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Nunamiutuqaq (Building from the Land)

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NUNAMIUTUQAQ (BUILDING FROM THE LAND)
Bridging Culture and Climate Sustainability through Architecture in the Canadian Arctic[1]

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"We receive from the land, and we know that. The land, the people, and the animals live harmoniously with each other. And if you respect the land, and the animals, and the water, they will in turn respect you."

—Emily Angulalik, Executive Director of Pitquhirnikkut Ilihautiniq / Kitikmeot Heritage Society

The concept of sustainability—and its connotations of reciprocal respect between people, wildlife, and the surrounding natural world—is a driving cultural force for Inuinnait, a culturally distinct, regional group of Inuit[2] living in the Central Canadian Arctic. In contrast to Western understandings of the term,[3] Inuinnait visions of sustainability—as indicated through Emily Angulalik's quote above—are often less oriented to conserving environmental resources for purposes of future exploitation, than to cultivating and maintaining an enduring state of balance and understanding between human and natural worlds. It is within such a balanced ecosystem that the unique identity, language, and values of Inuinnait culture have resided for hundreds of years, and upon which its continuation depends.[4]

Traditionally, the sustainability of the built environment has been a lesser concern for Inuit. For centuries, Inuinnait were a nomadic people literally at home on the land, with the physical landscape providing all the materials needed to survive and thrive in the extreme climate of the Arctic. Winter houses, *igluit*, were made of snow. Summer tents, *tupiit*, were created from the skins of caribou and other animals that

FIG. 1. THE LOCATION OF CAMBRIDGE BAY (SITUATED ON VICTORIA ISLAND) IS INDICATED AT LEFT, WITH A CLOSE-UP VIEW OF THE INUINNAIT REGION, AND CONTEMPORARY INUINNAIT COMMUNITIES INDICATED IN THE RIGHT-HAND IMAGE. | PI/KHS USING BASEMAP SOURCES FROM GOOGLE MAPS AND WIKIPEDIA.

sustained Inuinnait with food. Driftwood and the tree line at the southern edge of their territory provided wood needed to frame tents, buildings, and transportation. Like many highly nomadic Indigenous groups, the success of their architecture does not solely rely on the enduring quality of materials but rather on the access to and sharing of cultural knowledge.

Beginning around 1910, as outside cultures, ideas, and materials were introduced to the Inuinnait region, the concepts of architectural sustainability underwent a transformation. Critical knowledge surrounding Inuinnait architecture—in terms of both its vernacular design and construction materials/methodologies—began to be lost. Inuinnait experiences of the built environment moved from their own knowledge base toward a more foreign logic of federal policy, building codes, and design.[5] In the present day, housing built in the Arctic is often high-cost, made with low-grade materials, and designed in ways that do not support the cultural traditions of Inuinnait.[6] Buildings became imposed on Arctic landscapes, people, and cultures, rather than integrating them into their design. At the structural sustainability level, these issues have led to a breakdown in building efficiency, giving rise to various problems such as overcrowding, mold growth, heat loss, and increased energy consumption. At the level of social and cultural sustainability in Northern communities, the impacts have been even more profound. As remarked by Peter Dawson,[7] northern architecture has a history of being "spatially designed around EuroCanadian concepts of family, community, economics and administrative control," quite literally leaving no space for the expression of Inuit ways of life. This has ultimately undermined the foundations of Inuit traditions, including kinship, sharing, social relations, food consumption, and hunting and gathering lifestyles.[8]

Nunamiutuqaq, meaning "Building from the Land," is an Inuit-led program specifically crafted to realign architecture with the unique characteristics of the northern environment, its people, and language. The initiative aims to explore how Inuit-driven priorities for sustainability, emphasizing coherence and respect between human and natural environments, can be seamlessly integrated with the practical material requirements of northern infrastructure. In 2019, Pitquhirnikkut Ilihautiniq (PI/KHS)—an Inuit-directed cultural centre based in Cambridge Bay, Nunavut—teamed up with the Southern Alberta Institute of Technology's (SAIT) applied research group called Green Building Technologies Access Centre (GBTAC) to better understand how traditional Inuinnait building design and priorities for the environment can inform energy-efficient infrastructure in the North. This team—including Qillaq Innovations, Aurora Energy Solutions, and CHOU Consulting & Development of Cambridge Bay—began collaborating on the design of new facilities in Cambridge Bay, with the ultimate goal of creating a highly experimental workspace dedicated to the documentation, revitalization, and mobilization of Inuinnait knowledge. This interdisciplinary project bridges Inuit traditional knowledge with cutting-edge materials and technologies to focus on Inuit concepts of *hilamut ingattaqtailidjut iglughamik* (green building design) and to develop buildings that are integrated with the Arctic environment and supportive of the lifestyle and culture of the people who inhabit it.

This article provides an overview of the Nunamiutuqaq project to date, focusing on its work to reposition infrastructure development as a northern-led pursuit. The authors first provide a concise overview of the historical progression of traditional Inuit architecture in the Central Arctic, highlighting the systemic barriers that have impeded its sustained development. They then pose a crucial inquiry: how can these barriers be effectively surmounted? The authors propose addressing this challenge by devising strategies that seamlessly incorporate advancements in energy-efficient and renewable technologies. Importantly, they advocate for maintaining a strong connection between the design, construction, and maintenance of buildings with local people and their indigenous knowledge. This conversation is explored through the collaborative design process for Kuugalak—a customized cultural workspace and surrounding campus for Cambridge Bay slated for construction in fall 2023—focusing on the emerging methodology and process for bridging the cultures, capacity, expertise, and experience of Northern and Southern partners to reassess existing standards for building in the North and engineer new solutions. A final section of the paper describes the lessons learned from this project as presented during the proceedings of a knowledge exchange workshop held by all project partners in June 2022.

A HISTORY OF INUINNAIT BUILDING

Inuinnait are a population of Inuit living on and around Victoria Island (Kitlineq) in the Central Canadian Arctic, an area of Nunavut currently known as the Kitikmeot region. Inuinnait populations primarily live in four contemporary communities: Cambridge Bay, Kugluktuk, Gjoa Haven, and Kugluktuk (see fig. 1), with a population of roughly 3000 individuals (Statistics Canada, 2021), grown significantly from census numbers of 800 individuals estimated by anthropologists at the time of Western contact roughly 100 years ago.[9] The term Inuinnait means "the people" in Inuinnaqtun, a language uniquely used by them and with approximately 500 speakers remaining. For centuries, Inuinnait have resided in a consistent region, fostering a deep cultural synchronicity with the environment. This enduring connection with the natural world persists, influencing Inuinnait language, values, and knowledge.

As a part of this ecosystem, Inuinnait architecture has consistently evolved in response to its social and climatic environments.[10] Inuit migrated into the Canadian Arctic around 800 years ago. Like their Alaskan ancestors, Inuit originally built large and elaborate year-round houses, with structures using bones from bowhead whales—an animal central to Arctic food economies at that time. The earliest of these houses followed building templates from the comparatively wood-rich shores of Alaska, with separate rooms to cook food over an open fire. During the "Little Ice Age" around 1450 CE, the Arctic experienced a cooling phase. As a result, sea ice expanded, making whale hunting a progressively uncertain endeavour. Driftwood supplies became increasingly scarce. Inuit architecture adjusted. During winters, Inuinnait transitioned into snow houses on the sea ice, focusing their economies on seal hunting which provided both food and a source of fuel to be burned in soapstone lamps. In the summer months, there was a noticeable surge in the popularity of inland caribou hunting among the Inuinnait community, with groups establishing smaller, mobile camps, utilizing caribou-skin tents to facilitate their movements and enhance the overall efficiency of the hunting experience.[11]

Inuinnait were among the final Inuit groups to experience the impact of the Western world, and substantial interactions did not take place until 1910.[12] Acculturation rapidly followed, with trading posts, the Royal Canadian Mounted Police (RCMP), and missionaries moving into the area to bring their respective order to a "newly discovered" population. As early as the 1920s, concerns were raised about the pervasive effects of external influences on Inuinnait culture.[13] With wage economy and Western goods playing an increasingly important role in many Inuinnait lives, traditional styles of housing began to incorporate new materials and design features into their houses (see fig. 2).

FIG. 2. THE INSIDES OF INUINNAIT DWELLINGS, SUCH AS THIS *IGLU* NEAR KUGLUKTUK DEPICTED IN 1949, BEGAN TO BE RECONFIGURED TO ACCOMMODATE IMPORTED TOOLS AND MATERIALS. | DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT / LIBRARY AND ARCHIVES CANADA, E010934224-V8.

Following the Second World War, the Canadian Arctic grew increasingly recognized as a tactical location for military and government presence. In 1952, a cooperative project between the Canadian and American governments introduced a string of continental defence radars known as the Distant Early Warning Line (DEW-Line) spanning the entire length of the 69th parallel, designed to detect incoming missiles and nuclear threats from the USSR. During the construction of the DEW-Line sites from 1954 to 1957, more than 460,000 tons of material were transported to the Arctic. This significantly altered logistical development and fostered cross-cultural encounters in the region.[14]

In 1959, the Department of Indian Affairs and Northern Development initiated its inaugural housing program for Inuit, aiming to combat elevated rates of respiratory illness in their communities. Simultaneously, adult education programs were implemented, focusing on instructing Inuit in the correct utilization and upkeep of southern-style housing. The underlying assumption was that the assimilation of the Inuit into Western lifestyles was an inevitable trajectory.[15] Within a decade, however, the failure of this strategy was evident. In a scathing report by the Department of Indian Affairs and Northern Development[16] regarding the state of Inuit housing, authors systematically outline the failure of government housing programs to adapt to the locations and lifestyles of their residents:

> The need for housing in the North was perceived by government employees from the South, and solutions to the problem were devised in Southern Canada. House models have followed architectural precedents from the Southern world, to be built with construction materials imported into the North, and they often show little recognition of Eskimo cultural patterns and values. They have been designed and field tested in Ottawa, apparently by men who have had little experience in Arctic living. Each house type has been placed in the North in large quantities, at a high cost, without first determining if it is truly adequate—not only for the climate but for the people . . . Priority has been put upon the low capital cost of the units and ease of transportation. Attention has been concentrated not on the long-range costs of replacing inadequate houses which may deteriorate after a few years, but upon the immediate cost of getting shelters in place so that short-range goals are met.

Fifty years later, many of the systemic issues cited above still apply. The infrastructure of Indigenous communities across Canada continues to be widely problematic, and nowhere are its many challenges more evident than in the Canadian Arctic. Many of the buildings created for the North—both historically and now—are adopted from designs imported from regions that do not face the Arctic's unique environmental and social challenges. Common issues present today include poor housing conditions, severely limited access to building materials, and accessibility to affordable housing.[17] Health concerns such as tuberculosis have been observed as more prominent in Indigenous communities across Canada, often linked to building conditions. The high cost of housing and building materials, exacerbated by a pan-Arctic housing shortage, results in a deep cycle of structures being designed and built according to financial limitations rather than energy efficiency and occupant health. Additional factors such as unreliable shipping and supply chains, lack of staff, and climate change further undermine the quality and structural sustainability of buildings. This cycle is further perpetuated through Northern governments' lack of capacity to create and implement new policies as quickly as the south, good examples being found in Nunavut's continued adoption of NBC 2015 standards (National Building Code of Canada), and the Qulliq Energy Corporation's slow entry into the grid integration of renewable energies.

A 2021 report produced by Nunavut Member of Parliament Mumilaaq Qaqqaq, based on her Nunavut-wide housing tour, provides distressing testimony as to the current state of housing conditions. Of two Kitikmeot communities, she notes,

> [they were] the worst mould I saw in all of the communities. Units that were only 2 or 3 years old were leaking from the windows and in the corners of ceilings (sometimes ceilings being 10+ feet high). Water damage was definitely a big concern in many homes. Although there were these concerns there were also great initiatives in mould remediation and training for mould prevention. Newer units often didn't have a back door or secondary exit, many expressed concern around their safety in the event of fire or need to escape.[18]

How has an architectural system recognized as deeply flawed managed to perpetuate in the Canadian Arctic? Much of its lasting power is due to the number of barriers facing change. More obvious obstacles to construction in the Arctic include climate and geography. The Arctic environment is both unique and extreme. Winter temperatures regularly reach 50°C, and daylight hours alternate between months of perpetual light and darkness. It is primarily a tundra environment, providing few local materials for construction purposes. The Arctic's physical removal from national networks requires greater lengths to procure and send materials. Communities are fly-in only, relying on annual summer barges for larger deliveries. Shipping is expensive, a cost that filters into almost every commercial product available in communities. On average, construction costs for buildings in Nunavut are three times higher than in Southern Canada.[19] This has directly contributed to both housing unaffordability and scarcity in Nunavut, with 52% of its population living in social housing,[20] and 56% of Nunavummiut living in overcrowded homes.

Across all these barriers is the looming threat of climate change. Warming rates in the Arctic vastly exceed the global average. This has profound and wide-ranging effects, from the thawing of permafrost to changes in wildlife migration to the breakdown of infrastructure and transportation routes. The impact of climate change on both the Arctic environment and our project in particular will be addressed at greater length later in this article.

PROJECT ORIGINS

Pitquhirnikkut Ilihautiniq / Kitikmeot Heritage Society (PI/KHS) is an Inuit-directed non-profit organization based in Cambridge Bay, Nunavut. Incorporated in 1996, they have dedicated 27 years to renewing Inuinnait culture and the Inuinnaqtun language, and to innovating through the wisdom and experience of the Inuit. The organization is governed by a board of Inuinnait Elders and an Inuinnaq director, who help ensure that all operations—from administration to research and programming—are governed through Inuit knowledge, language, and values. Located in a landscape that has been facing the dangerous effects of climate change for decades, PI/KHS recognized that action must be taken to address the equally rapid change in Inuit relationships to their surrounding world. They sought to develop a more holistic approach to ensuring balance between human and natural environments, one that could express the culture's profound environmental knowledge and its preparedness to embrace and integrate new ideas, technologies, and challenges presented by the current climate crisis.

In 2016, PI/KHS began laying the foundation for a new cultural campus in Cambridge Bay to realize these climate goals alongside increased dedication to language immersion and the learning of land-based skills in an urban environment.[21] A highly customized building for cultural production was required, with a design guided by Inuit traditional knowledge and values, but also anchored in more future-oriented materials and technologies as required by a rapidly changing climate. This building and surrounding campus was to be named Kuugalak in reference to a waterway beside its location; one of the local rivers Elders say used to run wide and deep, but had reduced to a smaller trickle through climate change. The hope for the new campus, they furthered, was that it would enable Inuinnait knowledge, like that river, to once again flow freely.

A project titled Nunamiutuqaq ("Building from the Land," in Inuinnaqtun), was set in place to document traditional principles of Inuit architecture, and critically ask how they could be upheld through modern materials and innovation in the green energy sector. From the start, this research was driven by three key questions:

1. What lessons can we learn from the history of Indigenous architecture in the Arctic? Inuit and their ancestors have occupied the Canadian Arctic for 4500 years. Throughout that time, their dwellings have consistently evolved in response to changing social and natural environments, yet also maintained architectural features critical to sustaining culture and comfort. Can time-tested features and values of Inuit architecture be used as cultural templates for contemporary construction in a replicable and scalable manner?

2. How can Inuit-led infrastructure change how we live in the North? Over the last century, Arctic infrastructure—from buildings to land development and energy grids—has heavily relied on concepts imported from the South, leaving little space for Inuit and local populations to express their priorities and knowledge for the creation of living, learning, and working environments. How do we develop new spaces genuinely needed and wanted by community members; built and maintained by local companies and experience; and use Arctic-based innovation and experience to pilot new directions for architecture in the North?

3. Inuinnait highly value environmental sustainability and stewardship (a long-standing cultural principle known as "avatimik kamattiarniq"). In what ways can this respect inform the ways that we think about Northern infrastructure as a tool for climate adaptation and mitigation? From the use of local construction materials to traditional strategies for energy efficiency, Inuit built environments merge with, and support their surrounding landscapes. Can contemporary advancements in sustainable and renewable building technologies be used to maintain this cultural connection to the natural world?

In 2019, PI/KHS reached out to the Southern Alberta Institute of Technology's (SAIT) Green Building Technologies Access Centre (GBTAC) for support in answering these questions. GBTAC's team is composed of engineers, architects, technologists, environmental scientists, and red seal tradespersons, and explores key research themes of net-zero energy, building integrated renewable energy, architectural ecology, and education and industry transformation. GBTAC's expertise was further paired with a Cambridge Bay-based team of industry professionals, including 100% Inuit-owned companies Qillaq Innovations and Aurora Energy Solutions, and CHOU Development and Consulting, with the ultimate goal of creating a project that fosters and supports local solutions to changing how buildings are created in the North. This group will be referred to (often in the collective first person) as the project "team" throughout the remainder of this article.

Since the 1950s, there have been a number of experimental attempts by non-Inuit to address the complex needs of construction in the Arctic through building design. Many of these have operated on the premise that granting Inuit access to the standards of living expected by urban, Southern Canadians, requires those same standards to be materially reproduced. The resulting construction of small, prefabricated plywood houses—the "matchbox" and "512" models (the latter named after its square footage) being prime examples—became tools for "internal colonialism," not only through reliance on designs and building materials ill-equipped for the North, but their conceptualization of wholescale Arctic communities "designed on a pattern suited to southern Canadian suburbs."[22] Complex cultural issues quickly came to the fore with these buildings, with their space and design rarely affording the needs required by resident family size and reliance on land access and harvesting. These issues have only been exacerbated by the more recent advent of large, multiplex buildings to cope with widespread housing shortages.[23]

While attempts have been made to integrate Inuit lifestyle into Northern architecture, few of these have been guided by Inuit. One notable early pilot in the Arctic community of Kinngait involved the use of Styrofoam-based blocks as a replacement for snow to construct traditional *igluit*. Arctic scholar Scott Dumonceaux noted:

> The Styrofoam igloos and other housing models tested in the 1950s were designed to fit in with traditional Inuit mobility, subsistence practices and mimic existing forms of Inuit housing. They were also developed by people with experience living and working in the Arctic . . . But what the Inuit community at Kinngait actually thought of the plastic structures is unknown. And it was exactly because the Styrofoam igloos were designed to align with Inuit culture that they were discontinued.[24]

Dumonceaux frames the conceptualization of a Styrofoam *iglu* in the post-war era belief of high modernity, or the notion that science and technology often serve as critical components for social benefit.[25] This question of if, and how, advancements in the science of architectural materials can be used to support and enhance the traditional culture and knowledge of Inuit became central to our thinking around this project.

BUILDING A FOUNDATION

The Arctic has always been a difficult place to build, but the extent of this difficulty became highlighted during our team's first planned meeting in March 2020. The unforeseen pandemic shut down physical access to the Arctic, throwing northern territories into a new, and often ill-equipped, reality of virtual engagement. Supply chains ground to a halt, materials prices skyrocketed, and uncertainty became the only certitude. While highly disruptive to our project, COVID19 served to underline the need for solutions that strengthened local resilience and self-sufficiency. For the following year, our team gathered weekly in online venues to troubleshoot the rapidly changing realities of our project.

FIG. 3. MACKENZIE PORTER STANDS BESIDE A STYROFOAM *IGLU* IN THE COMMUNITY OF KINNGAIT (CAPE DORSET), NUNAVUT, *C.* 1956. | LIBRARY AND ARCHIVES CANADA / ROSEMARY GILLIAT EATON FONDS, E010836042.

The first major obstacle we encountered was a lack of existing documentation surrounding building best practices in the Arctic. In Northern communities, building performance data, construction feedback, and lessons learned are rarely recorded or shared, let alone compiled and inventoried in a single location. There is little communication or knowledge sharing between northern construction companies, further minimizing the likelihood of deviation from familiar materials and methodologies, and dissuading the integration of successful new solutions back into formal building codes or territorial standards. This ultimately prevents widespread innovation and inhibits the voices and experiences of Northern residents in regard to Northern housing.

A priority for the project became to compile best construction practices for building in the Arctic. Throughout the summer and fall of 2021, our team held meetings, workshops, design "charrettes," and dozens of interviews with Cambridge Bay industry experts (construction and energy sectors), home and cabin owners, Elders and knowledge keepers, traditional architecture experts, and the municipal government. This wide survey of local knowledge and experience allowed us to assemble a database of infrastructure recommendations for the new building. This database (see fig. 4) outlines key insights into construction, including constraints and issues with existing renewable materials and technologies, how to increase the cultural and domestic usability of built spaces, Arctic-specific design needs and considerations for building envelopes, foundations, water/sewage, heating, shipping times and supply chain recommendations, building automation systems, and high-risk factors from climate change to human error.

Water	Drinking water	In the new development in Cambridge Bay, all units have their own water tanks. This is a preferred option.
Water	Drinking water	Consider where water tank is positioned in the building. It needs to be in a visible place, with an external light to warn when it is empty or need cleaning.
Water	Sewer	Human error: Glycol heat tracing: occupants forget to turn the line on and off in winter/summer. This leads to freezing pipes. Clean up and replacement is costly and time consuming, as parts need to shipped up to the community
Water	Sewer	Consider human error in installation and/or operation when deciding location of piping and sewage system. Balance need for protection from freezing temperatures and damages and consequences if system fails, (i.e. installing systems within the house is not a good idea).
Water	Sewer	Septic tank installation should take into account the permafrost. Once upper layer is removed, permafrost will melt and tank will collapse
Water	Sewer	Connection with exterior piping: the ground will move and solid connectors do not allow for movement. Opportunities for joints to break. Look at flexible piping.
Water	Sewer	Consider traditional use of the building during workshops: blood and grease to be disposed off in the sewer - low flow fixtures might not accommodate those specific needs
Water	Greywater	Not something commonly used in Cambridge Bay
Energy	Passive solar	Too much heat gain in the summer. Consider Indoor blinds or outside shutters (useful for safety as well)
Energy	Passive solar	Too much heat gain in the summer: electrochromic windows, linked to automated building system to regulate interior temperature. They are, however, not commonly available. Windows might crack with extreme cold, it will be hard to replace or repair. Consider supply chain.
Energy	Passive solar	Use Sunpath chart and block the sun penetration through architectural design. The sun path is changing very rapidly (gaining 40 min a day), which makes it challenging to design

FIG. 4. AN EXAMPLE OF THE DATA BEING COLLECTED FOR THE COMMUNITY DATABASE. | A DOWNLOADABLE VERSION OF THE FULL DATABASE CAN BE FOUND AT: [HTTPS://WWW.NUNAMIUTUQAQ.CA/COMMUNITY-DATABASE].

In addition to understanding contemporary building practices in the Arctic, our project sought to investigate more future-oriented strategies. There is very little accessible knowledge about the extent of current and predicted climate change in Cambridge Bay. Our project accordingly sought to identify the climate change risks and impacts associated with the design, construction, and operation of our new campus and building. Throughout the summer of 2021, we investigated extensively about perceived climate change impacts on the land and community buildings over time, using these observations to better understand how—and how quickly—the land is changing within the span of local memory. We reflected on seasonal land patterns, including prevailing winds, snow accumulation, drainage flow, and water accumulation during spring melt. Information gathered from this work was paired with available climate data and background research on similar infrastructure studies across the Arctic, to form the basis of our first high-level "Climate Risk Assessment."[26]

While PI/KHS has always tried to operate in an environmentally conscious manner, the practice was more oriented toward Inuit values than quantified measurements of the organization's programs and energy footprint. In preparation for the construction of an energy-efficient building, it also became important to have benchmark data against which that centre's efficiencies could be measured. In 2021, PI/KHS partnered with Blue Sky Engineering to build more local understanding in how energy use is measured and assessed, how much energy their existing building and practices consume, and how this compares with other similar institutions at a national scale. Having this benchmark data (and awareness of what the data actually means) allowed PI/KHS staff to better assess the green energy options presented to them, and judge the efficacy of costly future infrastructure against other potentially less costly and more impactful organizational changes such as the prioritization of digital programming and minimizing staff travel. PI/KHS further created infographics to help break down the complex information behind the energy audit (fig. 5), and held climate adaptation terminology workshops to build upon and fill gaps in previous efforts to find definition for modern climate phenomena in the Inuinnaqtun language.[27]

BUILDING DESIGN

There are many logistical and material considerations when building in the Arctic. The next phase of the Nunamiutuqaq project focused on making these decisions. Reduction of waste, for example, was identified as an important consideration for the Kuugalak workspace, informing design choices that could avoid directing excess waste to the already limited waste management facilities in Cambridge Bay. Low and zero-waste products and packaging were prioritized. A prefabricated building assembly using structurally insulated panels allowed for a 40% reduction of landfill wasted compared to stick frame construction, eliminating off-cuts and mismeasurements, reduce shipping costs and emissions, and saving salvageable materials from the landfill at the end of the building's life.

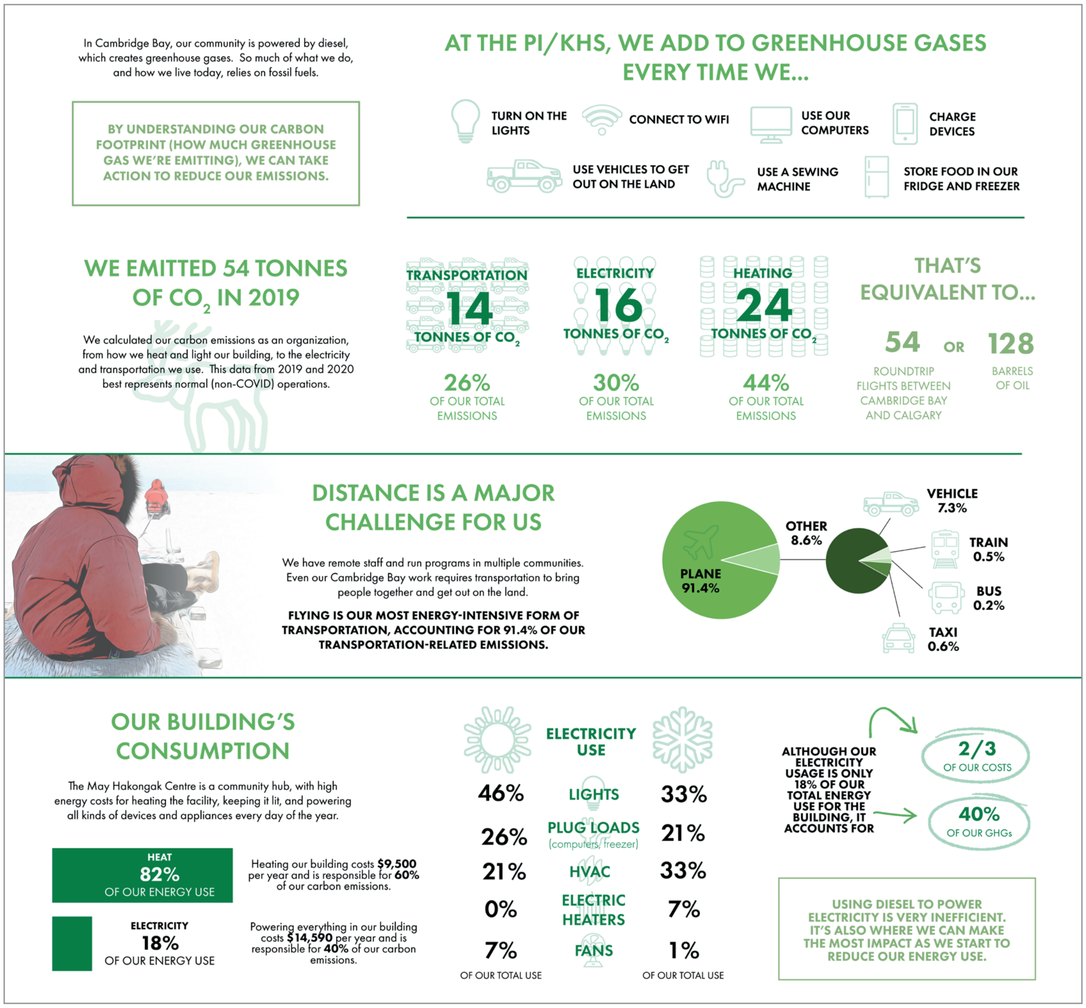

FIG. 5. INFOGRAPHICS BREAKING DOWN THE RESULTS OF PI/KHS'S ENERGY AUDIT. | FULL REPORT AVAILABLE AT: [HTTPS://WWW.NUNAMIUTUQAQ.CA/CARBONINVENTORY].

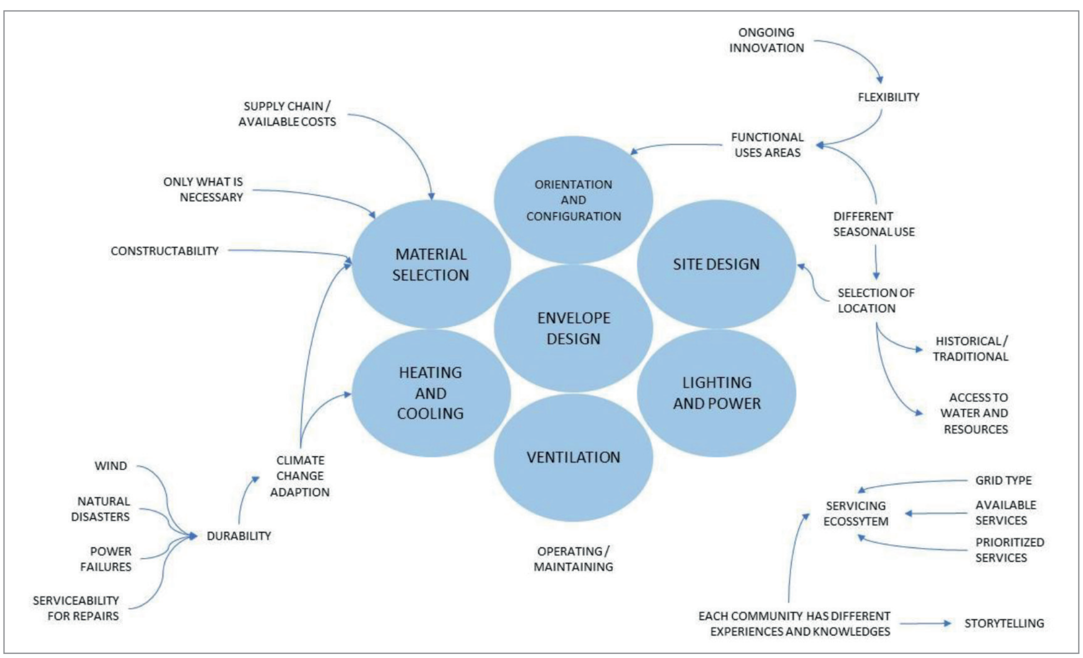

FIG. 6. A SCHEMATIC OF PROJECT DESIGN DEVELOPED DURING A CALGARY-BASED KNOWLEDGE DISSEMINATION WORKSHOP ATTENDED BY ALL PROJECT PARTNERS IN 2022. | *NUNAMIUTUQAQ KNOWLEDGE MOBILIZATION: A REPORT ON WORKSHOP PROCEEDINGS MAY 30TH-JUNE 3RD, 2022*, [HTTPS://WWW.NUNAMIUTUQAQ.CA/KNOWLEDGE-MOBILIZATION-WORKSHOP].

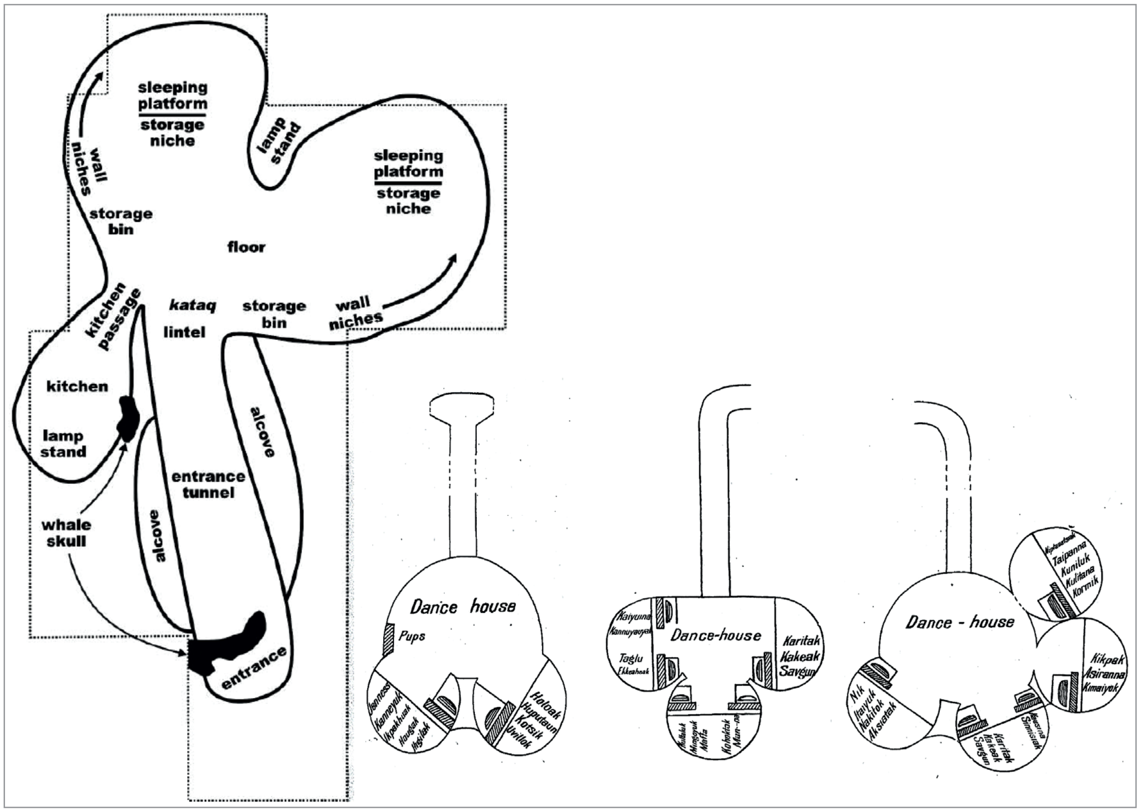

FIG. 7. RIGHT: MAP OF ACTIVITY AREAS IN AN ARCHAEOLOGICAL THULE WINTER HOUSE AT QARIARAQYUK (IN WHITRIDGE, 2004, P. 232). LEFT: VARIOUS CONFIGURATIONS OF INUINNAIT *IGLUIT* DOCUMENTED BY ANTHROPOLOGIST DIAMOND JENNESS *C.* 1916. | JENNESS, DIAMOND, 1923, *THE COPPER ESKIMOS. PART A: THE LIFE OF THE COPPER ESKIMOS. REPORT OF THE CANADIAN ARCTIC EXPEDITION, 1913-1918,* VOL. 12, P. 71, 74-75. WHITRIDGE, PETER, 2004, "LANDSCAPES, HOUSES, BODIES, THINGS: "PLACE" AND THE ARCHAEOLOGY OF INUIT IMAGINARIES," *JOURNAL OF ARCHAEOLOGICAL METHOD AND THEORY,* VOL. 1, NO. 2, P. 213-250.

The design of the workshop space was additionally guided by information gathered through meetings, workshops, and interviews with the goal to ensure the space reflected the cultural needs of the community and its users. Key design considerations in this regard included:

- Culturally aligned flooring: as most cultural activities require participants to sit on the floor, staff indicated the need to have warm, soft flooring for sewing, while meat butchering and skin preparation required colder, harder surfaces, thus emphasizing the need for floor temperature differential within one space.

- Management of heat flow, air, and light: traditional Inuit buildings included venting at the top of the *iglu* and sometimes large, south-facing windows made of compacted ice to allowing light for activities such as sewing.

- Storage: Elders discussed entrance/vestibule designs in *igluit* with cold-trapping characteristics and ample room for storage. In particular, this entrance should allow for storage at different temperatures for skins, foods, and tools, all having their own optimal temperature profiles.

- Furniture that fits: Elder conversations outlined specific height requirements for benches, work surfaces, and windows. Too often, they noted, interiors are designed for average heights that do not reflect the realities of Elders or many Inuit.

Traditional Inuinnait structures ultimately formed the basis of our blueprinting process for the new building.

The first design for the new building's floorplan (fig. 8) featured a series of purpose-specific modular rooms fixed to a central collective activity area. In addition to mimicking cultural precedents, the modular approach was applied to research new possibilities for pre-fabrication through structurally insulated panelling and to experiment with concepts of addition/removal of building pods on an as-needed basis. The long entrance corridor of traditional snow houses was reimagined as a multi-staged entrance to create a buffer between warm interior temperatures and the outside cold. A high ceiling in the central room was designed for storage potential, with a top skylight that emulated the traditional *iglu* vent (called a nose, or *qingaq*).

The next version of our design began to focus on introducing energy-efficient solutions. Spaces between the room pods were eliminated to decrease the amount of building surface exposed to blowing snow and wind.

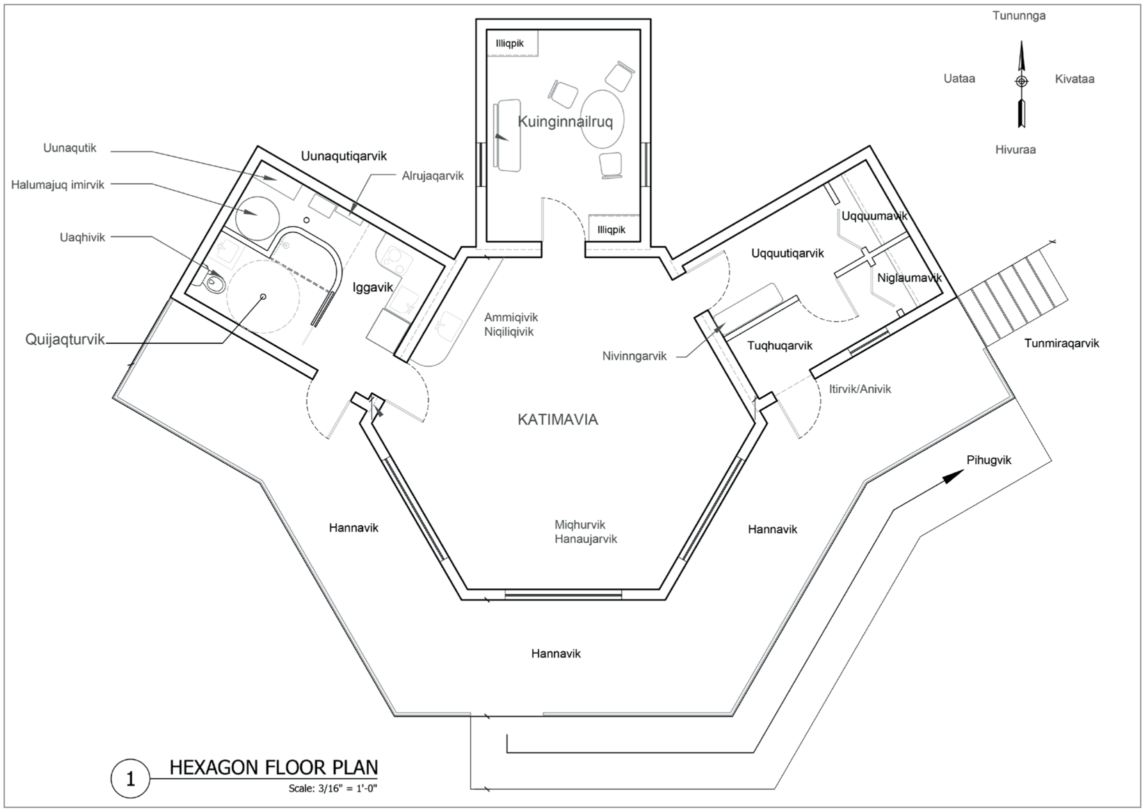

FIG. 8. A PRELIMINARY FLOORPLAN. INUINNAQTUN TERMINOLOGY WAS USED TO DEFINE THE SPACES AND ACTIVITY AREAS. | PI/KHS AND SAIT GBTAC BUILDING PLANS AND BLUEPRINTS. ON FILE AT PI/KHS ARCHIVES.

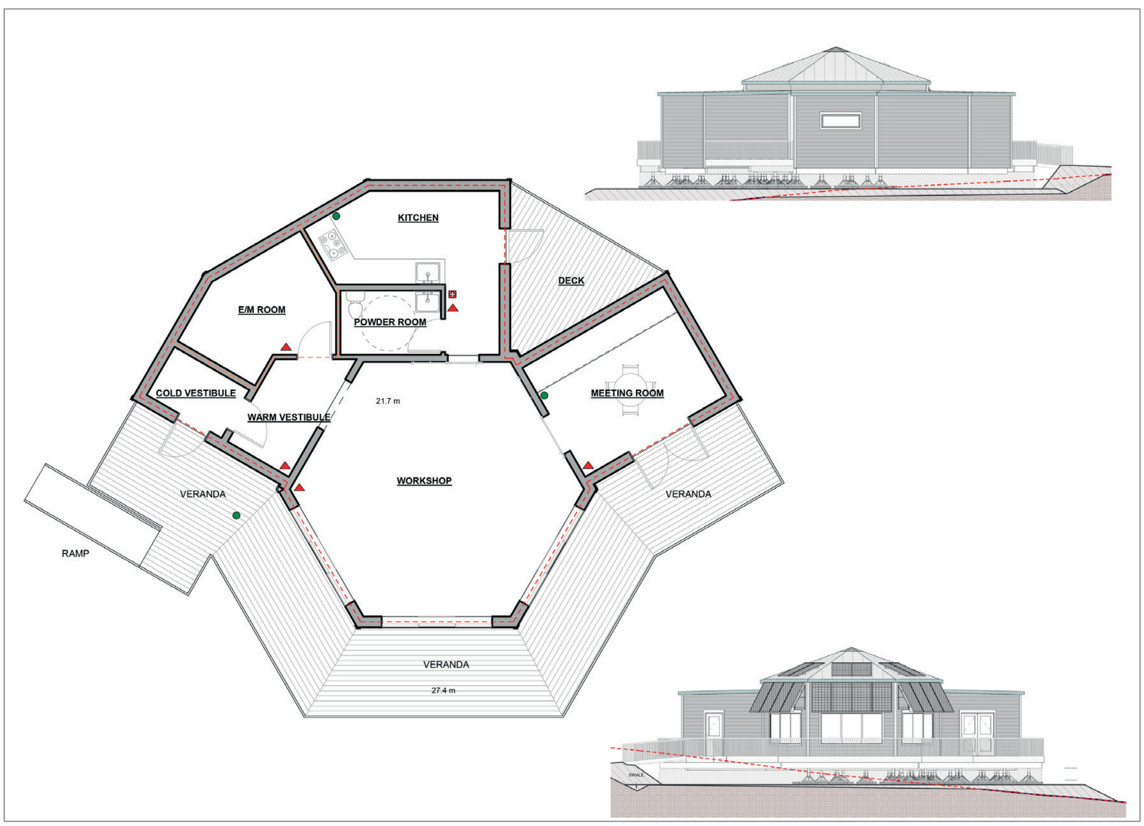

FIG. 9. SUBSEQUENT DRAFT DESIGN SHOWING THE FLOOR PLAN AND PROFILE OF THE BUILDING WHEN OPTIMIZED FOR ENERGY EFFICIENCY. | PI/KHS AND SAIT GBTAC BUILDING PLANS AND BLUEPRINTS. ON FILE AT PI/KHS ARCHIVES.

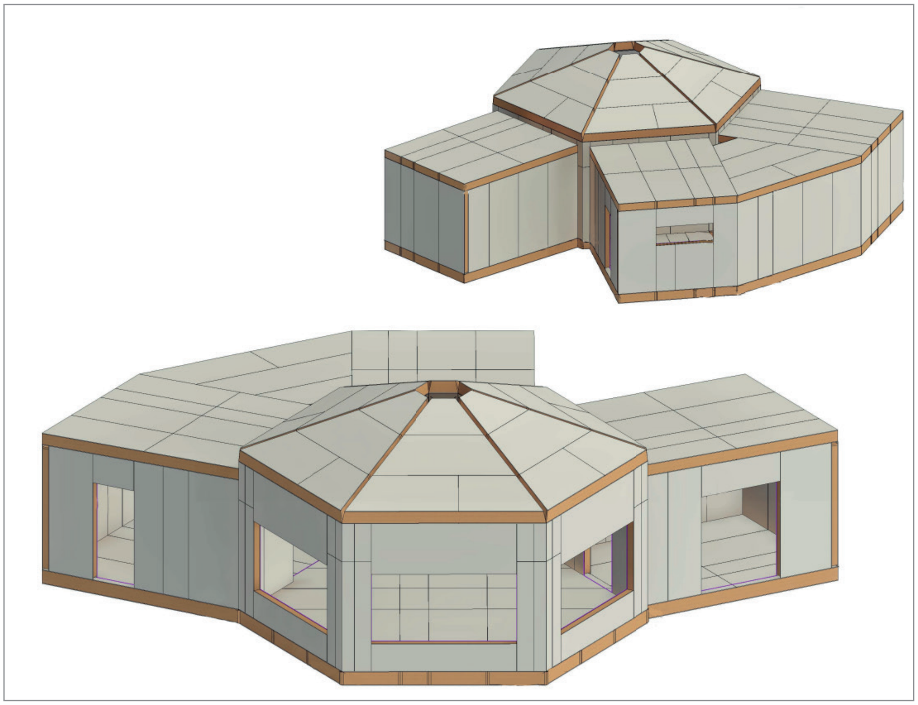

FIG. 10. A STRUCTURAL MOCK-UP ILLUSTRATES THE USE OF SIP PANELS TO FORM THE ENTIRE BUILDING'S ENVELOPE INCLUDING FLOORING, WALLS, AND ROOFING. | ZS2 STRUCTURAL DESIGN PACKAGE FOR KUUGALAK BUILDING. ON FILE AT PI/KHS ARCHIVES.

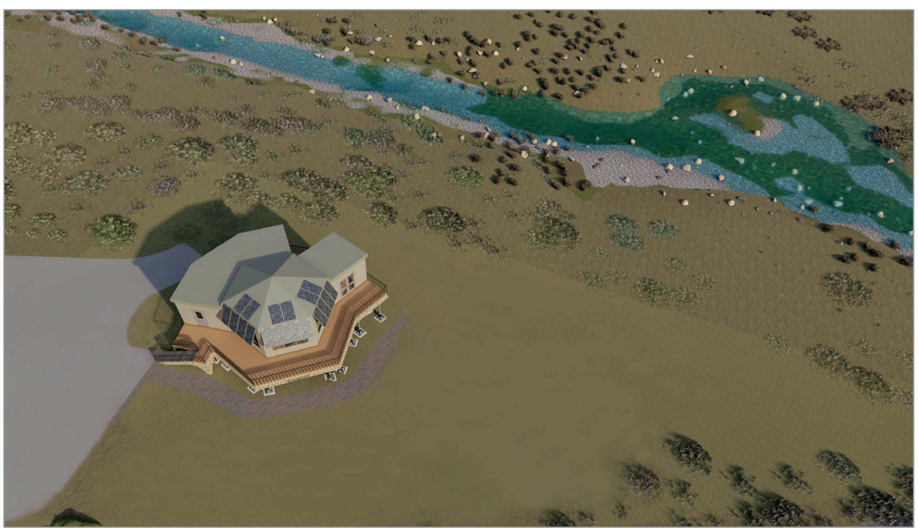

FIG. 11. A 3D RENDERING OF THE PROPOSED KUUGALAK WORKSPACE *IN SITU* ON THE SURROUNDING CAMPUS. | IMAGE CREATED BY SAIT GBTAC BASED ON STRUCTURAL BLUEPRINTS. ON FILE AT PI/KHS ARCHIVES.

The size of the building was increased to accommodate renewable energy and mechanical equipment, and to give more space to prioritized activity areas such as cooking. A second, wind-facing deck was added to the rear of the building to serve as a winter freezer for skins and cultural materials, and a summer production area for the preparation and drying of fish and meat. The entrance's air buffer was further improved through the addition of indoor insulated panels to regulate temperature fluctuations and decrease humidity build-up that results in the front door icing shut (a common Arctic issue). An adjustable in-floor heating system was installed to warm the floor for certain cultural activities, while also being able to keep it cold for others, such as hide work and meat preparation. Extensive built-in storage space was added to the building's meeting room. The skylight was removed due to the projected amount of energy loss.

MONITORING AND EVALUATION

As much as the goal of Nunamiutuqaq was to build new cultural facilities, it was equally to produce a robust body of data and research to better understand the impacts of building typology, system, and material selection. While detailed performance data exists for buildings outside the Arctic, the northern region's unique climate, weather, and occupancy patterns often impact structures in ways that are still poorly understood. Toward these ends, we developed an extensive monitoring plan to help assess and evaluate our building's materials, technology, and design, with the goal of providing future Arctic construction projects with finer grained data and more opportunities for informed decision making. With multiple sensors built into our new building, we are able to monitor its performance both in real-time and over an extended period of time, so as to analyze trends, look for anomalies, and assess whether the building is achieving the energy-efficiency goals we have outlined for it. Our monitors target multiple areas of the building, including heat trace thermal transfer; water usage and supply temperature; hot water usage and electrical consumption; baseboard heater thermal transfer; total space heating thermal load; vestibule thermal load and electrical consumption; heat recovery ventilator (HRV) delta-temperatures and electrical

	Fuel Load Distribution (kWh)		Description
	Base Case	Proposed Case	
Space Heating	67,264.00	29,663.00	The HVAC Air Heating for conditioning space
Heat Trace[1]	3,947.00	3,043.00	Heat trace pipe around plumbing system
Mechanical Units	5,298.00	4,388.00	The electrical load at furnace, unit heaters under their assumed duty cycles.
Fans	5,195.00	2,761.80	Heat recovery fan units and kitchen range exhaust fans
DHW	363.30	194.00	Domestic hot water supply without heat recovery design
Lighting	1,154.00	404.10	General interior lighting
Water Pump	459.00	424.00	Pump for all water uses in the building
Appliances	4,573.00	4,573.00	Arctic Living Requirements and Kitchen
EUI (kWh/m²)	856.83	441.27	Building Footprint Area 103 m²
Electricity Grid	16,679.00	12,744.90	Carbon Factor[2] 0.795 kg-CO_2/kWh
Fuel-Diesel	71,574.30	32,706.00	Carbon Factor[2] 0.253 kg-CO_2/kWh
CO_{2eq} (Tonne)	31.37	18.41	Net equivalent mass of carbon dioxide emission
Renewable Source Generated Energy (kWh)			
Solar (kWh)	0.00	6,717.00	On-site electricity generation by 16 solar panels
$CO_{2e,Saving}$ (Tonne)	0.00	5.34	Net equivalent saving mass of carbon dioxide emission
Net Total			
Total (kWh)	88,253.30	38,733.90	Annual Net Total Energy in Fuels Consumption
EUI (kWh/m²)	856.83	376.06	Annual Energy Use Intensity
CO_{2eq} (Tonne)	31.37	13.07	Net equivalent mass of carbon dioxide emission

FIG. 12. ENERGY MODELLING FOR THE NEW BUILDING SHOWS EXTENSIVE ENERGY SAVINGS COMPARED TO BASE-CASE CONSTRUCTION IN NUNAVUT. | KUUGALAK CULTURAL WORKSHOP ENERGY MODEL REPORT UPDATE. PREPARED BY SAIT, JUNE 14TH, 2023, [WWW.NUNAMIUTUQAQ.CA/FEASIBILITY-STUDY].

consumption; thermal transfer in in-floor heating; room temperature and humidity; and envelope/wall system thermal performance. In addition to the technical performance of various structural materials and mechanical/electrical equipment, this monitoring plan attempts to account for the many other factors that can influence buildings, including the number of people using the space, how the space is used, and weather conditions.

When sharing monitoring strategies for Kuugalak with the wider Cambridge Bay community, multiple homeowners and construction companies expressed interest in having their own buildings similarly monitored for performance and efficiency. We saw an opportunity to develop a broader and more comparative database for Arctic building practices, and accordingly broadened our monitoring project to include six more community buildings representing a range of conventional and advanced building methods—from stick builds to structurally insulated panels. This, we reasoned, would allow us to better understand the impacts of different construction typologies and building choices—including building envelope, mechanical and electrical energy use, renewable energy systems, ventilation, and water use—in addition to considering the impact and role of different occupant habits in response to changing, and extreme climate conditions in the Arctic. Improving the quality and quantity of building science data is an essential first step for suggesting changes to territorial policy and building code, and making recommendations for developing more long-term and sustainable infrastructure in the Canadian Arctic.

The first stage of this community-wide monitoring project was to understand the challenges faced by building owners and occupants, and to catalogue the main issues with building performance in our community, such as high heating demand and humidity levels, issues with moulding and underperforming HRV systems, to name a few. Based on this preliminary research and community feedback, we designed a monitoring strategy with multiple sensors installed in similar areas across all the buildings to assess key points such as fuel and electricity use; water usage characteristics and profiles; thermal transfer and moisture travel through wall assembly; HRV performance; relative humidity (throughout the house and in venting and sewage stacks); ice build-up; and indoor air quality as measured by CO_2, humidity, particulate matter, and other criteria. Our team is actively reviewing and analyzing the data monthly (over a twelve-month period from December 2023 to December 2024) to capture all four seasons of building operations. In addition to quantified data, the program strives to keep human occupancy and ease of use as central components to determining the success of various building and material strategies. To these ends, we equally conduct surveys targeting occupants' energy habits, building use strategies, and ongoing levels of comfort. We publicly share fully anonymized performance and occupant data from this monitoring project as open data with our community and beyond, through a customized visualization portal to help us further build awareness, learning—and ultimately, resilience—in regard to energy efficiency and Arctic construction.

DISCUSSION

In May 2022, all members of Kuuglaak project met in Calgary, Alberta, for a weeklong knowledge exchange workshop to better integrate the team's research. This involved both the transfer of necessary technical skills to Cambridge Bay partners before on-site construction, and enhancement of Southern understandings about the ways in which Inuinnait culture and knowledge have guided design concepts and solutions. This workshop specifically aimed to create a space for "two-eyed seeing"[28] to bring Inuit and Western knowledge traditions together for a stronger vision of how to achieve Inuit priorities and vernacular in northern building design.

The workshop was structured as a series of thematic discussions designed for both cross-cultural education and adjustment of the building design, with the overall goal to mobilize Inuinnait knowledge and experiences in order to better inform the construction, maintenance, and economic/climatic building considerations in the Arctic. The conversations that ensued speak strongly to the project as one anchored in more human dimensions of building in the North. In revisiting some of the major discussion themes, and listing the conversation points outlined by participants, we come closer to the definition of this project's unique methodology and challenges.

Uncertainty and Human Dimensions of Climate Change

Climate change is an escalating concern in the Canadian Arctic. This region sees the heightened effects of human influence on the planet, with the onset of change happening nearly four times more rapidly than elsewhere in the world,[29] posing an imminent threat to food and water sovereignty, as well as access to culturally appropriate activities and traditional ways of living. Recent studies underscore the challenges that Nunavut will specifically encounter as a result of climate change, including a remarkable reduction in the number of cold days and rise in average temperature.[30]

The impacts of climate change are increasingly evident to those living in the Arctic. A group of Elders from Cambridge Bay virtually connected to our workshop to discuss climate change as directly observed over the course of their lifetimes. More open waterways are present during the coldest months, and unusual species of animals have started to appear. Ancestral knowledge about the landscape, which has been in place for centuries, increasingly needs to be reassessed. Changes in the thickness of ice, for example, have created unsafe situations in areas that have long been used for travelling and hunting.

Climate change also impacts building technology and sustainability science. The mitigation of anthropogenic climate change effects gradually gains more importance. Reduction of the carbon footprint with more energy efficiency, use of minimal impact materials, geographical positioning, and smart/biophilic design are all tools that can be used to support efforts into both the mitigation of, and adaptation to climate change. One of the main research questions driving the building of Kuugalak is how to create more climate resilient, energy-efficient buildings for the Canadian Arctic. Research has been carried out with an objective of being highly energy efficient, exceeding current community construction standards, and setting a precedent for high-performance buildings in the North. This includes a reduction in electricity consumption and heating fuel, and production of solar photovoltaic. High building envelope performance includes structurally insulated wall panels (SIPs) made from magnesium oxide, and R60 flat roof, high-performance windows, and increased airtightness with minimized thermal bridging. Energy-efficient systems comprise boilers, HRV, plumbing, mechanical, electrical, and lighting in order to reduce energy demands. Space has been included to add batteries in future years to contribute to energy storage and building resiliency. Key concepts were sourced from traditional Inuit architecture—including passive solar and solar shading techniques, building orientation, fenestration, as well as foundation and permafrost considerations. Thinking surrounding risk mitigation was ultimately present in every aspect of Kuugalak's development, through the creation of models and solutions for increasingly extreme conditions such as permafrost degradation, drainage of meltwater, heavier snowfalls, and more extreme winds.

Bridging Northern and Southern Realities

Planning issues are always present when building in the Arctic, hence the need for replicable and feasible technologies and techniques. Transportation of materials can be expensive and cause significant delays. Many standard materials applied in the South, such as concrete, pose noteworthy challenges to construction in the Arctic as there is only a brief and unreliable window of seasonality where it can be used. Prefabricated structural panel systems such as those selected for Kuugalak can diminish these logistical challenges, as they allow for off-site manufacture and shorter on-site building periods, which also reduce the project costs. Prefabricated systems selected for use in Kuugalak are fireproof and mold-resistant, improving both the overall quality of the building structure and the quality of life it affords.

Discussions focused on how construction projects need to take into consideration that building in the Arctic means adapting to the extreme climate. Various solutions for the Kuugalak building were discussed, including in-floor heating as a temperature distribution strategy. Cambridge Bay builders provided insights into the many locally devised solutions for Arctic housing to better suit extreme weather, such as creating extra-long gooseneck vents to deal with the cold and intense winds of the Arctic, retrofits to boiler chimneys to prevent ice build-up, and strategies for routing snow around houses to prevent excessive winter drifting. Also highlighted is the importance of ease of installation and operability when selecting northern construction materials, as human error accounts for many of the product failure issues being experienced. An important note of caution was also extended to newer technologies and renewables. While solar and battery storage are becoming more popular, and technology has become more efficient, there still are a few instances where they are being applied in the Arctic, creating insecurity in terms of unknown performance, cost-effectiveness, and lack of local professionals skilled in their ongoing repair and maintenance.

Materials and Construction Methodologies

Prior to the introduction of western architecture, Inuit communities primarily relied on two types of constructions depending on the season. *Igluit* were winter dome-shaped dwellings made of *pukaangajuq* (hard snow). Averaging 3 to 3.5 metres high, and 3.5 to 4.5 metres in diameter, those dwellings would normally house a family but could be bigger to accommodate more people during community gatherings. To deal with moisture and humidity build-up, a caribou skin-covered air vent in the roof could be opened or closed as needed to adjust for comfort. Summer months would see the use of *tupiit*, simple tents sewn from caribou or sealskin, and supported by driftwood frames. These highly portable structures facilitated people's travel for hunting and fishing. Understanding and keeping these traditions alive is important to guide new projects into design choices that have been proven to work in tandem with both the natural environment and the human lifestyles developed in response to those environmental realities.

In Arctic settings, attempts to move beyond the use of local, land-based materials and design commonly create more issues than they solve by further distancing buildings from the land they inhabit. Solutions such as insulated concrete must be balanced alongside seasonality, as it is impossible to mix or pour during freezing temperatures (typically present during all months save for July and early August). The extreme weather conditions in the Arctic create a series of other considerations, such as ice accumulations on chimneys and sewer stacks, which must be maintained during winter. Chimneys must be closer to the edge of the roof for easier access when such maintenance is necessary. Conversely, excess heat brings another set of challenges. Boilers work year-round, which may cause excessive heat in the building. The sun's rays, even during months when the temperature is well below zero, can magnify through windows and heat a building well past the point of comfort.

In alignment with these architectural values, Kuugalak's design aspires to be a part of its human and natural environment. The building responds to the natural features and topography of its landscape. The building's southeastern-facing position and large solar awning have been designed to actively absorb the sun's heat and light during colder months and to minimize passive solar overheating during the warmth of summer. The building's design centres on a large circular room for collective activity in homage to *qalgiit*, traditional snow houses built to accommodate community gatherings. Three walls of windows bring in natural light and create a space that minimizes physical barriers between the indoors and outdoors. The building's entrance has been designed as a buffer between the outdoor temperatures and the inner main room, functioning much like the "cold trap" entrance of traditional *igluit*. Equal attention has been given to the ways in which the building's temperature intersects with the cultural activities that will occur there, with colder areas designated for work with meat and hides, and warmed floors for Elders and community members to conduct their work. The building specifically allows for different temperatures to store skins, meat, and traditional tools, each having their own optimal temperature profile.

Maintaining Connections to Land

Architecture needs to be designed not only to physically fit a community and its landscape but to further support the maintenance of cultural connections to the land. The continuance of Inuit culture and worldview are not reliant on the physical materials being used in a building, but on how that building shapes the activities, quality of life, and aspirations of those that live inside of it. As such, the design of Kuugalak must aim to provide affordances to Inuinnait culture and language, and support their continuation.

The cultural significance of having Kuugalak's design intrinsically connected to the land is one of the most pivotal points of the project. Cambridge Bay Elders described the comfort of *igluit* during winter and their abandonment in warmer seasons; as the structure began to drip, they would move. As they moved, tools, clothes, and skins would be reused, but families would only reuse someone else's past dwellings with Elders' approval or if they had no means of getting resources themselves. This would show respect for the land and people who came before them. Their way of life demanded that whatever was taken, had to be provided for in return.

The sharing of knowledge was also critical, especially in intergenerational contexts. More senior Inuit would carry the knowledge of how to build traditional dwellings and receive physical assistance from youth, thus transferring the information to newer generations through observation, participation, and experience.

Renewable Energy, Operation, and Impact on the Community

The Nunamiutuqaq project seeks to develop a net-zero-ready approach for its Kuugalak building. A net-zero-ready building is defined as a home that is so energy efficient that a renewable energy system can offset most of its energy consumption. In this approach, user behaviour is weighted equally to materials or techniques of construction; in other words, the already traditional ways of living of the Inuinnait coincide perfectly and harmoniously with the technological approach to reduce emissions and develop a more energy-efficient building.

Another technology being implemented at Kuugalak is solar energy. Photovoltaic panels are a relatively common technology in the South, but are just emerging in the Arctic as a solution to household and small producer energy savings. The arrival of the technology has outpaced the ability of local energy companies to net metre its energy and adapt to its aging diesel-powered energy grids. The inclusion of solar panels at Kuugalak is not only a means of producing clean, renewable energy and protecting the building from passive heating during summer, but a way to begin educating local community members and corporations about the possibility and need for such energy-saving technologies.

Such goals need to be well documented, as Kuugalak hopes to do through its extensive monitoring program, to better understand, benchmark, and promote best practices that will pave the way to future policy and building code change for Nunavut. To be able to confidently say this is a beneficial technology for other communities of the Arctic, the effects of the building on the permafrost, moisture build-up, and indoor comfort need to be well documented and analyzed. Adapting to the land and environment is key, especially in this pilot project. This monitoring program also ensures we can see where changes need to happen and what is not working well, so we can confidently share it as a replicable and scalable solution.

CONCLUSION

Storytelling is an important aspect of Inuinnait culture. It is a way of sharing language, culture, and teachings. As the Kuugalak structure develops its shape and personality, it also becomes a story; one of reward and frustration, cross-cultural interactions, and the bringing together of different skills and realities. For PI/KHS and the community members involved in this work, the most important deliverable of the Nunamiutuqaq project is not necessarily a new physical building, but rather the context it creates to draw out, listen to, and document stories about how Inuit have been, are, and can further be, living in the North in a manner that aligns with their culture, environment, and valuations of comfort and efficiency. The many engagements the project has engendered have resulted not only in the sharing of knowledge but also in the creation of meaningful relationships that bridge North and South and create the motivation and close connections required to properly rethink and address the deep cycle of thinking and building architecture that genuinely fits the Arctic.

NOTES

1. Acknowledgements: As was hopefully obvious through this article, the Nunamiutuqaq program has been successful only because it is carried by a community. This community consists of those individuals mentioned throughout the paper—Northern residents and industry, Elders, cultural producers, staff, students, and community members. We would like to acknowledge the wider team of PI/KHS and SAIT staff who have supported this project (Darren Keith, Elayne Merritt, Alex Chen, Helen Blewett, Pam Gross, Pam Langan, and many more), with specific thanks to Kuugalak Elder's Committee members Annie Atighioyak, Eva Kakolak, and Bessie Omilgoetok. We would also like to acknowledge the contributions of others—Bright Spot Climate, who has been creating infographics, podcast material, and renewable energy primers for our project outreach, and Dr. Max Friesen from the University of Toronto, who has supported the integration of archaeological results into our building design. Our thanks also go out to the anonymous peer reviewers and editors of our article at *JSSAC*, whose insights and support were so valuable to the preparation of this article for publication. Last but not least, we would like to acknowledge the generous support of our program funders, which include the Canadian Northern Economic Development Agency (CanNor), Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC), The Federation of Canadian Municipalities Green Municipal Fund, the Government of Nunavut, Canadian Heritage, Infrastructure Canada, the Social Science and Humanities Research Council (SSHRC), Polar Knowledge, and Indigenous Clean Energy.

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