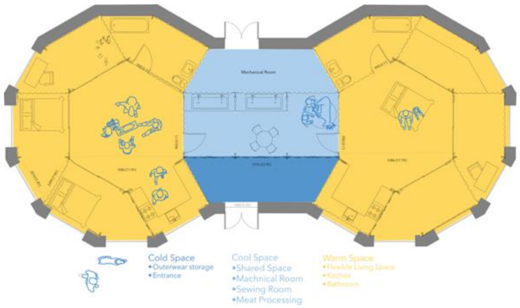
Solar Decathlon Design Challenge 2023

Concordia University
New Housing | 2023-04-03

Built For The North

Project Summary

Iqaluit, is located in Nunavut, Canada. This subarctic landscape reaches temperatures of -40 F, wind speeds of up to 62mph, and daylight ranges from 4 to 21 hours. For the past 5000 years Inuit communities have inhabited these extreme climates and continue to do so today, making up around 50 percent of Iqaluit's population. Today, Iqaluit is suffering from a housing crisis. Overcrowding is six times the Canadian average and sixty percent of Nunavummiut live in public housing, 98 percent of which are Inuit. Housing initiatives, starting in the 1960s, imported designs from the South that were insufficient for the climate and culture. Now a vast number of homes are deteriorating. Furthermore, the designs and materials do not address traditional practices, which creates opposition to Inuit culture. Access to adequate housing is essential for the wellbeing of Inuit communities. There is a need for housing that addresses the extreme climate and competing cultural needs. We are a team of 5 students in the Building Engineering program at Concordia University. It is with this in mind that we humbly attempt to address some of these issues around housing design in the Canadian North. We hope to present a project that will be more considerate to the needs of the modern Inuit family and appropriate for the extreme climate.



Design Strategy

The main pillars of our design are culture and sustainability. In-depth, preliminary research was also heavily valued. This is of particular importance due to the foreign geographic and cultural nature of Iqaluit to our Montreal based team, but also due to the long history of colonialism experience by the Inuit people. Our design goals are to meet net zero, achieve zero waste and low embodied carbon, and attend to traditional practices. Our design will foster a sense of togetherness through collective spaces. Our structure will be composed of up-cycled shipping containers -a waste material of Iqaluit- and materials with low environmental impact from a full life-cycle perspective. Passive design and energy efficiency strategies and renewable energy technologies will be utilized. Prefabrication will also be key to delivering an affordable project in the short time available for construction in the arctic summer.

Project Data

- Location: Iqaluit, Nunavut, Canada
- 2 Family Units : ~ 2000 sq. ft.
- Heating Demand: 117,729 kBTU/ ft^{2}yr
- Climate Zone: 8 (subarctic)
- Construction Cost: 350$/sq. ft.
- HERS Score (without renewables):42
- EUI: 74 kBTU/ft^2/yr

Technical Specifications

HVAC : Hybrid Heating Design System

- Hydronic Heating System
  - Cold Climate ASHP (30kW)
  - Vegetable-oil fired mCHP (12kW)
- DualCore ERV (150-300CFM)

Energy: Hybrid Generation System

- Wind Turbine (3kW), PV (1.7 KW System), 26.6 kWh hybrid inverter + battery storage

Envelope: External Panel I-Joist Assembly

- Roof R-Value: R59
- Wall & Floor: R-Value: R50

Structure: Shipping Containers & Timber

- Foundation: Multi-Point Space-Frame

Supervisors

- Dr. Athienitis, Net-Zero, PV Systems
- Sarmad Al Mashta, Architect
- Dr. Zaheeruddin, Control Systems
- William Semple, Architect & Northern Housing Expert

Project Highlight

1. Architecture: Euro-Canadian housing programs, i.e. bedroom, kitchen, living room, do not properly address Inuit family needs. It is common for them to sleep together in the living room and use bedrooms for playrooms or workshops. Rather, Inuit communities describe space by temperature, cold, cool, and warm. The cold space is the entrance, the cool space is for sewing hides and processing meat, and the warm space is living space. The structural shipping containers are situated around a hexagon to create a central gathering space and the two units are connected by communal rooms.

2. Engineering: Prefabrication is a key component of achieving a high quality design in Iqaluit given the rainy summers and cold winters and the shortage of skilled labor. It ensures increased precision of envelope connections, a controlled environment avoiding built in moisture, a shorter time on site, and requires less skilled labor. Establishing prefabrication in Iqaluit would provide year-long construction and utilize the cost effectiveness of our design. The assembly process is, involves first laying the multipoint foundation, second the floor panels, third the structural shipping containers and timber, fourth the non-structural wall panels, and lastly, the roof panels.

3. Durability and Resilience: An extremely airtight and durable water resistance barrier is used to ensure water and air tightness, a high R-value will endure arctic temperatures, and continuous exterior insulation will prevent thermal bridging. The plywood and shipping container provide a vapor barrier to protect from condensation, and the final interior hemp-plaster layer will provide a second continuous air barrier. Furthermore, the multipoint foundation, designed for unstable soils, will accommodate for potential future melting of permafrost due to climate change.

4. Embodied Environmental Impact: All materials chosen are biodegradable or recyclable at end of life. Although materials must be shipped to Iqaluit, all materials are sourced within 20 miles from Montreal, to reduce as much CO_2 from transportation as possible. Waste vegetable oil could offer a renewable energy that is locally accessible, reduces waste, and reflects past traditions of using whale oil for lamps.

5. Comfort and Environmental Quality: To achieve thermal occupancy comfort, a high R-value envelope will be designed and a DualCore ERV implemented. A continuous supply of fresh air with high sensible and latent heat recovery is provided to maintain indoor air quality for dry indoor conditions in the cold climate. A centralized HVAC system is proposed for the house where a Cold Climate Air-to-Water ASHP will be supplemented by a vegetable oil-fired micro–Combined Heat and Power (mCHP) system for heating the hydronic heated floor system (propylene glycol-water). The construction materials selected for the spaces will provide and ensure acoustical comfort to the occupants. DualCore ERV selected for mechanical ventilation.

6. Occupant Experience: The implementation of the smart hybrid inverter with battery storage will provide seamless transition of sources for heating and on-site generation. The flexibility of the design can provide a large communal space providing occupants the ability to continue their family cultural traditions. Hemp plaster and woods are chosen for the interior finishes, which will provide thermal storage, acoustic quality, and a warm aesthetic.

7. Integrated Performance: The building form and orientation was designed in relation to local sun and wind patterns. Matlab simulations determined optimal wall R-value and window to wall ratio. Combination of wind turbine, PV system, mCHP and the hybrid inverter with battery storage provide energy to meet and surpass demand.

8. Energy performance: Simulations have been performed to ensure energy efficient systems. The design has a HERS score (without renewables) of 42. The building achieved Annual Net Zero using wind, solar, and biofuel. The entire carbon footprint of these renewable energies will be used to determine sizing and the best combination.

9. Market Analysis: Iqaluit has minimal local resources and skilled labor. Logistic costs can be reduced through prefabricated assemblies. Volume makes up the greatest cost. A I-joist wall system allows for compact shipping, while maintaining a thick wall with high R-value. Using the shipping containers for the structure, is also considered to reduce costs and local waste.