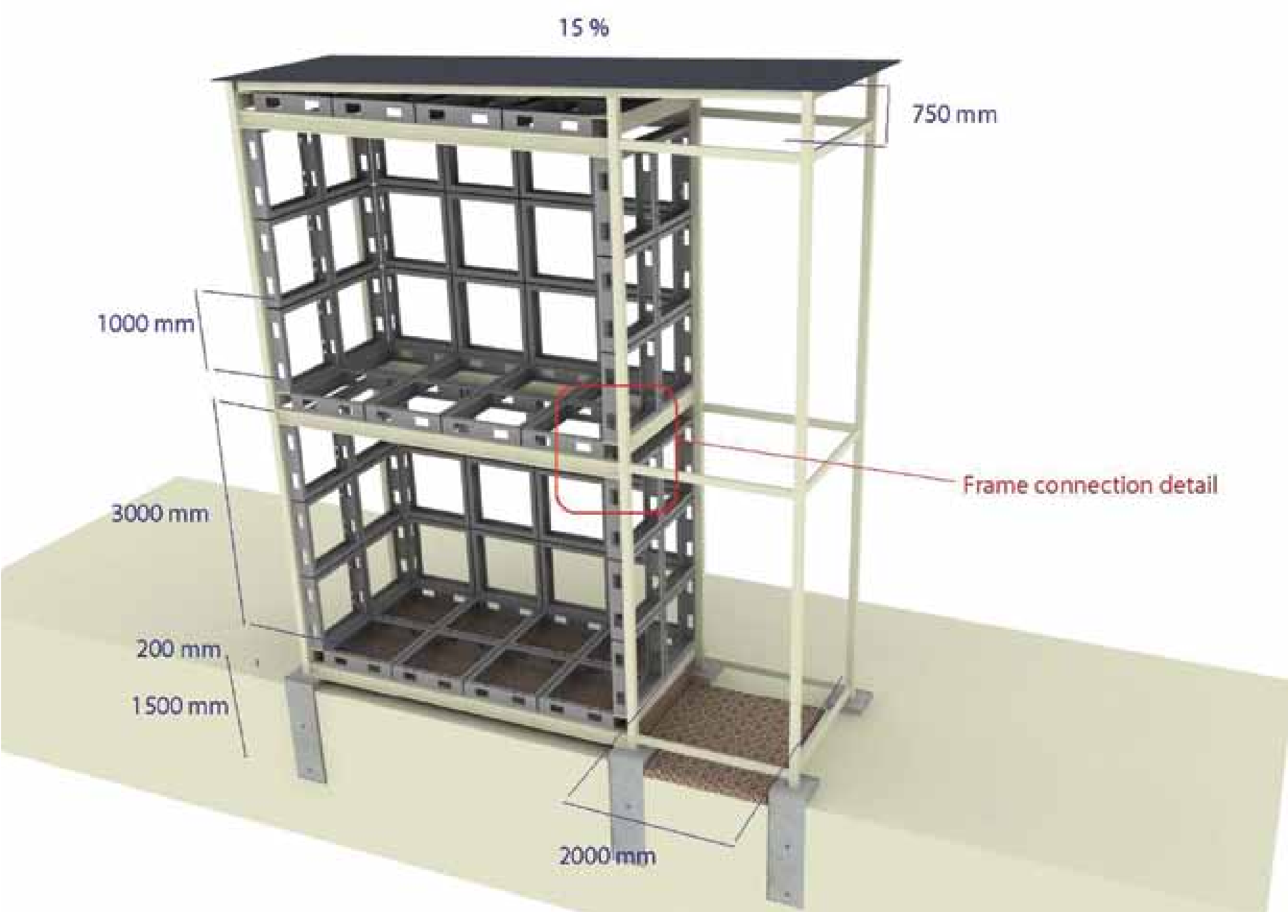
Modular Frame
The wall sections and floorplates would be housed within a modular frame. This frame would be similar to conventional post and beam assembly, and is intended to provide the primary structural support for the entire unit. The frame could be designed to suit any floorplan or elevation dimensions. The frame's crib form provides an opportunity to design each home with a double skin or double envelope that is customized to its environmental context.

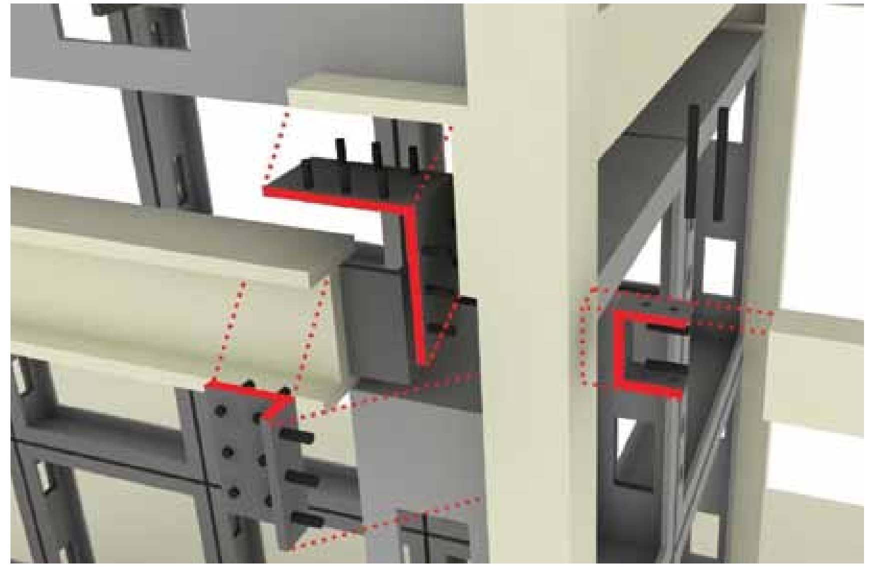
Together, the modular frame and square studs create a complete modular structural system that could be combined and stacked to arrive at a variety of unit sizes.

THE OPEN LATTICE

Construction System | Structural Components

Together, the modular frame and square studs create a complete modular structural system that could be combined and stacked to arrive at a variety of unit sizes.

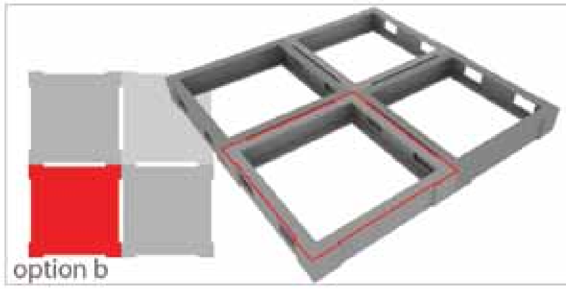


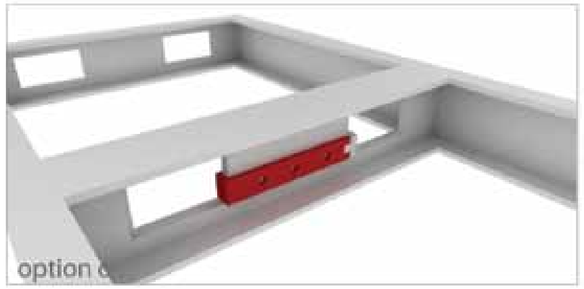


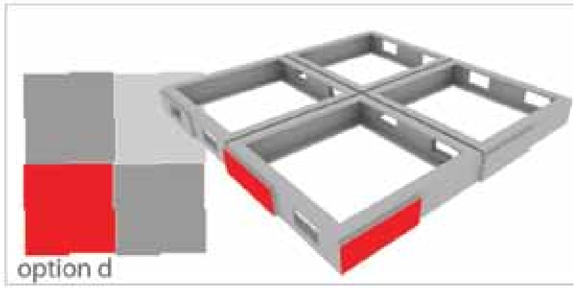
Connections
Connections could comprise of steel plates and bolts. Other material options for these connections could include plastic or wood.

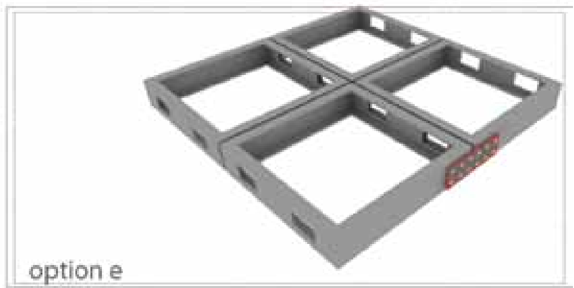
The square studs would be connected with a 3cm gap remaining bewteen, which could be used to clip on finishing panels of any kind.

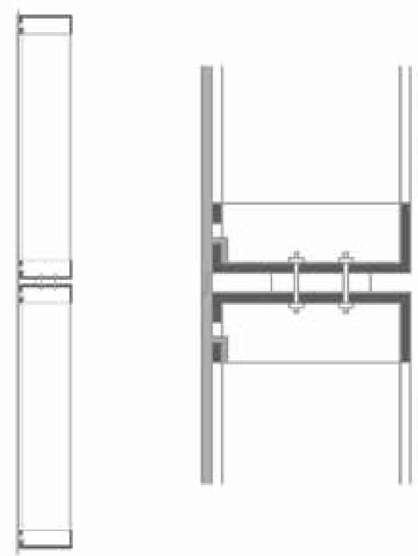
THE OPEN LATTICE
Construction System | Structural Components



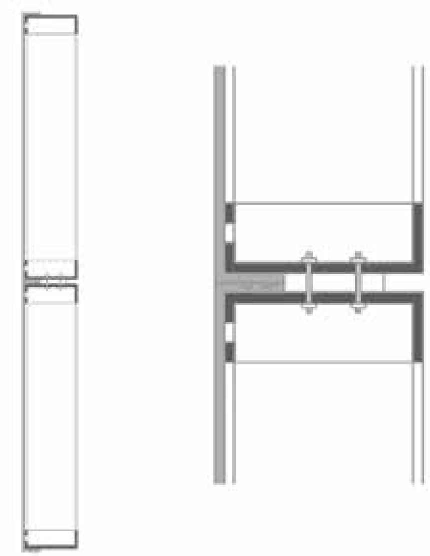








option a



option b

Connections
The square studs would be connected with a 3cm gap remaining bewteen, which could be used to clip on finishing panels of any kind.

THE OPEN LATTICE

Construction System | Systems Integration

The square studs would include spaces to run standard plumbing, pipes, wiring and duct work— resulting in a quick on-site installation. They could also integrate with alternative HVAC, water and energy capture systems, such as a radient floor, geothermal tubes or photo voltaic panels. In addition, the square studs could be finished with any type of insulation, and a variety of roof, floor, ceiling and wall panels.

These components (in addition to the foundation) could be viewed as the 'variable' or 'customized' elements of the modular housing system, as they would likely need to be modified for different site applications, according to climate considerations and user interests.

The square studs would be designed to accept service conduits through their centre (appoximate depth- 20cm) and cladding on either side.

Cladding could be applied in any size relative to the studs' dimensions (1x1m, 1x2m, 2x2m, etc.). As such, the cladding scheme could be used to break the monotony of the underlying grid, resulting in a clean and elegant, or extravagant and geometric facade.

Cladding and insulation could be applied in a factory or on site.

The 3cm groove left between the square studs, when connected, could also accept a partition wall or clip-on fixtures and furniture.

THE OPEN LATTICE

Construction System | Material Considerations

The Open Lattice scheme is primarily a structural and spatial concept that could be feasibily achieved with a number of material options. The core benefits of the scheme are best realized if selected materials are light to reduce the system's total weight, thereby reducing shipping costs and installation time. Other considerations when selecting materials are as follows:

It should also be noted that the performance of any material or product will be dependent on the design of the system in which they are operating, and their suitability to their context.

Structure
The structural material should be light and durable.

Connections
The joints will maintain the structural integrity of the system. Connections that are premanufactured as one continuous piece (rather than laminated together as many components) are less likely to fail.

Connections are required to connect modules and to support the 2m span. They would transfer the building's load from beam to column. Exterior panels need to be secured to prevent tampering and removal as a result of extreme weather.

Roof
The roof panel should be designed to manage snow loads and rainwater shedding. The complete roofing system would be combined with sheathing board, an air barrier and insulation, depending on the climate.

Ceiling
These panels would sit beneath the roof or floor panel. As such, they should be durable capable of resisting moisture damage, and removable (for maintenance on interior systems).

In Southern Ontario, the ceiling panels would be used in combination with insulation.

Interior Cladding
These panels would sit on the other side of the exterior wall. As such, they should be durable capable of resisting moisture damage, and removable (for maintenance on interior systems).

In Southern Ontario, the interior panels would be used in combination with insulation which would increase the overall thickness of the section.

These panels could also be used as interior partitions, slipping into grooves in the floor and ceiling.

Foundation
The structure is built without a basement to reduce the building's environmental footprint and save on site excavation costs.

MATERIAL OPTIONS

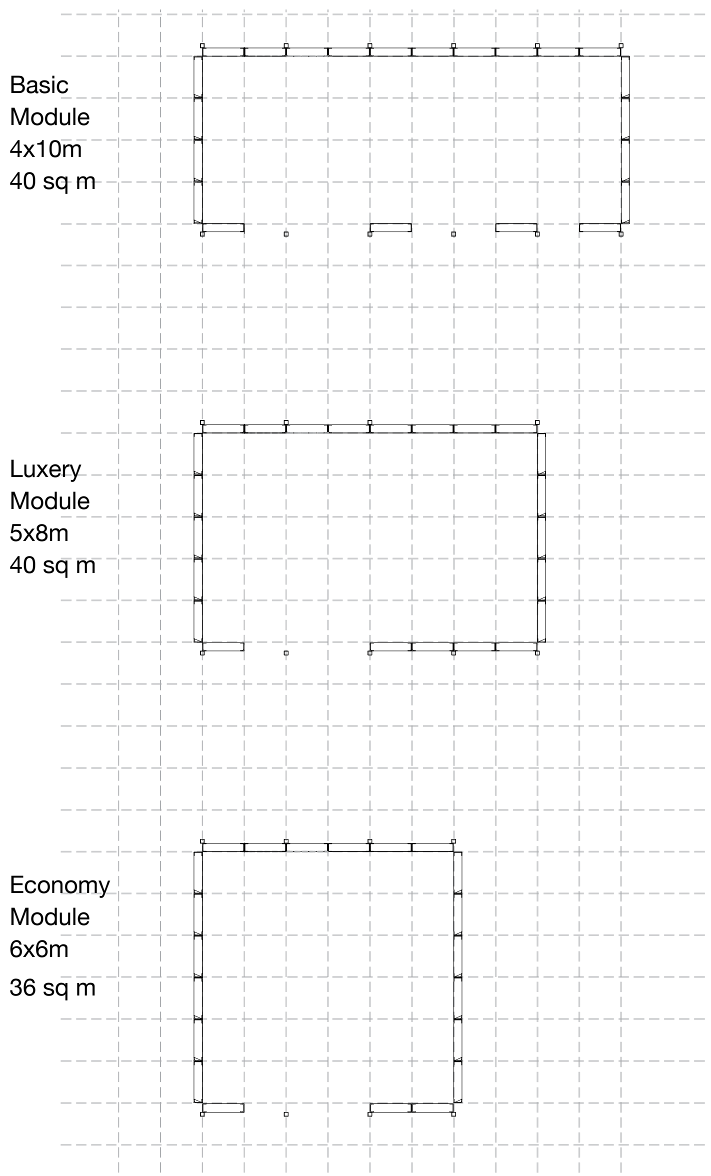
COMPONENT	MATERIAL	RATIONAL
STRUCTURE		
Square Stud		
Modular Frame		
Joint 1: Square Stud		
Joint 2: Wall Panels		
Joint 3: Modular Frame		
Foundation		
EXTERIOR CLADDING		
Roof		
Exterior Shell		
Exterior Wall		
Glazing		
Insulation		
Sheathing		

COMPONENT	MATERIAL	RATIONAL
INFILL		
Insulation		
Sheathing		
Vapour Barrier		
INTERIOR CLADDING		
Floor Panel		
Ceiling Panel		
Wall Panel		
SYSTEMS		
Heating		
Cooling		
Ventilation		
Water Capture		

THE OPEN LATTICE

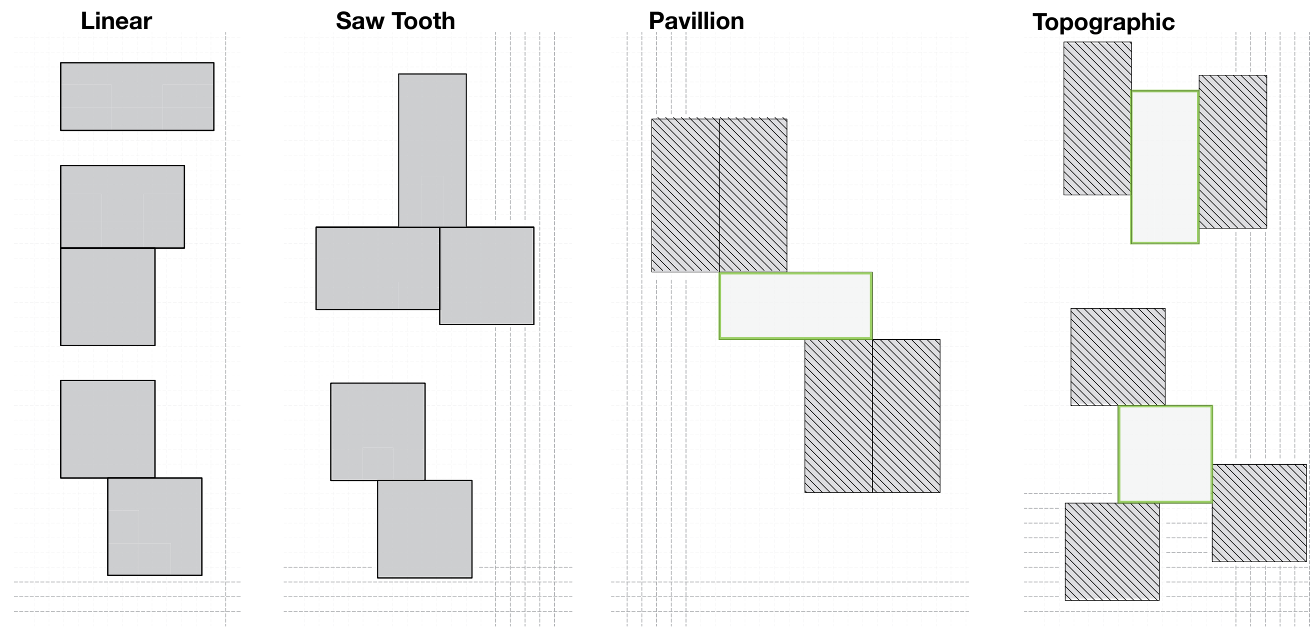
Spatial System | Modular Variations

With its main strucrural component being the small square stud, The Open Lattice System can achive any floorplate dimension that is a multiple of 1m.



Modular Variations
Unit layouts would be tied directly to the 1x1m grid system.

In this drawing we see three possible spatial configurations that have very different floorplates, but comparable total square footage.

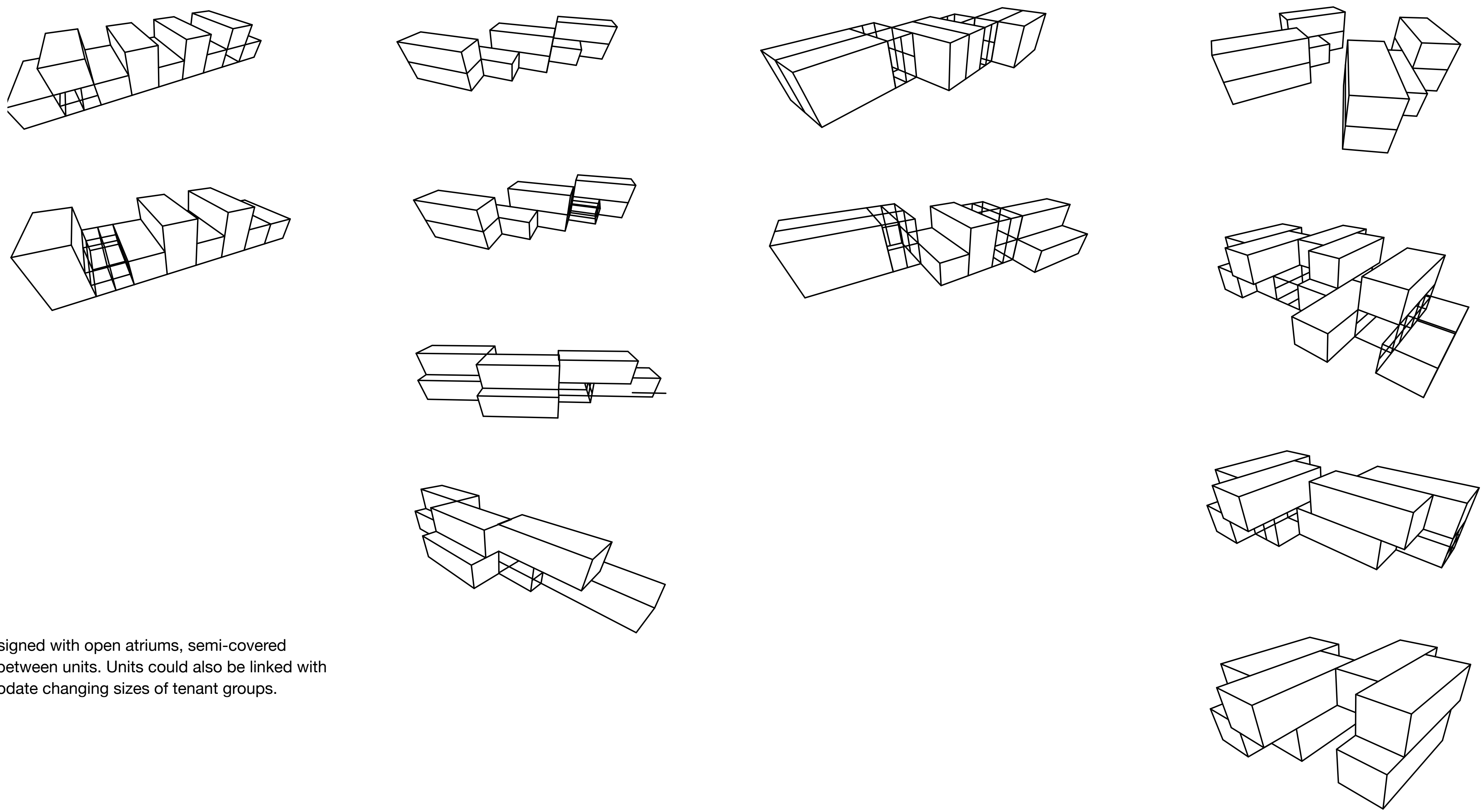


Site Clustering
These module variations can also be used to generate an infinate amount of unit clustering schemes.

THE OPEN LATTICE

Spatial System | Site Cluster Variations

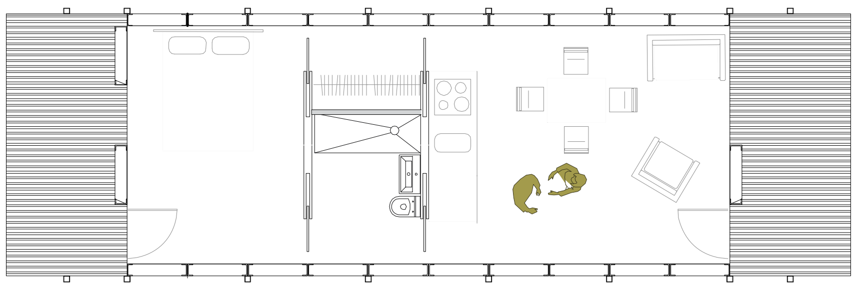
Linear **Saw Tooth** **Pavillion** **Topographic**



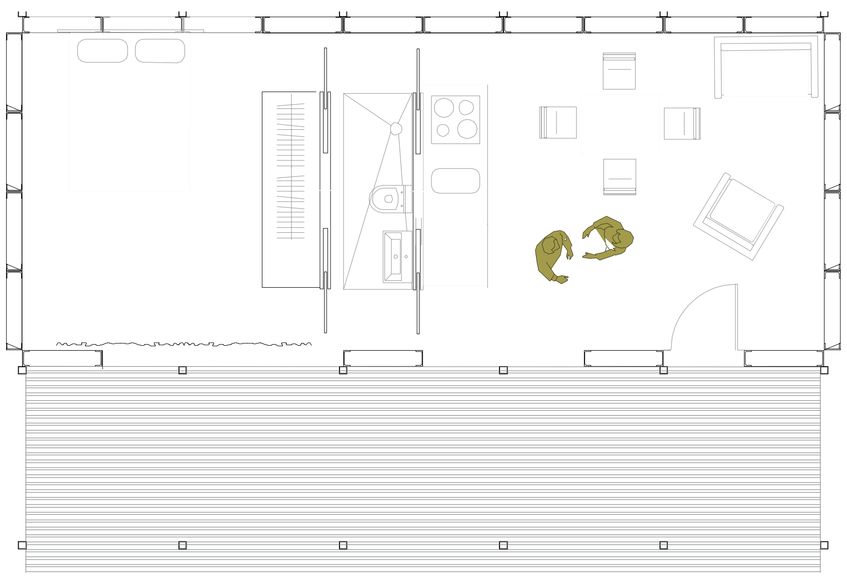
Site Cluster Variations
Site clusters could also be designed with open atriums, semi-covered walkways and rooftop patios between units. Units could also be linked with connecting doors to accommodate changing sizes of tenant groups.

THE OPEN LATTICE

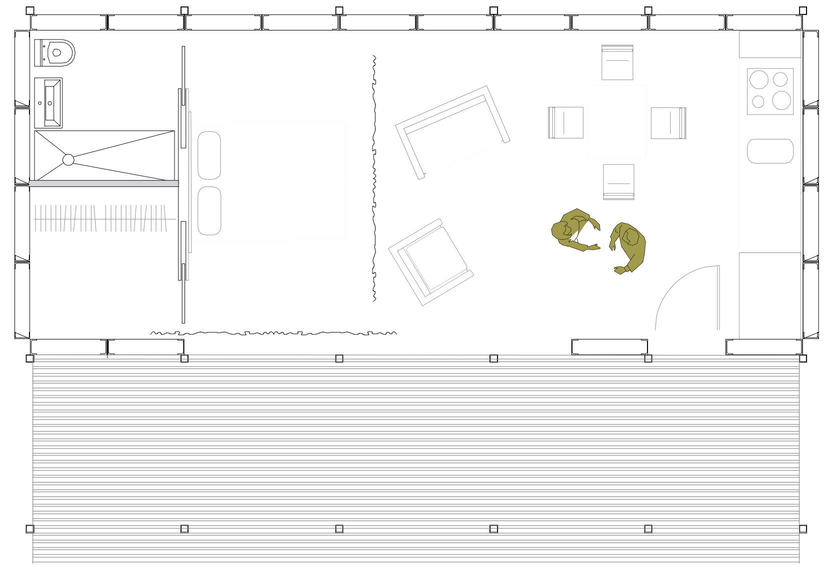
Spatial System | Floorplan Variations



Bachelor Module
Long Walls Shared, 40 sq m



Bachelor Module
Short Walls Shared, 40 sq m



Bachelor Module
Short Walls Shared, 40 sq m
Version Two (with bookend services)

Unit Plans
The unit plans are intended to provide a simple scheme that is open and light, in contrast to the underlying structure, which is heavy and rigid.

All wet systems have been organized around a central core, which is shared between floors. Placing the service core at the centre of the unit allows for flexibility in its clustering. These services areas (kitchen and bath) are also used as a transition space between public (living) and private (sleeping) spaces. This configuration makes the unit appear spacious – as the user will be able to see along the long walls from any point in the home. The unit's high ceilings also enhance this sense of spaciousness.

All storage space and walls would be designed with minimal thickness to maximize space. Ultimately, the modular grid system could be designed with a complementary furniture system that hooks on the wall.

Exterior terraces act as a buffer between the units, and borders around the space.

The bathroom could be designed with a light window at the top.

5.0

Modular Housing System: Site Variations

To evaluate the applicability of The Open Lattice system, the charrette team tested it on two site locations - one in Southern Ontario, Canada and one in Guanacaste, Costa Rica.

Although The Open Lattice was preconceived as a generic building system, it maintains enough flexibility to work with the conditions of each site.

The most important distinction and similarity between the sites is that they both are subject to weather extremes (snow, rain and heat). The Open Lattice's double skin/double envelope system is fundamental to managing these extremes. With modifications in orientation, window placement and materials selection, the system can adapt to either site, and provide a solution for passive heating and cooling.

In addition to addressing these climatic difference, the charrette team attempted to cluster the units in such a way that would preserve and celebrate each site's unique landscape.

A preliminary review of climactic data and construction precedents for the two test regions revealed the following:

GUANACASTE, COSTA RICA

Precipitation
From May to October there is a considerable amount of rain.
Design Response
It is important that the roof is designed to handle heavy precipitation without leaking

Temperature
There are only two seasons and temperatures remain high.
Design Response
This permits comfortable living in buildings that are open to the air but sheltered from the rain and sun

Humidity
Humidity levels are high
Design Response
Cross ventilation is imperative for comfort and to prevent mould

Sun Patterns
There is extreme sun glare which results in an uncomfortable amount of heat.
Design Response
In the tropics, too much light adds heat. Shade is critical to reduce effects of solar radiation. Natural ventilation in buildings is critical.

Prevailing Winds
Winds from April – December blow NE at 6-9km/hr, E at 14-16km/hr from December – February, and then NE at 15km/hr until April (strong winds carry dust)

Pests
Local pests include termites, wolf spiders (and monkeys)
Natural Disasters
Costa Rica is located between two tectonic plates and is prone to earthquakes, which affect building practices. For example, use of the tradition building material adobe was recently banned by the government.

Other Design Considerations
- Exposed stone and brick insulate, are durable, and require nearly zero maintenance.

- Shading drastically reduces natural lighting, which must be compensated for in other ways. While direct overhead lighting is effective, this also adds heat.

- Structures should be oriented to minimize direct solar gain and increase exposure to breeze

SOUTHERN ONTARIO, CANADA

Precipitation
There is no one rainy season. Instead the 864 mm (34 in) of precipitation are distributed uniformly throughout the year.

Temperature
Southern Ontario boasts four distinct seasons with extreme temperature fluctuations. Summers average at 20°C (68°F) and reach as high as 35°C and winter at about -6°C (21°F).

Design Response:
Use long walls that face the winter sun, limiting summer sun on east/west walls (20 or 30 degree leeway).

Pests
Local wildlife includes raccoons and squirrels

GENERAL CONSIDERATIONS
- Snow loads (40lb/sq ft in Ontario)
- Use landscaped walls as windbreaks to avoid direct winter winds.
- Views from within the building
- Interaction with the physical environment
- Soil: stability, building loads, frost line

SITE VARIATIONS

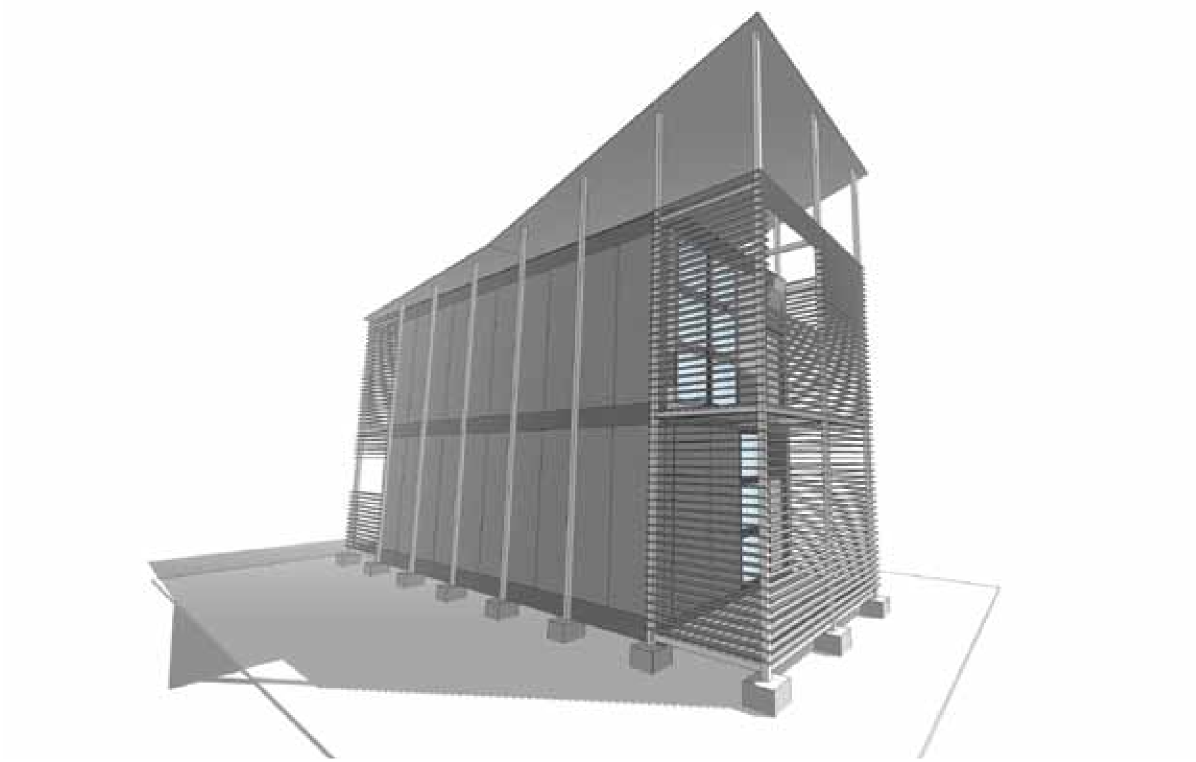
Basic Unit | Southern Ontario

The Southern Ontario unit is designed as a double envelope, oriented with the long, glazed wall to the south to maximize solar gain.

The front corridor forms an enclosed sun room which would preheat the air before it enters the main living space through interior windows. Combined with the air cavity at the back, the system creates an insulative air cavity.

SITE VARIATIONS

Basic Unit | Guanacaste



The Guanacaste unit is designed as a double skin, oriented with its windows on the east and west sides, to take advantage of the northeast prevailing winds.

The exterior corridor is treated like a shaded patio for outdoor living space. The patio would also serve to reduce solar gain to the interior spaces, while maintaining air flow.

SITE VARIATIONS
Basic Unit, East Elevation | Southern Ontario

West Elevations, Southern Ontario
Inhabitants would enter their units through the sun room corridor, the door to which would be on the east side of the building.

SITE VARIATIONS
Basic Unit, East Elevation | Guanacaste

East Elevation, Guanacaste
A shaded outdoor patio space is combined with the front entrance, for socializing or relaxing.

SITE VARIATIONS
Basic Unit, West Elevation | Southern Ontario

West Elevations, Southern Ontario

SITE VARIATIONS
Basic Unit, West Elevation | Guanacaste

West Elevation, Costa Rica
Windows are oriented to the east and west to take advantage of northwest prevailing winds.

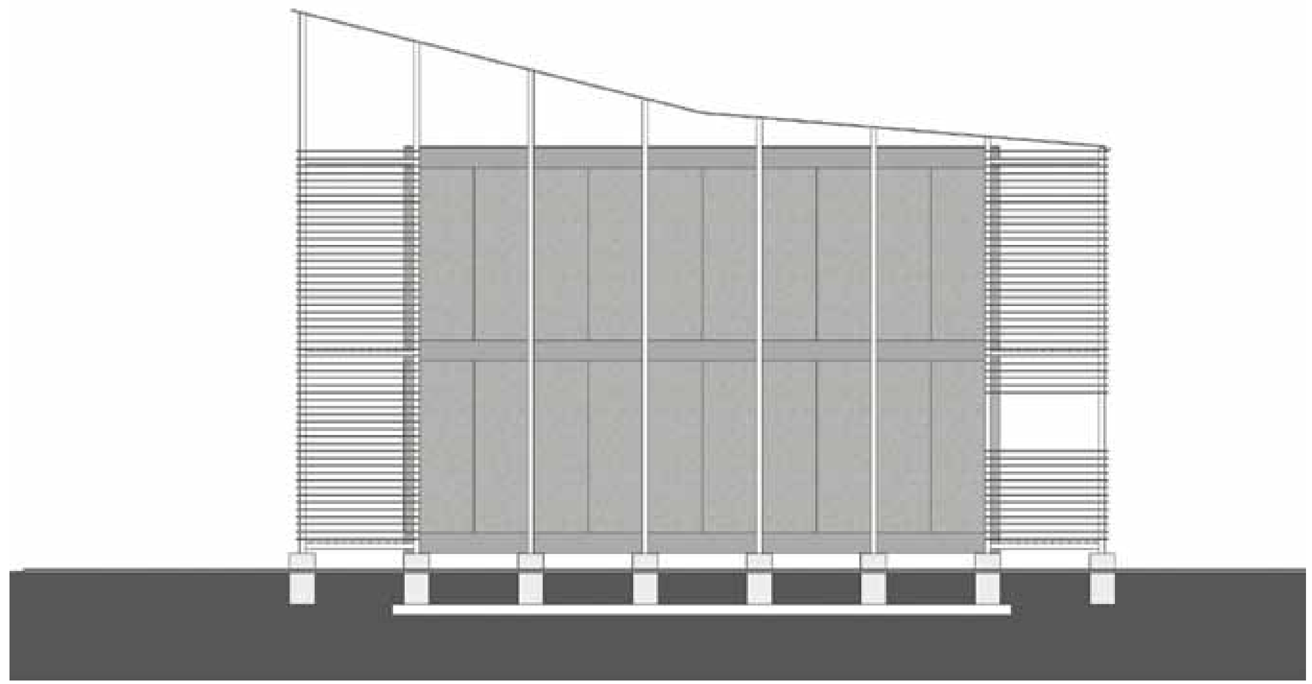
SITE VARIATIONS

Basic Unit, South Elevation | Southern Ontario

South Elevation, Southern Ontario
The longest wall is glazed and oriented to the south to maximize solar gain. This is combined with solar panels for energy capture, as well as wooden slats for shading in the summer.

SITE VARIATIONS

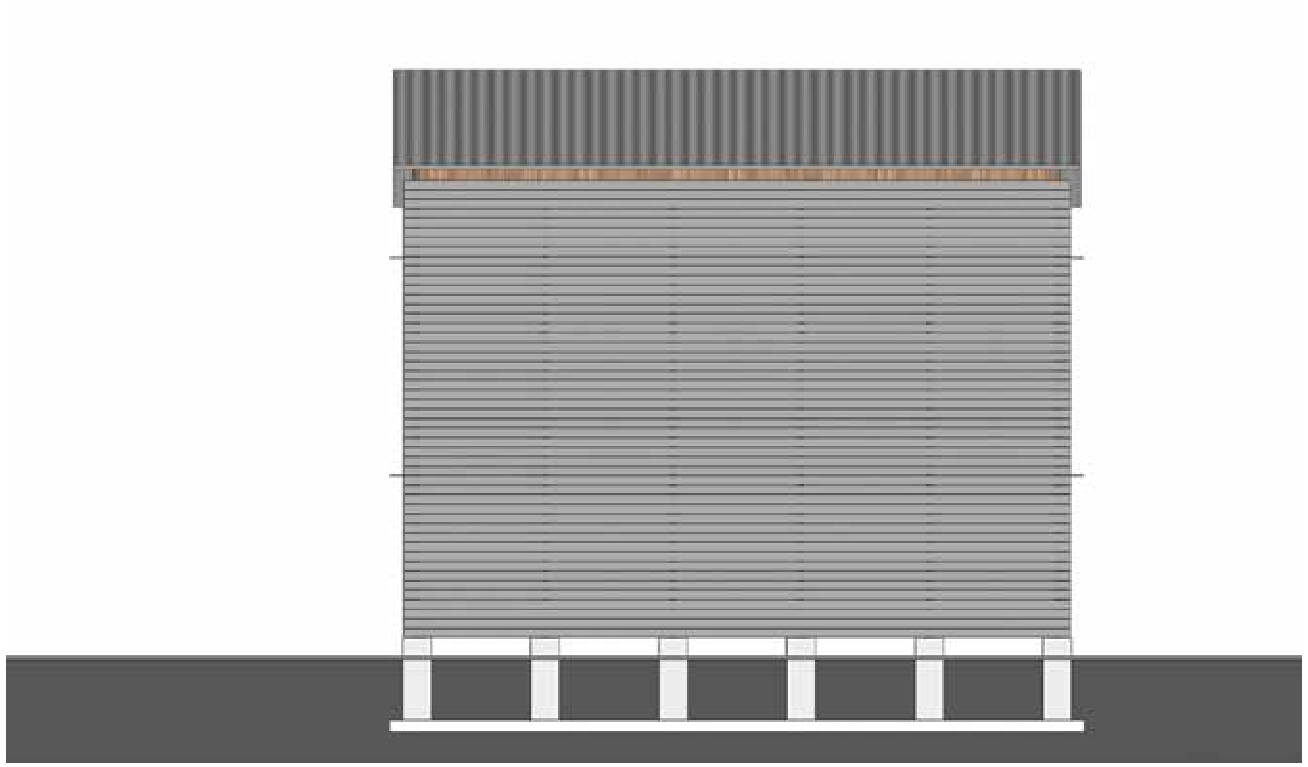
Basic Unit, South Elevation | Guancaste



South Elevations, Costa Rica
With a position of 5 degrees from the equator, sun angle does not play as large of a role in the passive heating and cooling of a building. Concrete (Plyceme) walls help to keep the space cool.

SITE VARIATIONS

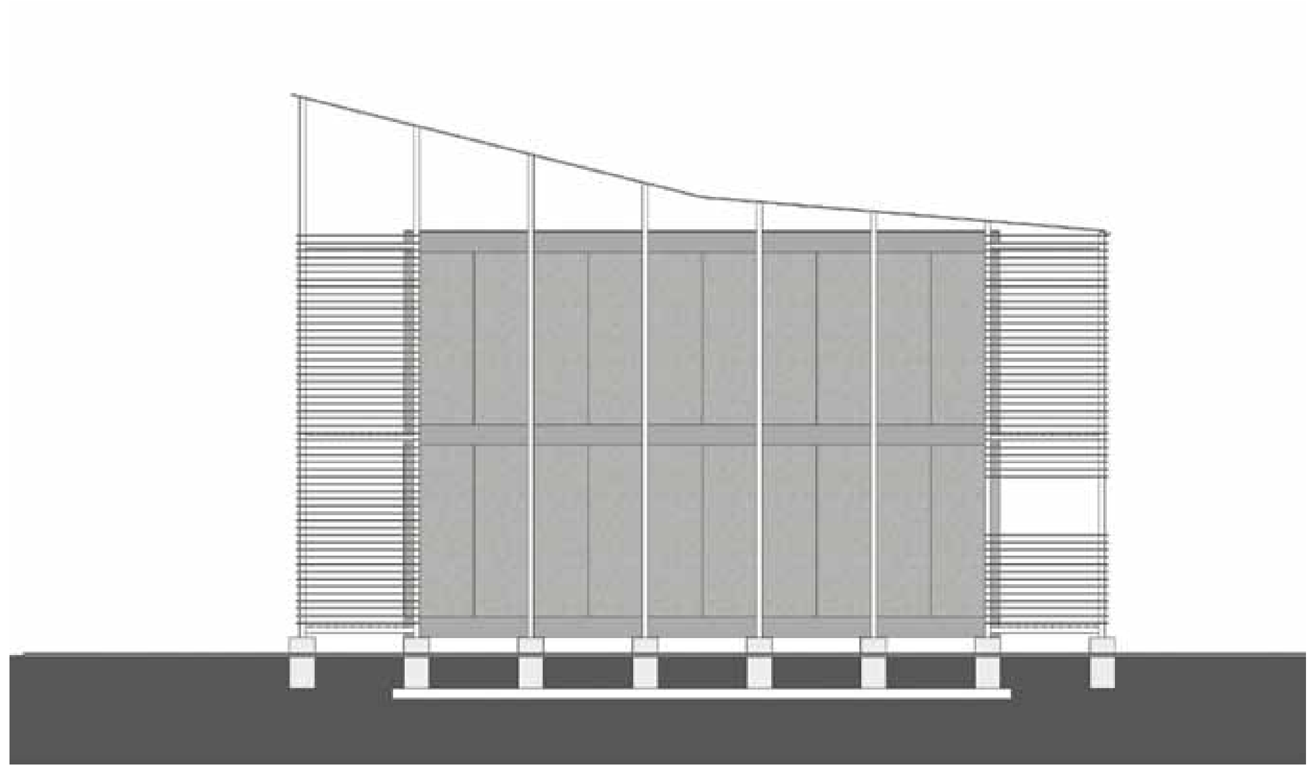
Basic Unit, North Elevation | Southern Ontario



North Elevation, Southern Ontario
The north wall could be treated with fibre cement board or recycled plastic wood slats to create the double envelope. This side could also be used as a utility area.

SITE VARIATIONS

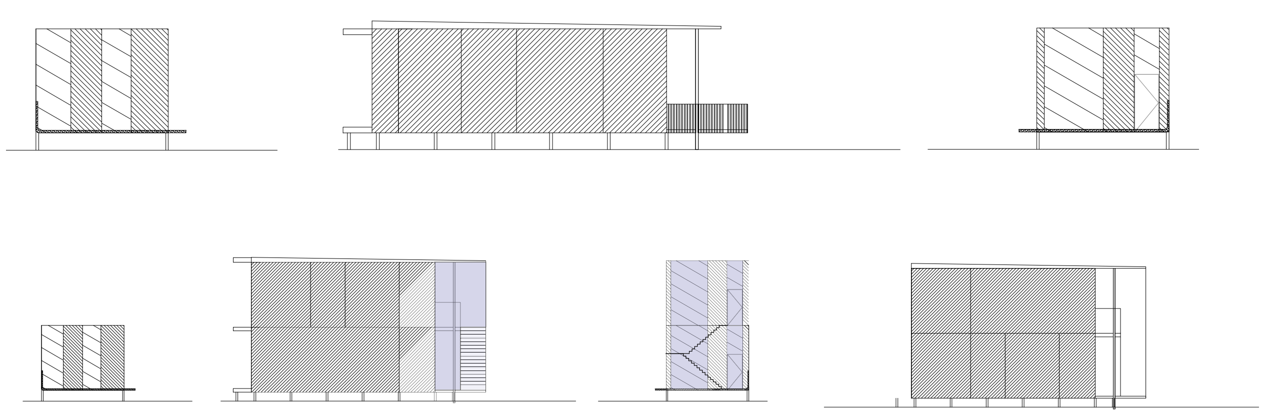
Basic Unit, North Elevation | Guanacaste



North Elevation, Guanacaste
The north wall could be treated with a Plyceme cladding, which is durable, cheap and manufactured locally.

SITE VARIATIONS

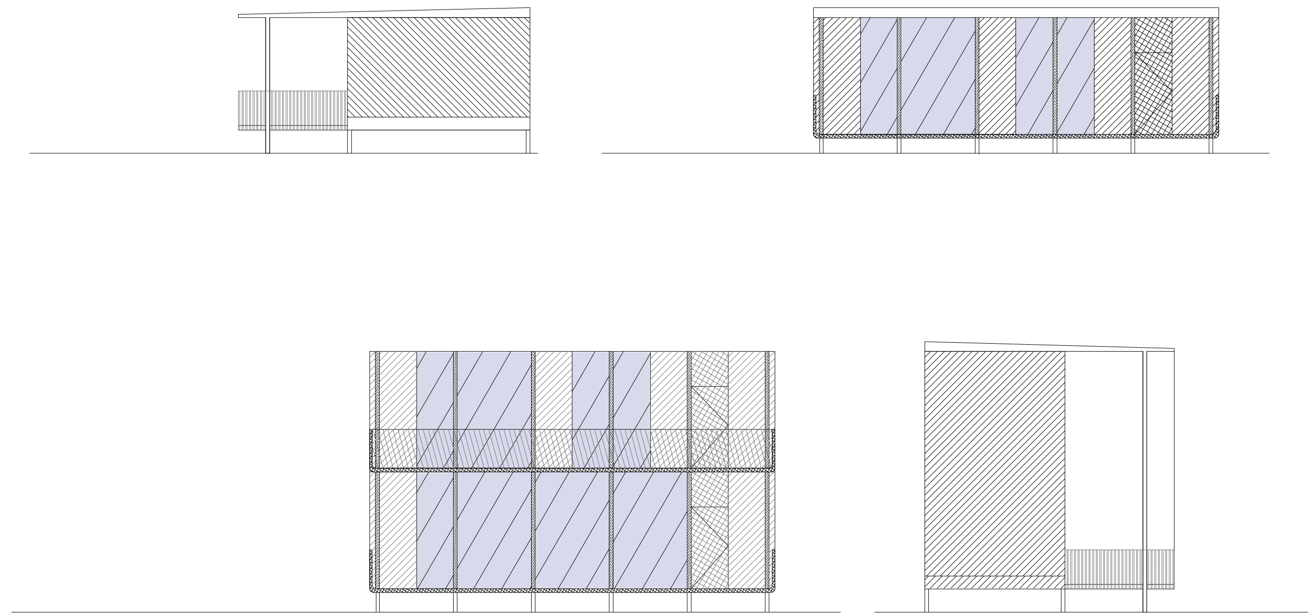
Basic Unit, Elevation Options | Long Walls Shared



Elevation Options, Long Walls Shared

SITE VARIATIONS

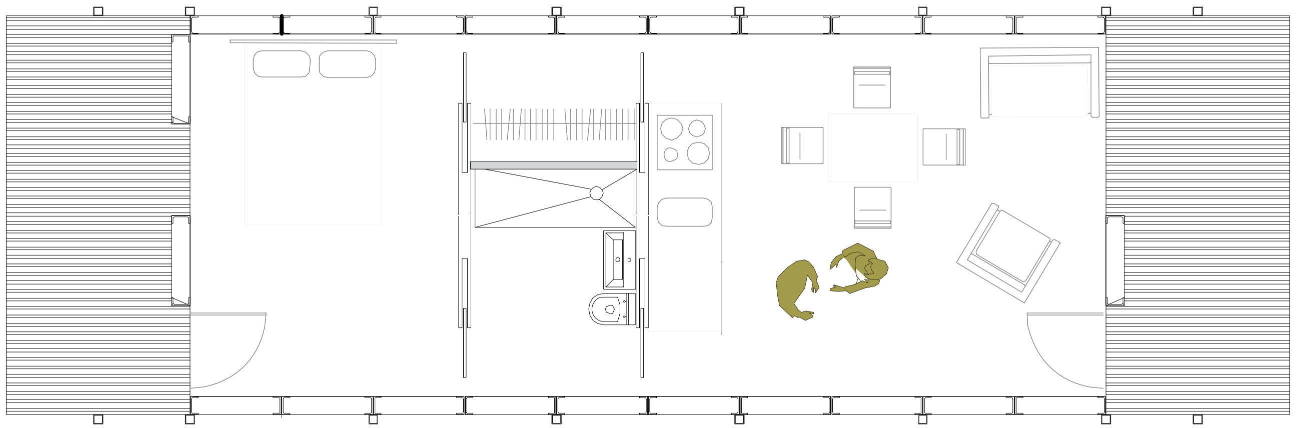
Basic Unit, Elevation Options | Short Walls Shared



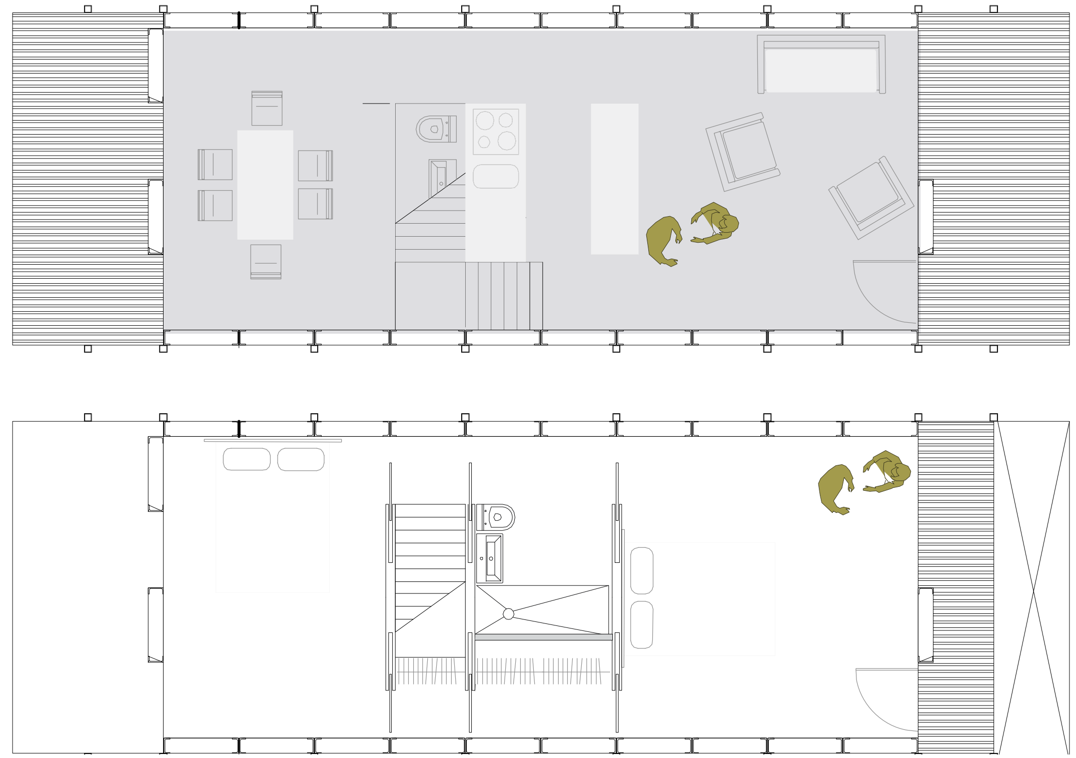
Elevation Options, Short Walls Shared

SITE VARIATIONS

Basic Unit, Plans, Long Walls Shared | Guanacaste



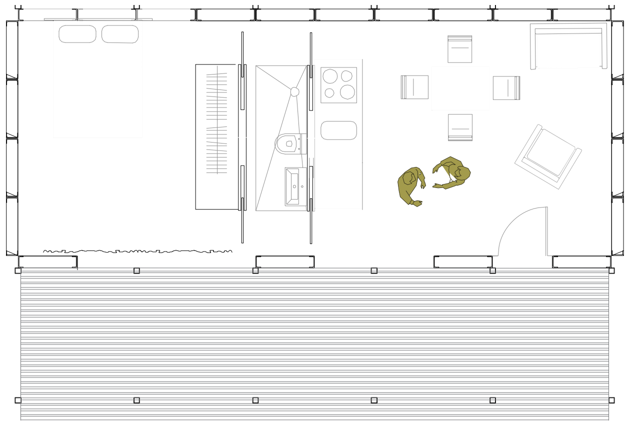
Bachelor Module, 40 sq m
Long Walls Shared



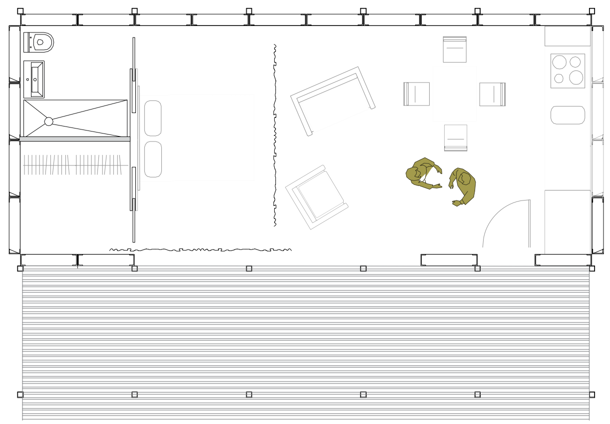
2 Bedroom Unit, Stacked, 80 sq m
Long Walls Shared

SITE VARIATIONS

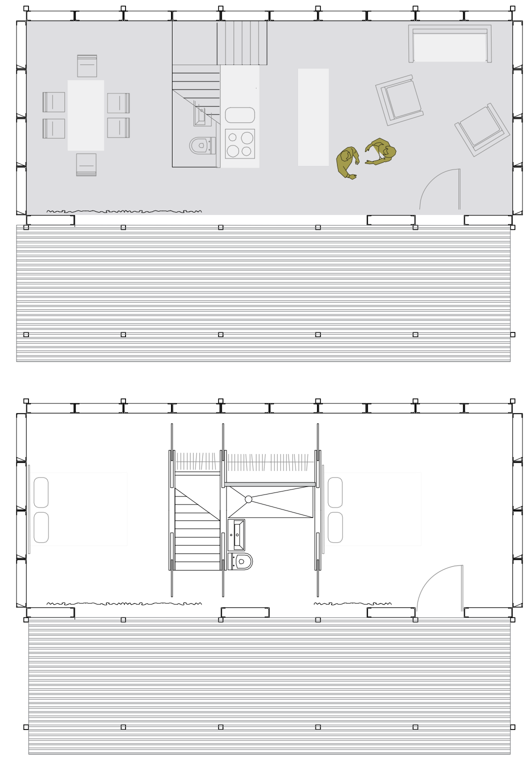
Basic Unit, Plans, Short Walls Shared | Southern Ontario



TYPE A



TYPE B

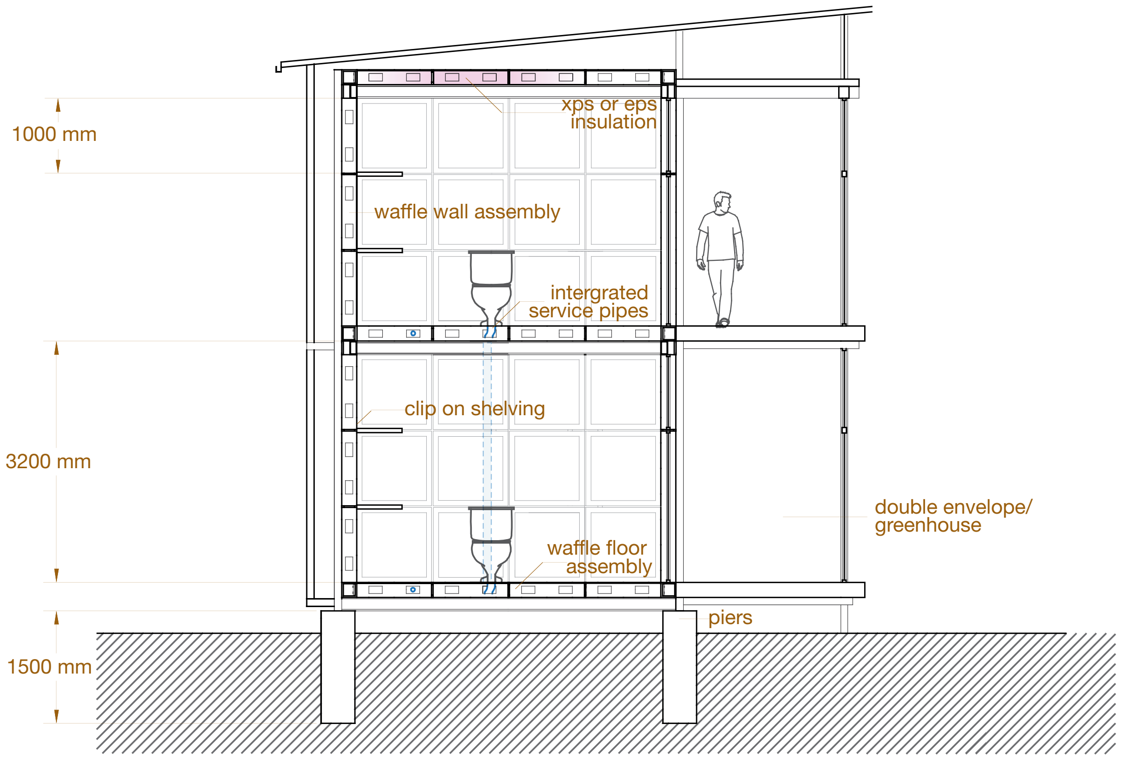


Bachelor Module, 40 sq m
Short Walls Shared

2 Bedroom Unit, Stacked, 80 sq m
Short Walls Shared

SITE VARIATIONS

Basic Unit, Section | Southern Ontario

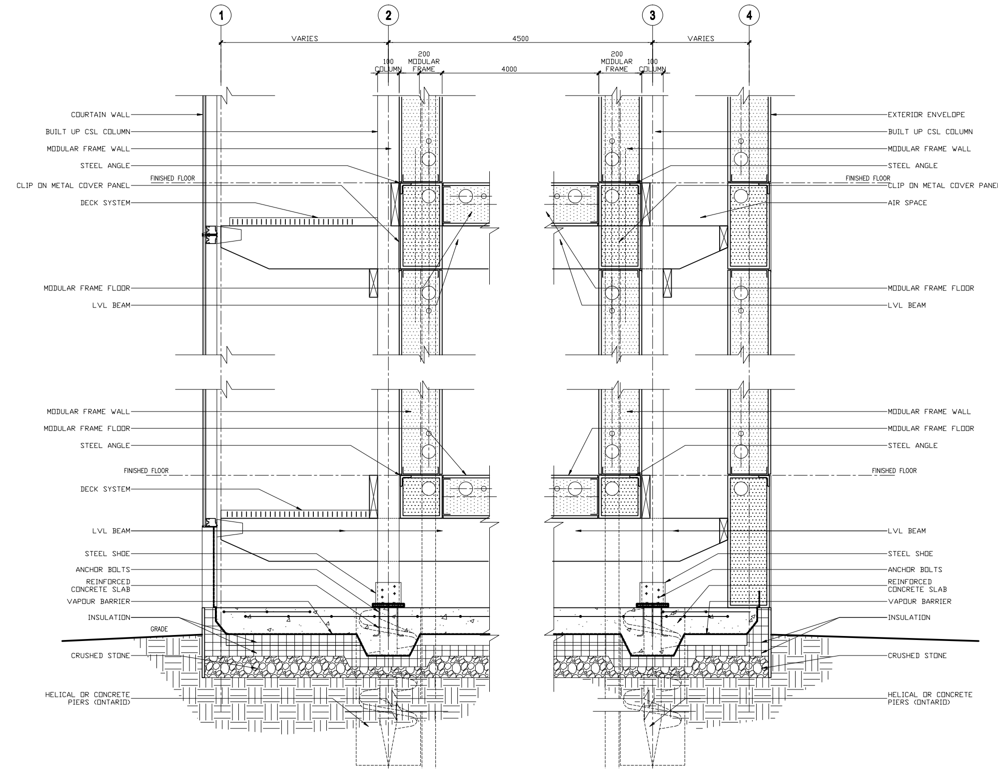


Section, Southern Ontario

The foundation would be set at a minimum depth of 4 ft (frost line) to accommodate the Ontario Building Code. Local gravel could be used to fill the space between the foundation and the structure to serve as thermal insulation.

SITE VARIATIONS

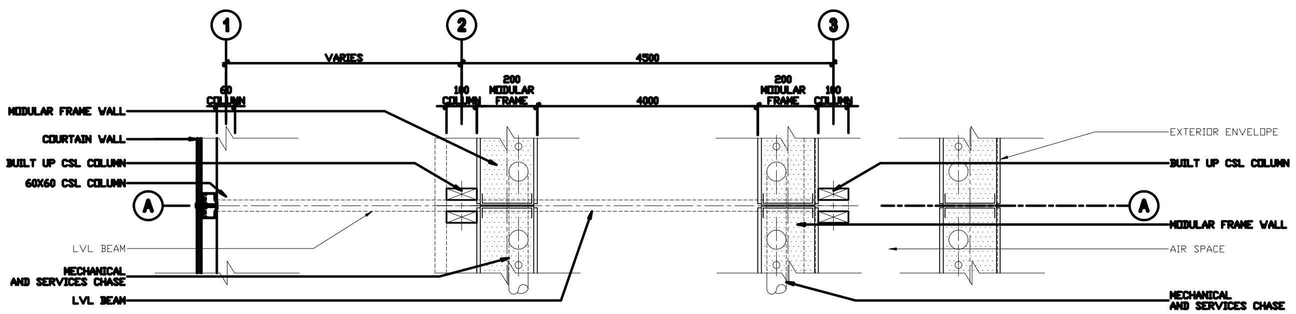
Basic Unit, Section Detail | Southern Ontario



Section Detail, Southern Ontario

SITE VARIATIONS

Basic Unit, Plan Details | Southern Ontario



Plan Details, Southern Ontario

“Economy in cost is exemplified by the savings that can be realized by designing structures that can be deconstructed, that is, taken apart without complete demolition and reusing their components for other structures. Economy of operation and maintenance are enhanced by designing smart, self-diagnostic and possibly, at least in part, self-repairing buildings and infrastructures, and considering lifetime rather than initial costs. Economy of construction as well as of operation and maintenance can benefit from the industrialization of construction and the still experimental use of robots.” Bugliarello, pg 60

MATERIALS SPECIFICATION

Exterior | Southern Ontario

Roofing
Sheet steel, metal shingle or recycled plastic shingles.

Glazing
Double or triple paned krypton/argon filled window, thermally broken.

Exterior Cladding (Shell):
Hollow polypropylene panels on the southern (glazed) façade, or another single pane of glass. (These panels could potentially be removed in the summer to open up the space.)

Exterior Cladding (Wall):
Cedar strip siding and fiberglass panel.

Foundation
Pier footing - cast concrete or helical). (Footing sizes will vary based on soil bearing capacity.)

MATERIALS SPECIFICATION

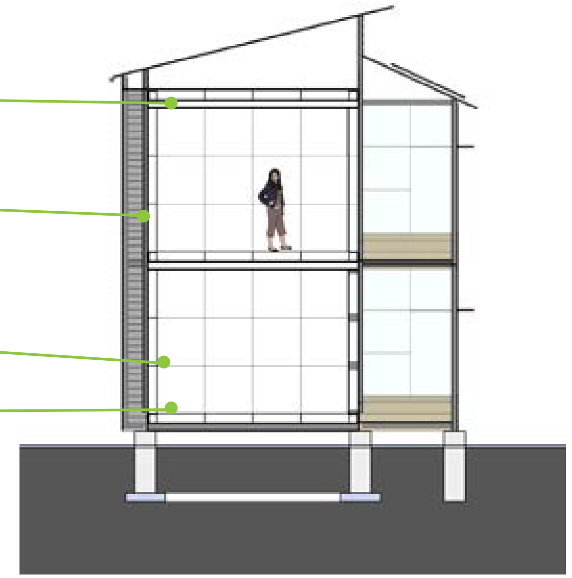
Interior | Southern Ontario

Ceiling
Drywall, coloured acrylic, or pop-in sheet metal panels.

Insulation
Expanded/Extruded polystyrene. (Same as in SIPs) (R-4, R-5 respectively)

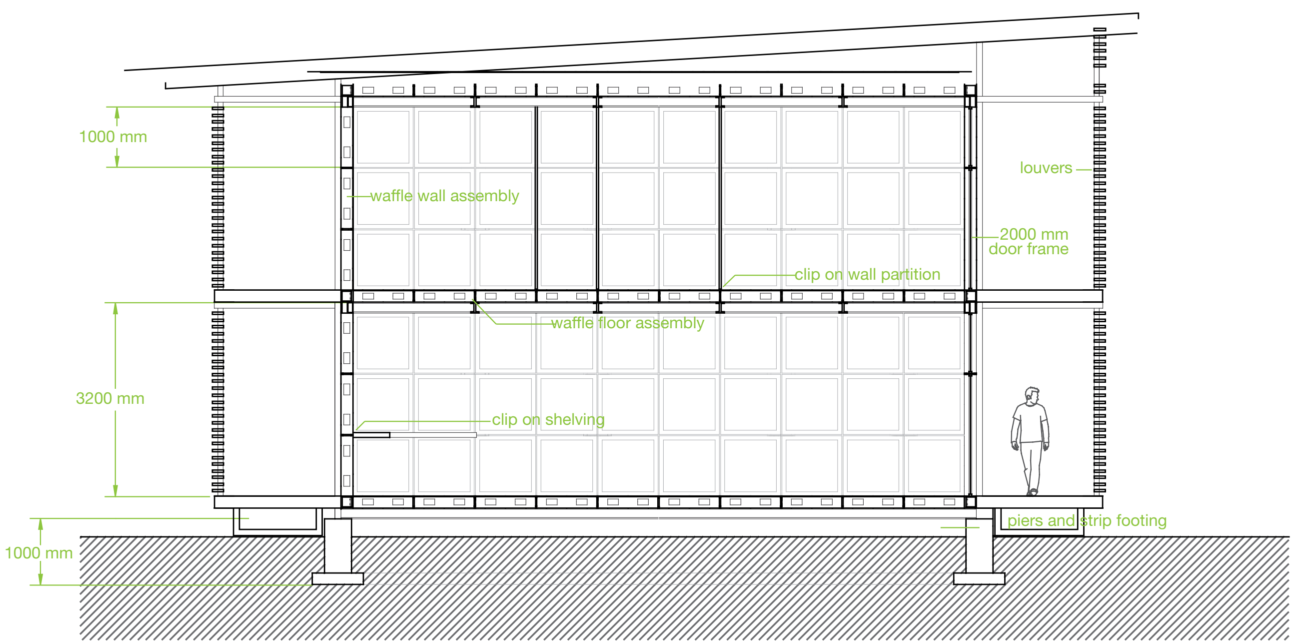
Interior Wall
Drywall, coloured acrylic, pop-in sheet metal panels.

Finished Floor
Porcelain tile or local hardwood. (Sized to fit over panel flange and allows for interior wall channels.)



SITE VARIATIONS

Basic Unit, Section | Guanacaste

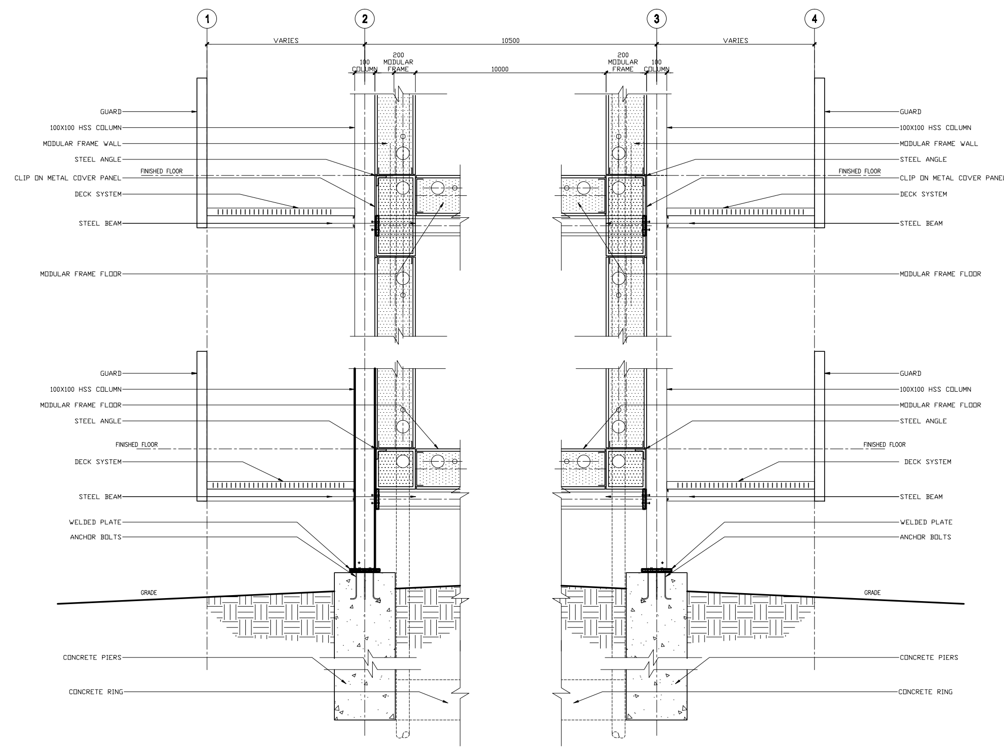


Section, Guanacaste
Since frost is not a consideration in Costa Rica, the foundation could be much more shallow. A small air gap could be left between the foundation and the structure to assist with air flow and cooling.

The roof would be enclosed with an insect mesh and would also provide a larger overhang to protect the building from sun and rain. Services would be shared between units on the joint, long walls.

SITE VARIATIONS

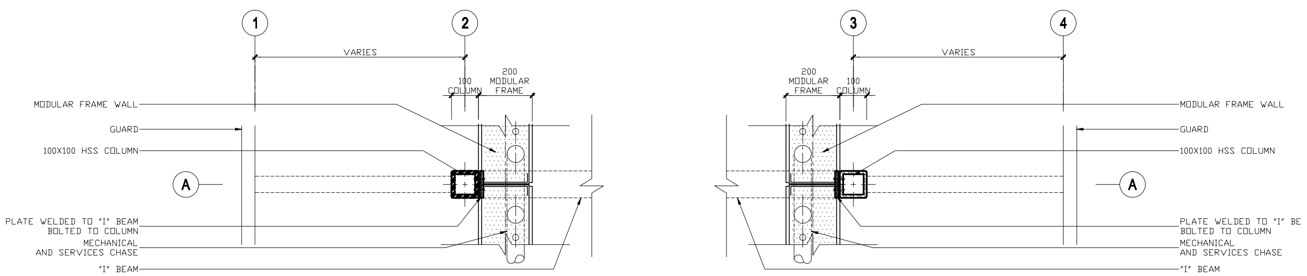
Basic Unit, Section Detail | Guancaste



Section Detail, Guancaste

SITE VARIATIONS

Basic Unit, Plan Detail | Guanacaste

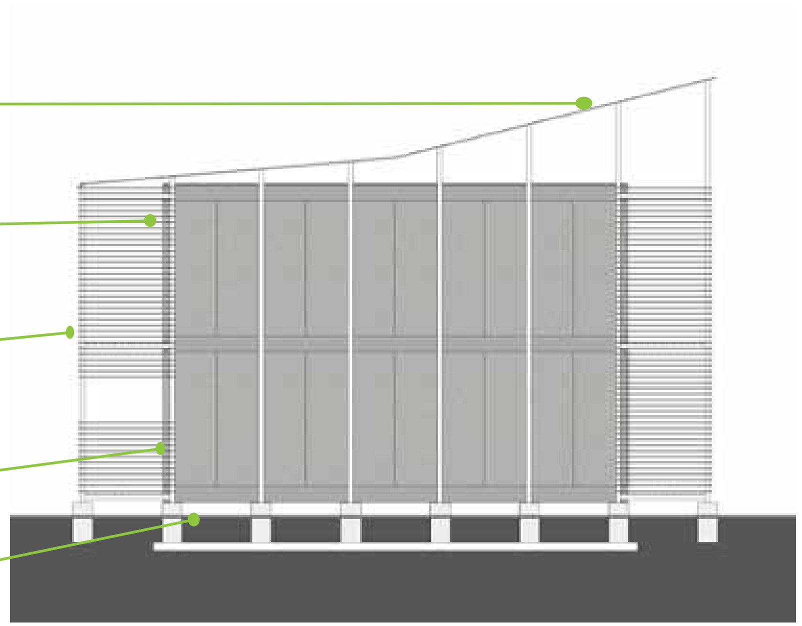


Site Plan Detail, Guanacaste

"A vast array of technological innovations are needed to respond to the challenges of urban sustainability.... The feasibility and timescale of developing and diffusing many of the innovations depend on factors such as the discount rates used to determine their cost to benefit ratios and how their costs are defined, including those of externalities." Bugliarello, pg 73

MATERIALS SPECIFICATION

Exterior | Guanacaste



Roofing
Sheet metal or metal shingle on sheathing board

Glazing
Single pane with insect mesh (glass or plastic)

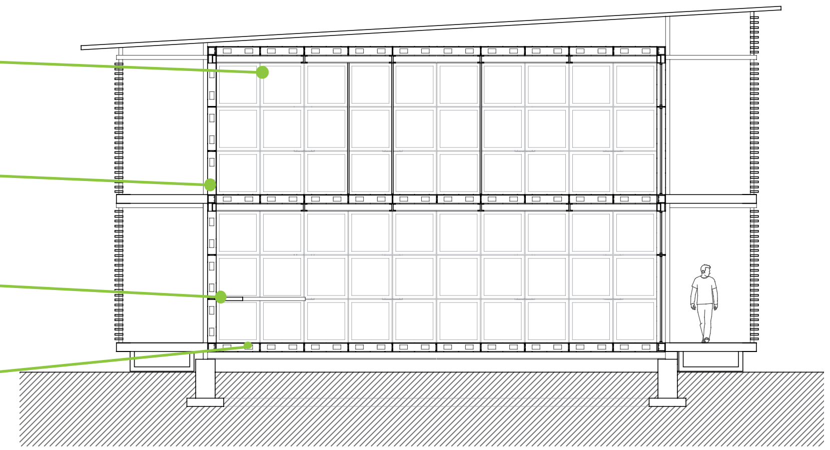
Exterior Cladding (Shell)
Cane Brava (bamboo) or thin wood strip and/or insect mesh.

Exterior Cladding (Wall)
Softwood siding or over Plyceme (Hardie-Board).

Foundation
Pier footing (cast concrete or helical). (Footing sizes will vary based on soil bearing capacity.)

MATERIALS SPECIFICATION

Interior | Guanacaste



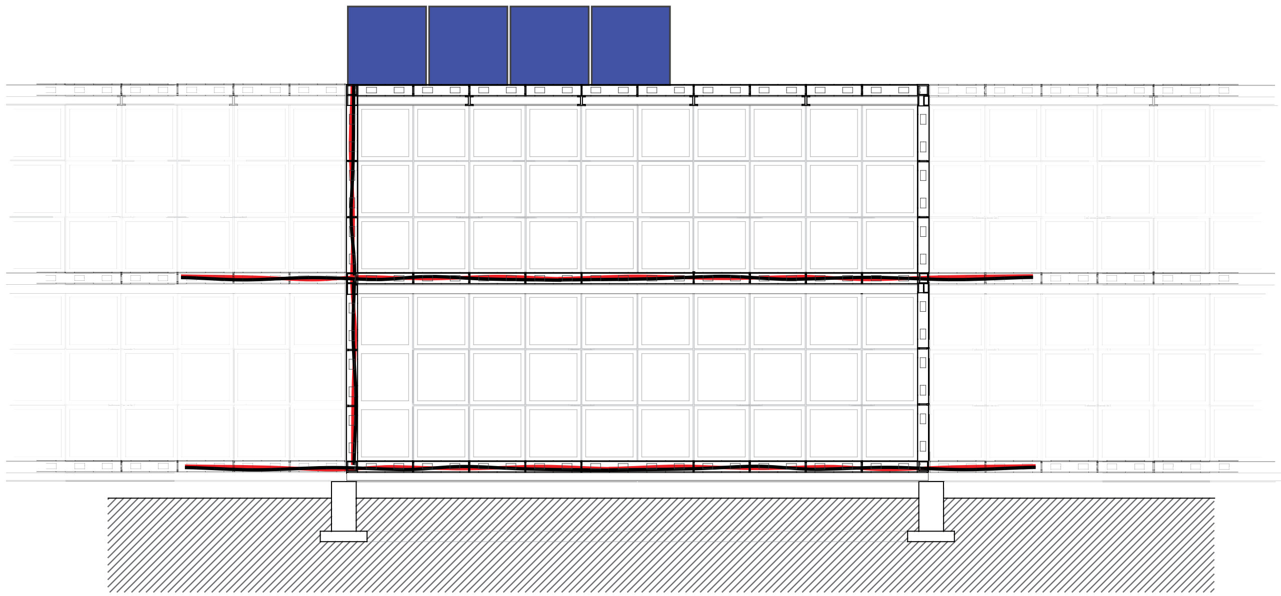
Ceiling
Coloured acrylic, wood strip or sheet metal.

Insulation
None required.

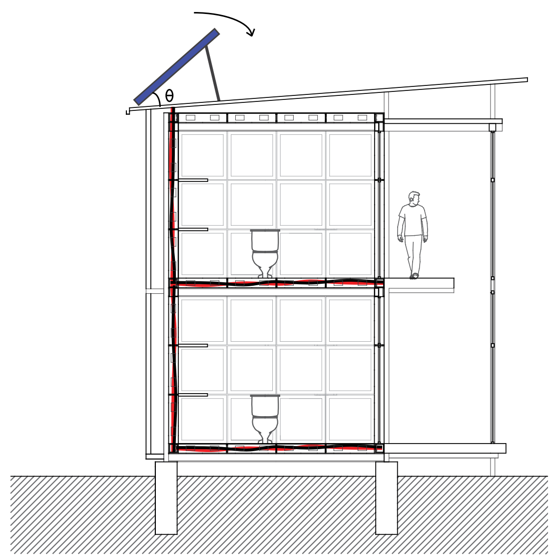
Interior Wall
Coloured acrylic, wood strip or sheet metal.

Finished Floor
Porcelain tile, bamboo or local hard-wood. (Sized to fit over panel flange and allows for interior wall channels.)

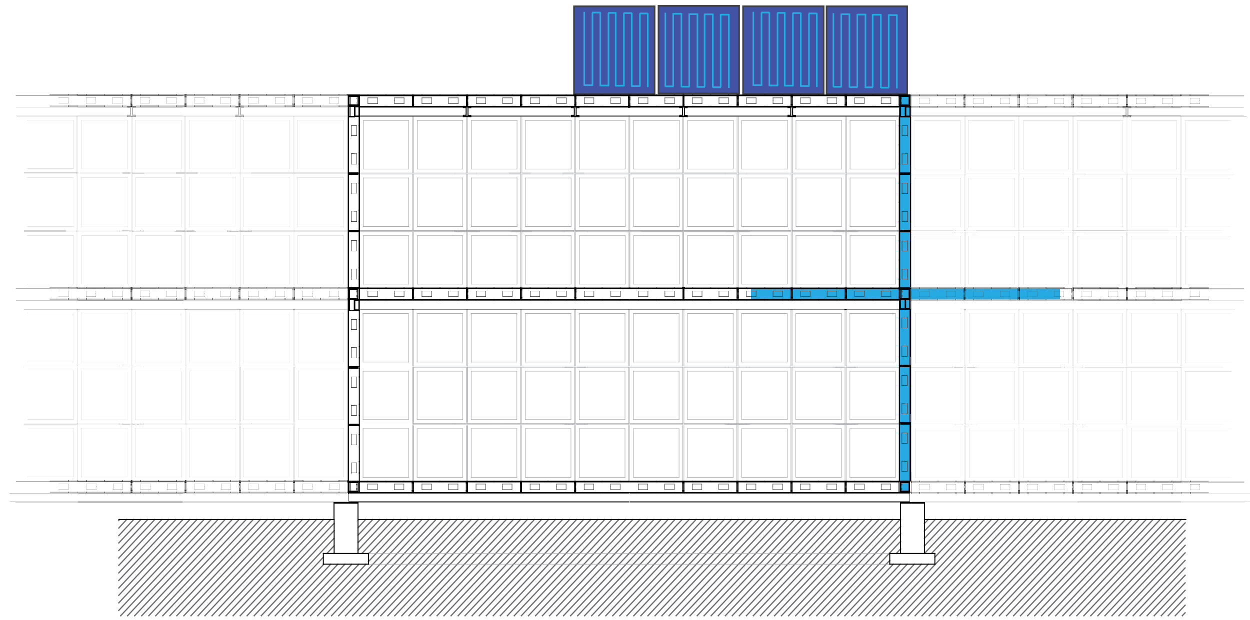
SYSTEMS INTEGRATION
Energy Management



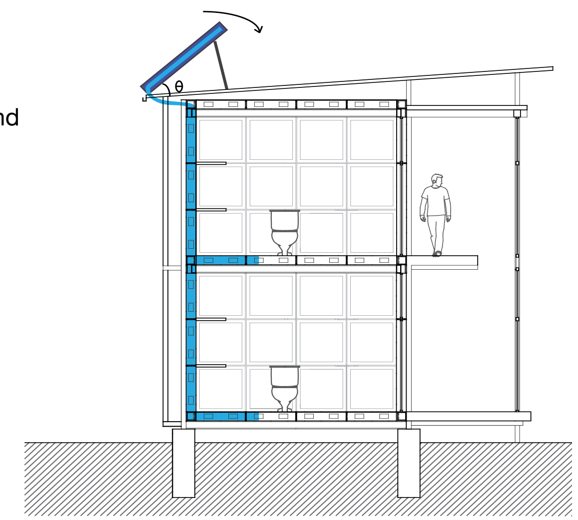
PV Panels
Adjustable solar panels on the roof could supplement electricity, with wiring running through the frames.



SYSTEMS INTEGRATION
Energy Management

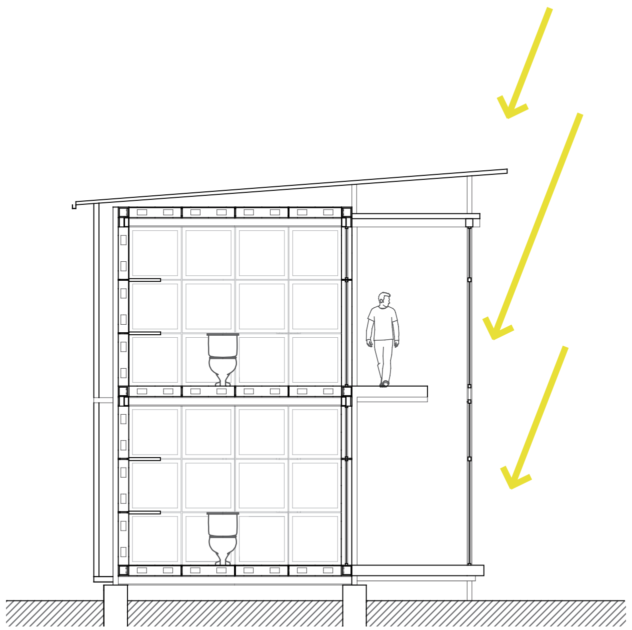


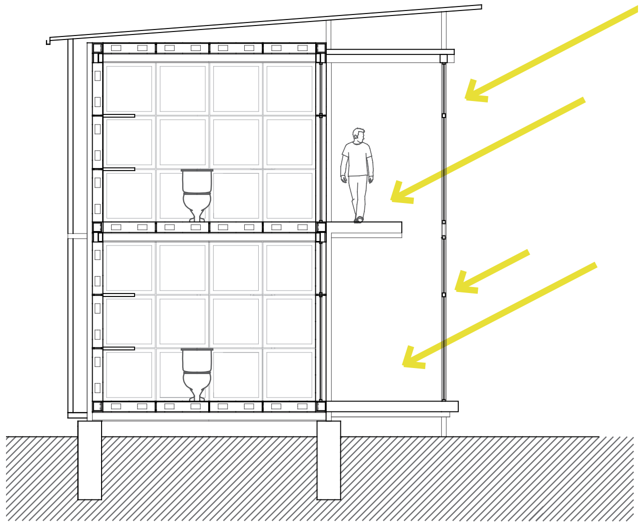
Solar Water Heating
Solar water heating could provide hot water throughout the year. Piping would runs through frames within the shared walls between units, which would also act as insulation. Additionally, an on-demand water heater could also be used to save energy.



SYSTEMS INTEGRATION

Heating, Ventilation and Air Conditioning



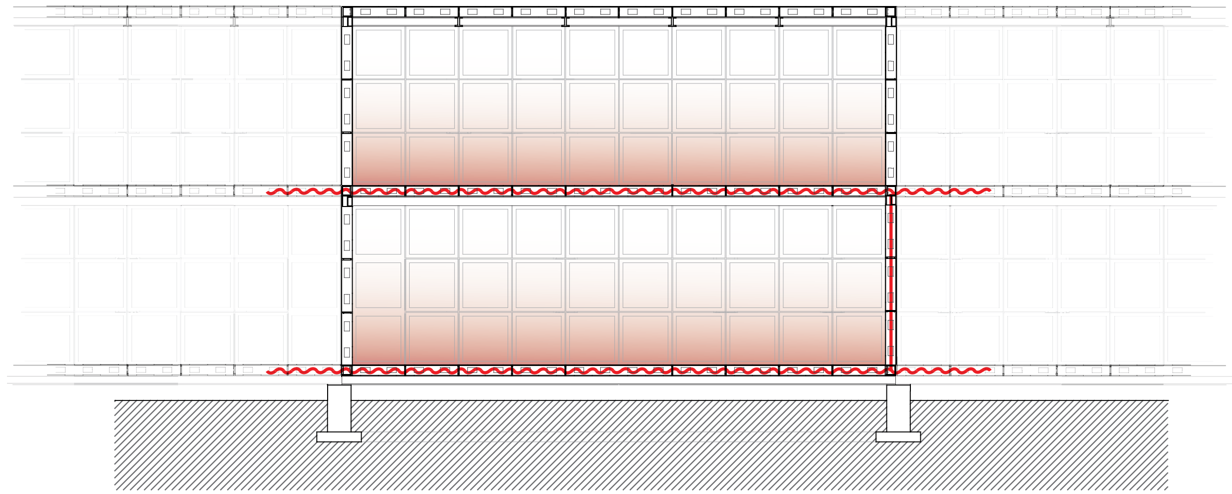


Passive Cooling
Overhangs provide protection from sunlight in the summer.

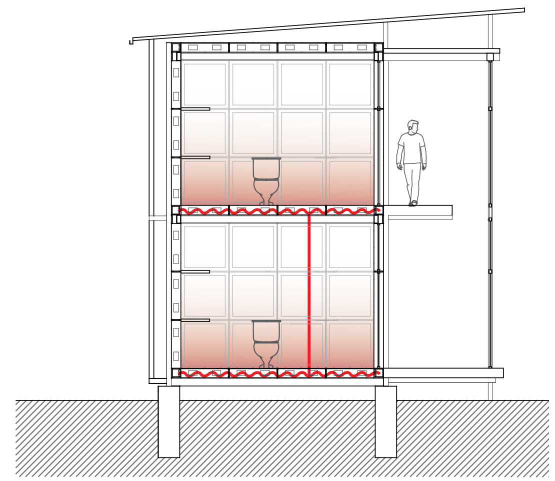
Passive Solar Heating
Glazing allows for passive heating in the winter. Concrete floor panels act as a thermal mass, collecting and storing heat, then slowly radiating it outwards. Additionally, a thermal mass could be created using rock, soil, water, cinder-block or brick.

SYSTEMS INTEGRATION

Heating, Ventilation and Air Conditioning

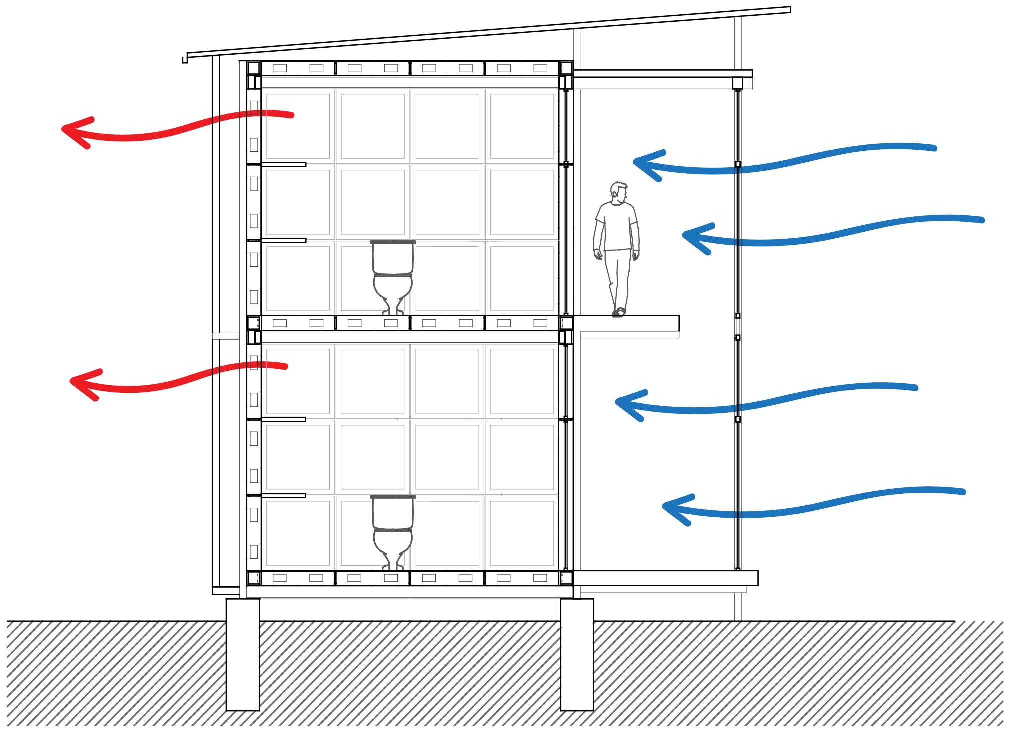


Radiant Floor Heating
Radiant floor heating could be installed within the flooring frames. This would allow large spaces to be controlled seperetely with separate circuits.



SYSTEMS INTEGRATION

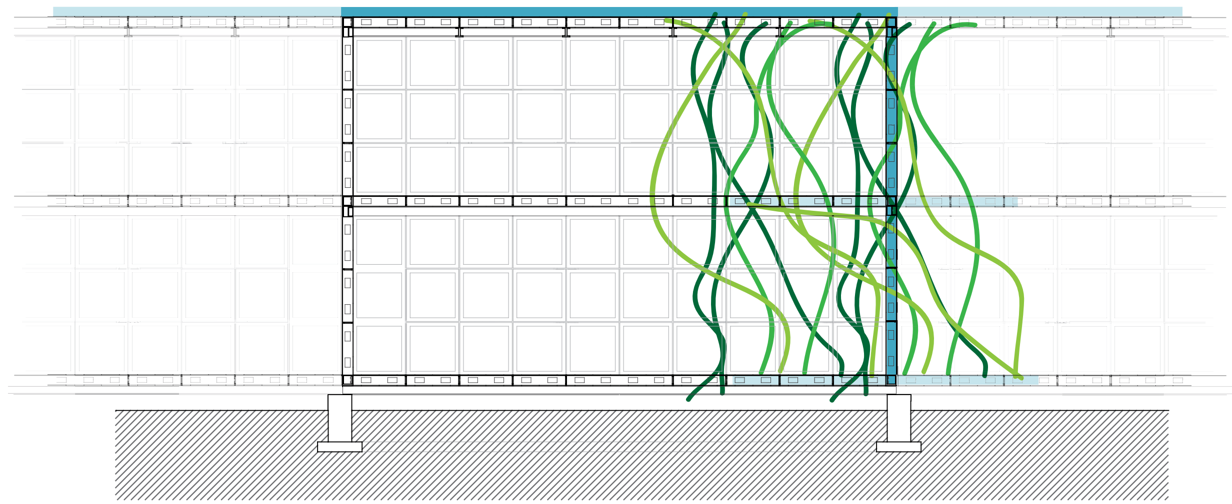
Heating, Ventilation and Air Conditioning



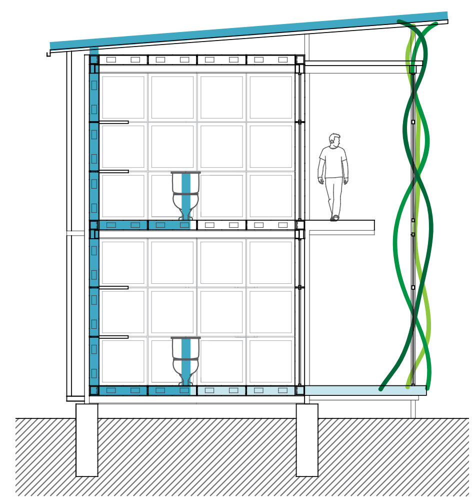
Natural Ventilation
Natural ventilation will cool the house in hot months, using operable windows on all sides and a gap at the top of the structure. The building's Tall ceilings will also assit with ventiliation. Additionally, evaporative water could be used in Costa Rica for cooling.

SYSTEMS INTEGRATION

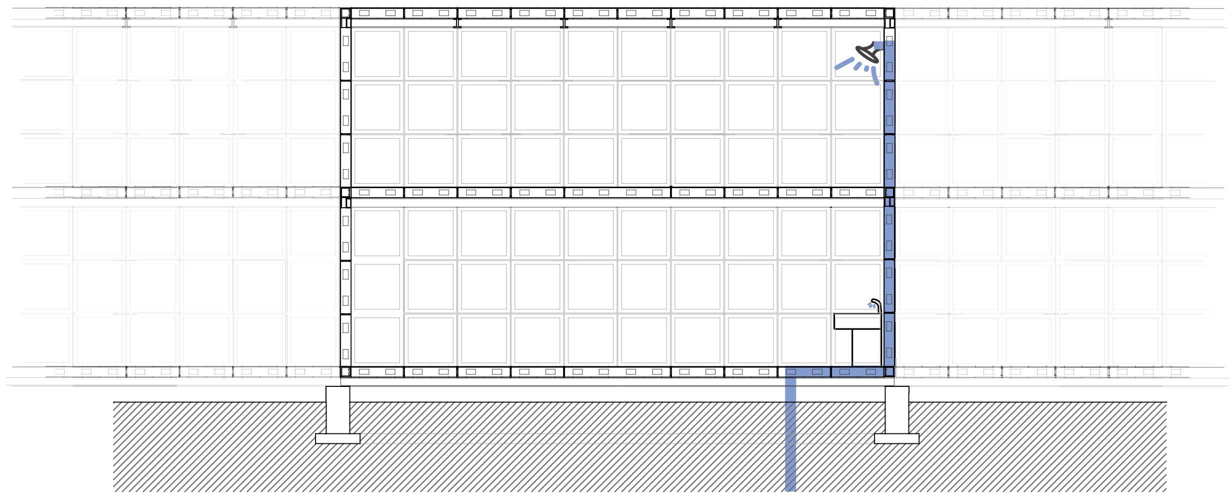
Water Management



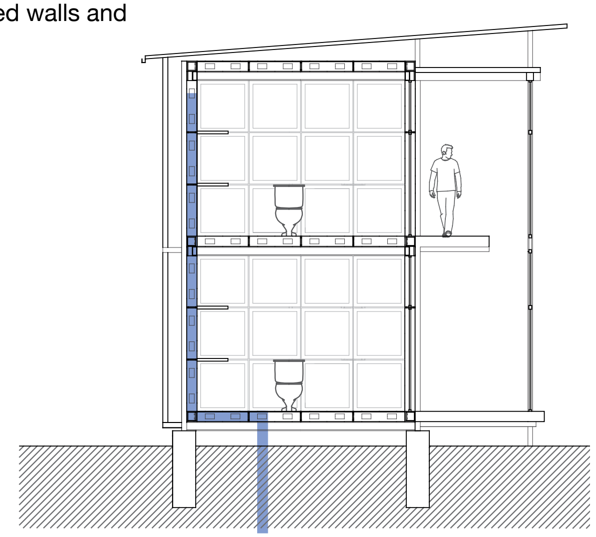
Rainwater
Rain water capture, filtration, and storage could be used for non-potable functions, such as flushing. This would require a separate set of pipes, adjacent to the potable water plumbing. Rain water can also be utilized as a means of irrigation, such as for a green wall which would also block the sun and cool the air.



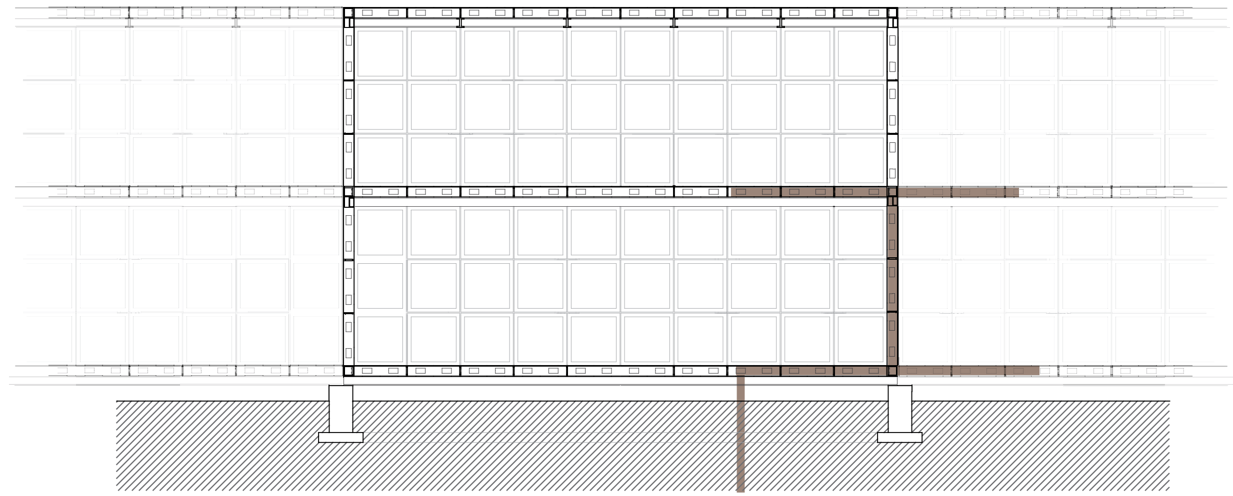
SYSTEMS INTEGRATION
Water Management

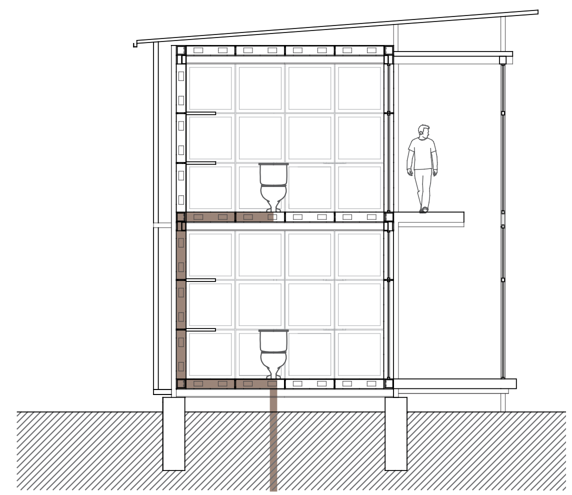


Water and Sewage Management
Conventional plumbing could be placed in the frames on the shared walls and can run through the flooring frames within individual units.



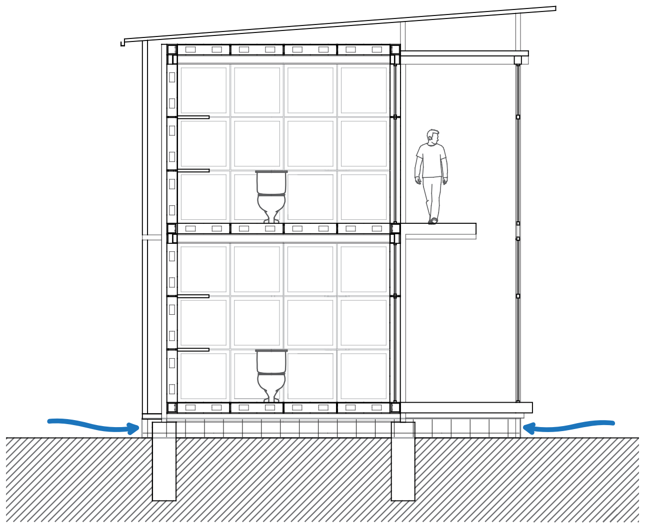
SYSTEMS INTEGRATION
Sewage Management

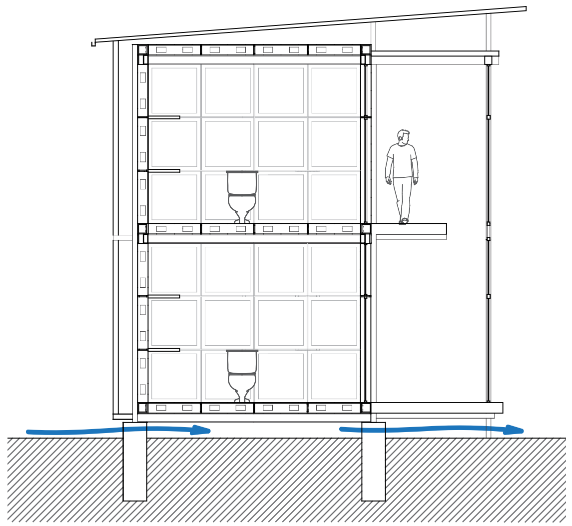




SYSTEMS INTEGRATION

Heating, Ventilation and Air Conditioning

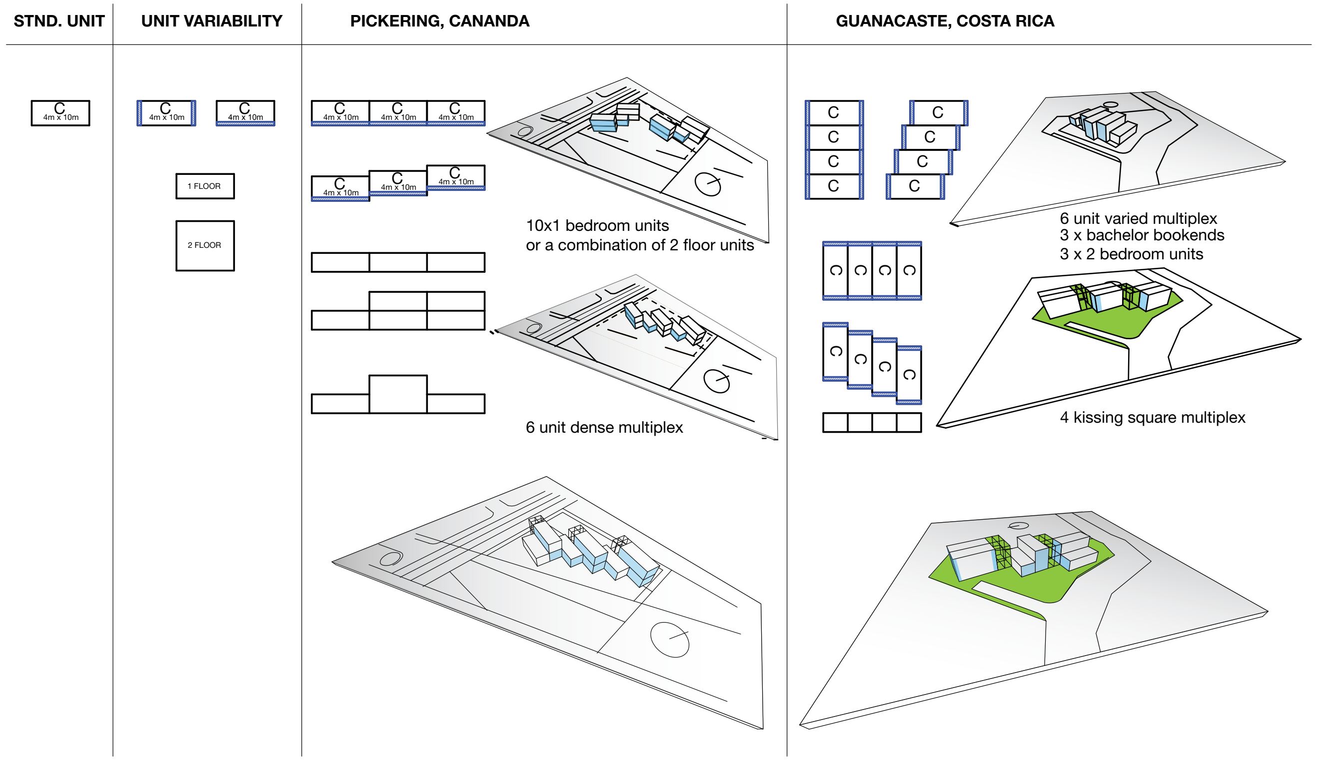




Foundation
Insulating the underside of the building will help prevent heat loss in the winter. Placing the foundation on pillars will allow for air flow under the building, helping to cool the building.

SITE VARIATIONS

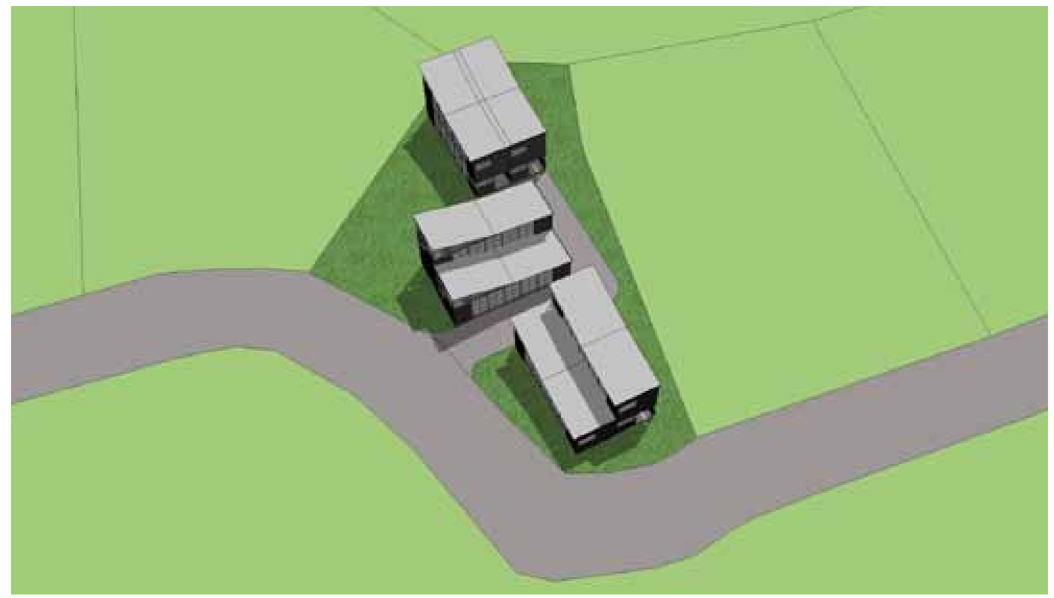
Site Clustering Options



Site Clustering Options

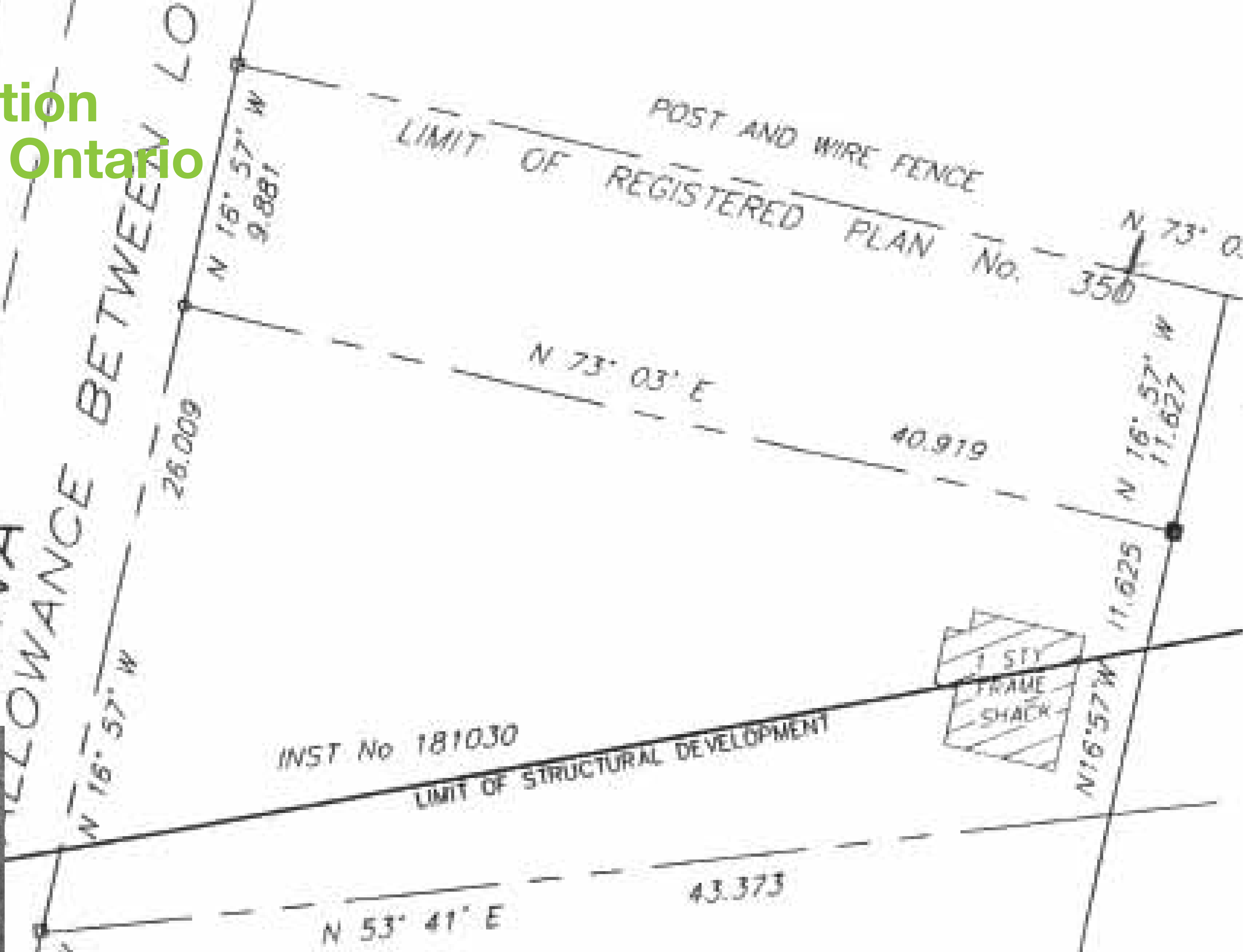
Units have been configured on each site to maximize use of space, while preserving outdoor living areas. Units could possibly be connected through their interiors to accommodate larger groups or families.

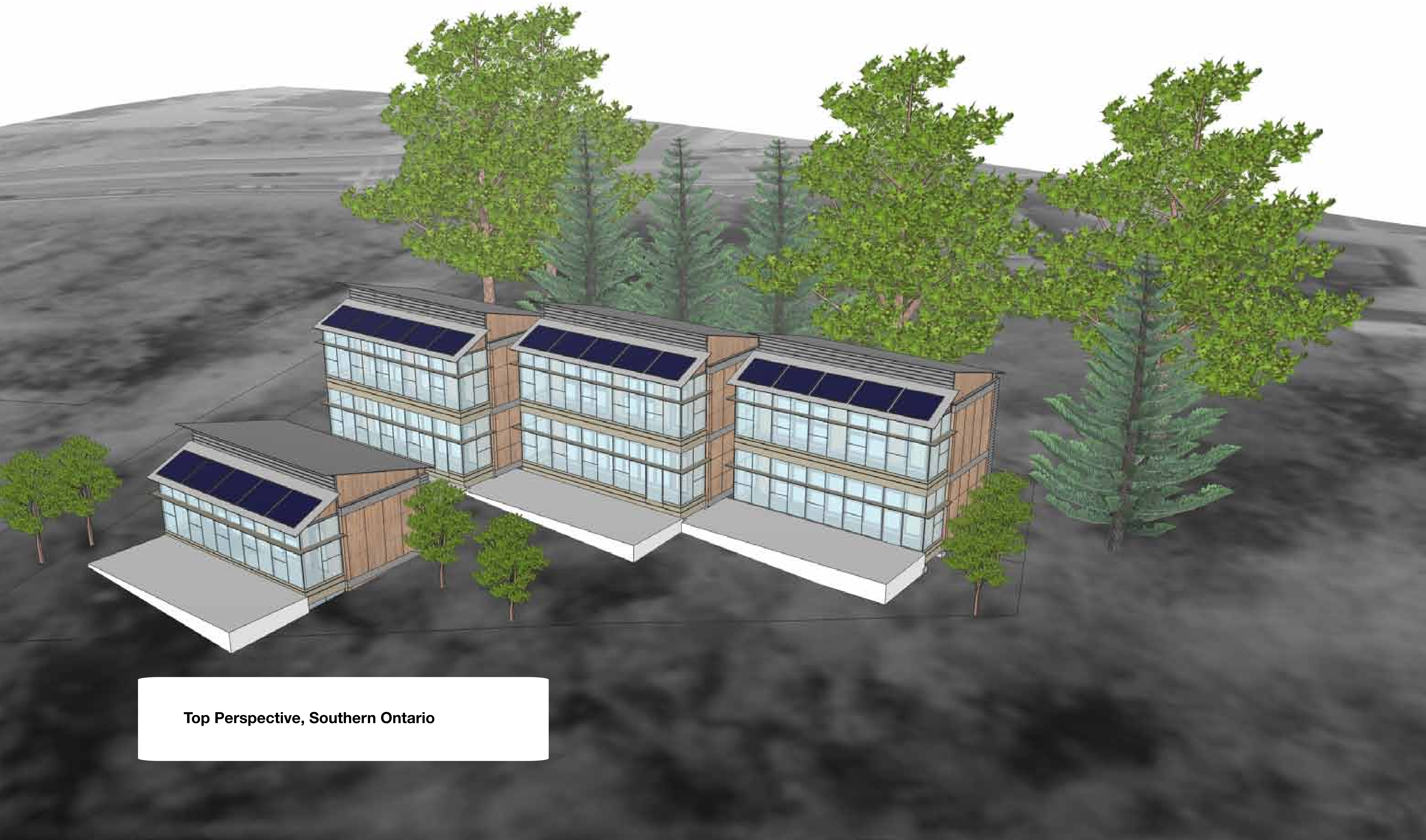
Southern Ontario, Canada



Guanacaste, Costa Rica

Site Variation
Southern Ontario
Canada





Top Perspective, Southern Ontario

South Perspective, Southern Ontario

East Perspective, Southern Ontario

North Perspective, Southern Ontario

West Perspective, Southern Ontario

Site Variation Guanacaste Costa Rica

Top Perspective, Guanacaste

North Perspective, Guanacaste

West Perspective, Guanacaste

South Perspective, Guanacaste

Private Walkway, Guanacaste

West Perspective, Guanacaste

6.0

Modular Housing System: Evaluation

SYSTEM EVALUATION

Building with the Open Lattice system compared to conventional and contemporary residential construction techniques.

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	THE OPEN LATICE SYSTEM	WOOD STUD FRAMING	STEEL STUD FRAMING	CONCRETE BLOCK/LIFT SLAB	SIP PANELS
COST Total construction and installation of fixtures and systems within a basic model results in a total cost of $180/ sq ft.		●●● Prices fluxuate.	●● Prices remain steady		
VALUE Design choices result in combined and multiple benefits.	●●●● The frame eliminates the needs for double studs and lintels. System would standardize window and door frames.			●●● Requires little insulation.	●●●● Light, structural and insulative.
EASE OF ASSEMBLY Minimizes time, specialized equipment and specialized training required for complete installation.	●●●● The system's predetermined dimensions and schematic design options eliminate on-site calculations and measuring. The system's components also act as a measuring tool. The square studs, when attached, provide rigidity for lifting into place.	●●● Requires a trained framing team, resulting in higher labour costs.		●● Requires skilled labour (masons) to install, for which there is currently a shortage in Costa Rica.	●●●● SIP construction decreases framing time. Also, sections can be manufactured with openings roughed-in so additional work to walls is minimal. The panels can be cut on site if necessary. New technology may be unfamiliar to some labour forces. Premanufactured.

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	THE OPEN LATICE SYSTEM	WOOD STUD FRAMING	STEEL STUD FRAMING	CONCRETE BLOCK/LIFT SLAB	SIP PANELS
EASE OF MAINTENANCE Minimizes specialized parts equipment and training required for repairs and upkeep	●●●● Components of the system can be isolated and repaired (for example, if a wall section is affected by water damage).				●●● According to some trade sites, there can be issues with SIP panels' breathability, and they may require additional venting to address interior moisture.
DURABILITY Resilient to the environmental conditions of the specific climate, natural phenomena, pests and standard usage patterns of a residential unit	●●●● High rigidity Has high compressive strength	●●● Wood studs are subject to warping. Wood can be attacked by insects.	●●●● Resistant to mould, rot, and insects. Non-combustable Will not shrink, split or warp. Subject to rusting if penetrated by water. Subject to melting in a fire.	●●● The resulting structure will be very durable, although the material will degrade over time if exposed	●● OSB has the tendency to delaminate and deteriorate.
SUSTAINABILITY Performs well on a life cycle cost analysis and demonstrates 'best practices' in sustainable building, including energy efficiency. Can integrate with regionally specific materials.	●●● Minimizes use of concrete. Double envelope is designed to manage the climactic extremes of the two regions. Minimized site impact as a result of pier foundation.	●●● Wood is considered to be a renewable material, other than the fact that forests are demolished. It also has low total emboddied energy.	●● Steel manufacturing includes high embodied energy, however waste is 100% recyclable. Contains thermal properties.	●●● Concrete is not sustainable.	●●● Highly insulative

	THE OPEN LATICE SYSTEM	WOOD STUD FRAMING	STEEL STUD FRAMING	CONCRETE BLOCK/LIFT SLAB	SIP PANELS
MOBILITY Light to ship and simple to de-construct for reuse of parts	●●●● Bolt attachments can be undone and reused.	●● Wood beams are typically connected using screws.		●● Concrete block cannot be moved once set in place.	●●●● Wall sections are easy to ship and also to transport around the site, depending on the size of each segment.
FLEXIBILITY Easy to modify, add and subtract spaces and features.	●●●● Could be prefinished on both sides or one (for example, on the exterior to allow interior customization)		●●● Design flexibility as a result of strength		●●● Limited in the kinds of finishes that it could accept

SUMMARY

In conclusion, the primary benefits of The Open Lattice system over other residential building systems are ease of assembly on site, as well as the built-in double envelope/ double skin, which allows for climatic customization.

The system could be built with steel or wood, depending on desired outcomes. For example, wood is claimed to be a more sustainable material, although steel may be more durable long-term, as it is less likely to degrade as a result of insects or rot.

7.0

Modular Housing System: Project Implementation

PHASE 1
PROJECT PLANNING

Although this modular housing system has been designed to suit many possible contexts, a pilot project should be developed according to the constraints of a specific context and user group.

At this point, the details of the design could be accomplished at varying scales of complexity. Factors that will affect the decision making process during design development include:

Materials Strategy
Components could be built using off-the-shelf materials, or with custom designed elements. The system could be executed using standard products, such as wood and screws, custom manufactured pieces, such as extruded plastics and metals, or a combination of both. The latter two would likely require some degree of fabrication in a factory.

Fabrication
Components could be fabricated by machine in a factory, or by hand on site. The latter would likely require skilled labour.

Installation
The system could be installed using a trained labour force, a supervised team of unskilled labour or a local team of friends and building enthusiasts. The latter would require a system that is simple to work with.

Shipping
The system could be achieved using exclusively Canadian materials, or could integrate ones sourced within Central America. If the materials are sourced exclusively in Canada, this would affect shipping costs.

Property Management
Unit services could be grouped and managed by one party, or separated to be maintained by individual inhabitants. This would likely depend on the management scheme for the complex, for example, rental versus sales.

Building Code
Each site would be subject to its own set of regional regulations, and should be refined accordingly.

PHASE 2
BUSINESS PLANNING

The ultimate model for delivering the units will affect possible funding avenues for the project's development. For example, if it is simple to construct, a sweat equity model may be appropriate. If it is cheap to produce, it may work as government subsidized housing. If it has low long-term operating costs, it could be profitable as a rental unit.

A preliminary plan should be envisioned at the outset of the project in order to coordinate resources to fund the pilot project. At the same time, completion of the pilot project will reveal the assets and weaknesses of the building system and therefore which approach to delivery is most applicable.

For example, if it is simple to construct, a sweat equity model may be appropriate. If it is cheap to produce, it may work as government subsidized housing. If it has low long-term operating costs, it could be profitable as a rental unit.

PHASE 3
PROJECT FINANCING

Financing for the ongoing design development and delivery of this system could work with a mix of the following models:

Capital Investment, Joint Venture
This approach would be applicable if the project's primary long-term goal is generation of profit.

Grants, Subsidies and Tax Breaks
This approach would be applicable if the project's main premise were aligned with that of the Ministry of Infrastructure or the government of Ontario. Such alignments could occur for example, if the project were intended to reduce overall energy expenditures of the housing sector, provide social infrastructure, achieve innovation in design research of sustainable technology or create jobs.

Sponsors and Partnerships
This approach would be applicable if the project was seen to be of potentially high profile nationally or internationally.

PHASE 4
PROTOTYPING, PRODUCT TESTING AND DESIGN DEVELOPMENT

Once these factors have been analyzed, the next step would be to engineer each building component, testing against desired performance criteria. For example, such criteria could include an extension of those already listed in this report (i.e strength to weight ratio, embodied energy, etc.).

This could also include completing a lifecycle cost analysis or a LEED for Homes analysis. In addition, this analysis may include review of fair labour practices.

The prototyping phase could also investigate all of the possible variants of the system. For example:

- Building the frame with wood and steel.
- Creating the connections as extrusions, with steel plates and with laminated plywood.
- Modifying the square stud for each of its applications: wall, ceiling and floor.
- Adding services and cladding to the square studs prior to site installation or during.

It is preferable to be comprehensive during the testing phase, rather than dealing with failure within a finished project. For example, potential product failures could occur with strength, water leaks, heat loss, mould build-up and deterioration of parts. These potential issues should be identified and resolved prior to implementation of the pilot project.

PHASE 5
PERMITS AND APPROVALS

Once the design drawings for the pilot project are complete, the approvals process with the authorities having jurisdiction in each region may take from 6-12 months to complete. In the interim, the process of obtaining bids from contractors, trades and suppliers could begin.

PHASE 6
IMPLEMENTATION OF PILOT PROJECT

Depending on resources implementation of a pilot project could take place as a self-build or with a designated project manager and general contractor.

It should be anticipated that the pilot will take longer to execute than subsequent builds, as a result of the steep learning curve. For example, trades people may require an orientation day before working with the system. As well, any specialized components should be fabricated in advance to the build.

PHASE 7
PROJECT EVALUATION

Following the pilot project, the system should be reevaluated on designated performance criteria.

Appendices

APPENDIX A:
SITE PROFILE, SOUTHERN ONTARIO

PICKERING, ONTARIO, CANADA

The owner's site in Pickering was originally developed in 1917. Today, site contains his personal home in the original structure. In addition, the original barn structure remains, which was redesigned and built by the owner as a rental property. This unit is currently used as a residence and office, and includes approximately 500 sq ft of parking.

SITE DEVELOPMENT

At present, the owner is undertaking renovations on his personal home and is interested in testing the charrette results on a garage addition. He also hopes to acquire the adjacent property, which is currently owned by the Ministry of Transportation, to possibly build residential units for rent or sale. Potential target audience groups could include families, seniors or students. The owner is interested in offering a rent-to-own scenario for students with portable units that could be relocated following their purchase. During the charrette, the team will focus on a multi-unit option for the adjacent property. The owner's hope is to acquire and develop this land within the year.

SITE CONDITIONS

Location: The owner's property is located at 1312 Alona Road, in Pickering Ontario, about 20km east of the town's centre. Pickering is neighboured by Markham in the north, Whitby in the east, Toronto in the west and Lake Ontario in the south.

Neighbouring Features: Two major roadways border the property – the 401 highway in the south and Regional Hwy 2 in the north. The Rouge River also passes along the west side of the property from the north and empties into Lake Ontario. The local area includes a strip mall (to the north), townhouses (to the north) a doctor's house (to the east), Binn's Kitchen (to the east) and a Montessori school (to the east). Other nearby features include the Metro Toronto Zoo, Rouge Hill Beach Park, the University of Toronto - Scarborough, Centennial College-Progress, the Annandale Golf and Country Club, and the Pickering Generating Station.

Circulation: The owner's existing property is accessed from Regional Highway 2 off of Altona Road. This road is a dead end and has the potential to be privatized.

Zoning: There are three types of zoning within the area: mid-level industrial, residential and commercial.

Conservation: The site sits next to Glen Rouge Park, which is part of the greater conservation area of the Rouge Valley Park and the Southern Ontario Greenbelt. The Rouge Park runs north-south from Stouffville to Lake Ontario, between Toronto and Pickering. "Rouge Park is over 47 km2, protecting two National Historic Sites and a variety of ecosystems joining the post-glacial Oak Ridges Moraine, roughly 50 km north of Toronto, and the City's biggest wetland, where the Rouge River empties into Lake Ontario." (Rouge Park. About Us. http://www.rougepark.com/about/index_about.php). Part of the conservation efforts for this region mandate municipalities to follow certain ecological criteria in urban development. The Park also undertakes annual ecological restoration work, which includes scientific research, tree planting and stream rehabilitation.

Drainage: The owner's property slopes steeply downward toward the two highways on the north and south and into a woodland and the Rouge River on the west.

Vegetation and Wildlife: The study site contains an uneven tree line, with both coniferous and deciduous species, that fronts both sides of Altona Road and the back fence, and cuts through the back third section of the property. This back area is also filled with mixed brush. The front 2/3 of the property contains trimmed grass.

Climate: "Moist Continental Climate, Deciduous Forest Biome: This climate is in the polar front zone - the battleground of polar and tropical air masses. Seasonal changes between summer and winter are very large. Daily temperatures also change often. Abundant precipitation falls throughout the year. It is increased in the summer season by invading tropical air masses. Cold winters are caused by polar and arctic masses moving south. Temperature Range: 31 °C (56 ° F). Average Annual Precipitation: 81 cm (32 in). Latitude Range: 30° - 55° N and S (Europe: 45° - 60° N)." (World Climates. http://www.blueplanetbiomes.org/climate.htm) "One thing that is interesting about this biome and its climate is that it has four distinct seasons; spring, summer, autumn, and winter." (http://www.blueplanetbiomes.org/deciduous_climate_page.htm)

Characteristics: The owner's property boasts a modest view of the Rouge River at the bottom of a woodland. As well, there is a significant amount of noise pollution emanating from the 401 highway. This noise is less significant at the north end of the site, possibly as a result of the central tree line.

Services: The property currently manages its waste using a septic tank.

Architectural Design Precedence: This part of Pickering is developed primarily with townhouses and large, single unit properties. Many of its homes are approximately 2000 sq ft with three storeys, sport multi-car garages in the front, spacious backyards and swimming pools in the back.

APPENDIX B:
SITE PROFILE, GUANACASTE

GUANACASTE, COSTA RICA

The study site in Guanacaste, Costa Rica is located within the Surfside Estates subdivision. This development houses a mix of foreign and local owners, many of who are retired and typically visit the area between November and April.

SITE DEVELOPMENT

The owner's intention is to develop the study site with residential units for personal use, rent and/or sale. Possible target audience groups could include tourists, foreign students and researchers, or local workers. The owner is also considering developing a collaborative research facility, which could be placed on his other empty farm plot nearby.

SITE CONDITIONS

Location: Surfside Estates is located on the northwest coast of Costa Rica, close to the town of Potrero and spans the length of Potrero beach. The beach sits within a protected bay and is therefore a low-traffic area. The beach is known for sport fishing and diving and, frequently harbors visiting cruise ships. Its marina is currently out of operation, but many boats are still moored in the bay. The study site is a 45-minute drive southwest from the Liberia airport, and a 20-minute drive north from the major coastal town of Tamarindo.

Real Estate: The Surfside Estate lots are priced starting at $65,000, waterfront building lots at about $800,000, and mainland homes for approximately $200-400K. Directly south of the Surfside Estates is the Flamingo Beach Resort, a luxury residential development with homes upwards of $1,000,000.

Construction: Construction costs in this region average at around $100/sq ft.

Circulation: There is paved road access to the Potrero area and dirt road access to the study site.

Geography: The site is nestled in a valley bordering the Pacific ocean, with surrounding peaks averaging around 200m.

Vegetation and Wildlife: The study site borders a small, protected greenbelt. It also contains protected tree species, such as the Guanacaste. Pests: The region is known for termites scorpions and spiders. In the dry season, mosquitoes appear 1/2hr before sunset.

Native Species: Local monkeys use trees for transportation. Many resident bird species including Macaws, parrots and finches.

Climate: Guanacaste, Costa Rica experiences two extreme seasons - wet and dry.

Sun Patterns: Sunrise, 6am. Sunset, 6pm.

Prevailing Winds: April-Dec, Northeast, 6-9km/hr; Dec-Feb, East, 14-16km/hr; Feb-April, Northeast, 15 km/hr.

Characteristics and Features: The Surfside Estates are patrolled by a security company and properties are fenced for safety.

Local Amenities: The local hardware store is a 45 minute drive.

Services: It is expected that foreign developers will install their own infrastructure as necessary. The Surfside Estates are serviced with telephone, cable, internet, electricity and water. The Surfside Water Board manages road maintenance, garbage collection, drainage and is investigating development of a sewage treatment plant.

Public Transportation: Local bus transportation is available for access to surrounding communities with morning and evening service. Horses are still used by local ranchers and have full access to all roads. Local residents use 4 wheel drive vehicles, off road motorcycles and bicycles. Golf carts are gaining popularity for getting around within the community.

Impact of Other Structures: Condominium developments are stressing local septic systems and water resources.

Architectural Design Precedence: Properties in the Surfside Estates are developed according to traditional Costa Rican vernacular, using a concrete structure, ceramic tile roofing, wrought iron barriers and pastel finishes. Mediterranean, Santa Fe and Modernist designs are now becoming popular with foreign developers.

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Links

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http://www.brightbuiltbarn.com/?page_id=6

Demaria Shipping Container
http://www.inhabitat.com/2008/10/03/demaria-shipping-container-house/

Kit of Parts (SIPs)
http://www.greenhomebuilding.com/QandA/manufactured/sip.htm

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