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Integrated Design in an Arctic Community Context – A Case Study of the Canadian High Arctic Research Station

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Abstract

This paper presents a case study of the design of a sustainable research facility in Canada's high Arctic through the perspectives of the client, architect, and engineer. Sustainability in this context means more than just energy use. Successful integration into the host community, promotion of local participation in construction and operation, and remote monitoring of system performance were some of the goals that required close collaboration between all stakeholders.

The Canadian High Arctic Research Station, located in Ikaluktutiak (Cambridge Bay), Nunavut, will help anchor a strong research presence in Canada's north. An integrated design process was used to meet the objectives of supporting world-class, multidisciplinary science and technology research, integrating into the host community, and being a leader in green and sustainable technologies for the Arctic.

Keywords – integrated design process, community consultation, energy modeling, building performance monitoring, commissioning.

1. Introduction

The Canadian High Arctic Research Station (CHARS) project was announced by the Government of Canada in 2007, when the Government committed to "*build a world-class Arctic research station that will be on the cutting edge of Arctic issues, including environmental science and resource* *development*" [1]. This paper presents a case study on the project objectives and design process from the perspectives of the design architect, engineer, and client.

The approximately 8000 m^2 facility is currently in the construction phase and is scheduled for operation in July 2017. A rendering of the 'campus' is shown in Figure 1, including the Main Research Building, the Field and Maintenance Building, and triplex housing units to accommodate visiting scientists and other 'medium-term' users of the Station.

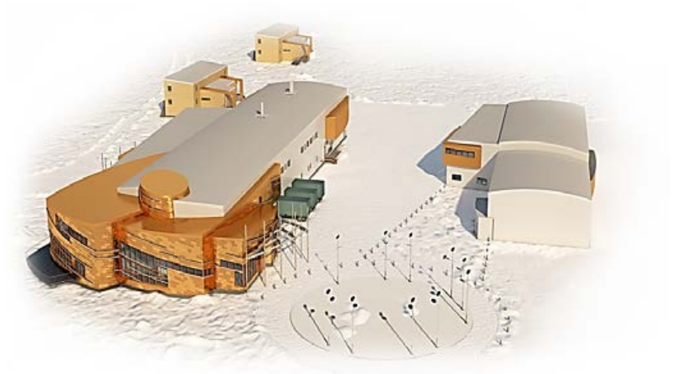

Figure 1: Rendering of the CHARS campus

CHARS was required to meet many key objectives, each extremely challenging in its own right. Three of these objectives are the focus of this paper: supporting world-class, multidisciplinary science and technology (S&T) research in an environment north of the Arctic Circle, integrating into the life of the predominantly Inuit community of Ikaluktutiak (Cambridge Bay), Nunavut, and being a world leader in the use and development of green and sustainable technologies in the Arctic.

Using the integrated design process (IDP) to design and deliver the CHARS facility proved to be essential to achieving this complex and ambitious set of goals. The IDP is defined as "a holistic approach to high performance building design […] It relies upon every member of the project team sharing a vision of sustainability, and working collaboratively to implement sustainability goals" [2]. Too often the IDP has been viewed as a tool limited to helping tackle and resolve difficult technical issues. Properly used, the IDP is a powerful holistic and humanistic tool and was instrumental in helping the project team deliver the CHARS facility as envisioned, with an especially strong emphasis on community integration.

2. Project Objectives and Science & Technology Program – the Client Perspective

Prior to engaging the design team, the client undertook a feasibility study to define the scale and scope of the CHARS science and technology program and the infrastructure, including identification of the host community of Ikaluktutiak (Cambridge Bay), Nunavut [1]. Benchmarking of other polar research facilities (both Arctic and Antarctic) helped identify important considerations for CHARS, including the need for flexibility in design to address changing research priorities, and a multi-disciplinary, in-house research program supporting a network of Arctic research. For CHARS, flexible and multi-disciplinary infrastructure will help support world-class S&T research. As discussed in the introduction, additional objectives include integration into the host community and being a leader in sustainability.

To help determine the research priorities for CHARS, multi-stakeholder consultations were held with academia, federal and territorial governments, the private sector, community members, and Indigenous organizations representing a broad range of scientific disciplines, institutional experiences and geographic scope. These workshops focused on developing S&T priorities for the Station, as well as key approaches and considerations to ensure success in delivering on the priorities.

Stakeholder consultations helped to identify the priority research areas for the first five-year Science and Technology Plan [3], listed in Table 1 with associated themes.

Table 1: Science and Technology Research Priorities at CHARS, 2014-2019

Theme	Priority Research Area
Sustainable resource development	Baseline information preparedness for development
	Alternative and renewable energy
Exercising sovereignty	Underwater situational awareness
Environmental stewardship and climate change	Predicting the impacts of changing ice, permafrost, and snow on shipping, infrastructure, and communities
Strong and healthy communities	Infrastructure for development

The research priorities were confirmed in parallel with the design process. This presented a particular challenge for the design team, as early planning was guided more by a vision than a complete functional program.

The end result, however, will be flexible infrastructure that can accommodate a wide range of research as specific priorities evolve over the life of the station.

A major aim of CHARS is to integrate into the host community of Ikaluktutiak (Cambridge Bay). This includes local participation in the construction and operation of the facility, incorporating public spaces within the facility, and making financial contributions to community projects.

During the feasibility stage, the client reviewed previous Arctic science infrastructure projects. It was found that support from host communities was instrumental to success. Project proponents consistently highlighted the importance of securing community support and ‘buy-in’ for infrastructure and activities. Involvement of the community took various forms, including consultations throughout the lifespan of the project, direct partnering with community organizations, and contracting to local firms to carry out construction work.

The importance of community integration was reinforced throughout stakeholder consultations by the client and design team. Stakeholders placed a strong emphasis on the need to leverage the skills and knowledge of Northerners and to engage them in the conduct of Arctic S&T. Through linkages with communities, territorial colleges, and local and territorial governments, CHARS can provide an opportunity for engagement, collaboration, and the development of stronger northern scientific capacity.

Sustainability was a third major objective for CHARS. The Station has a mandate to be a leader in green technologies for the Arctic, such as renewable energy or energy efficiency systems. In addition to lowering ongoing operational costs and greenhouse gas emissions, the intent is to provide a platform for testing of new or adapted sustainable energy technologies for the Arctic. The client set a target of LEED Canada for New Construction 2009 Gold certification, with a particular emphasis on energy and water consumption and sustainable operation of laboratories through the application of the Labs21 standard.

It was recognized that proven, reliable technologies are necessary to ensure safe operation of the facility, and that the Station could not rely on unproven technologies at the outset. Therefore, the client required the design team to consider future integration of sustainable energy technologies. Space has been reserved within the mechanical rooms and adjacent to staff housing to incorporate new energy systems. A robust performance monitoring system will be implemented to support this goal, as discussed in Section 5.

3. Community Consultations and Integrated Design Process

From the outset, the CHARS project was unique in many ways. The only possible response to this challenge was to innovate on all fronts. The integrated design process (IDP) was used throughout to assist the design team in delivering the project.

CHARS will be the largest polar research station built in a predominantly Indigenous community, as opposed to an isolated setting devoid of any human activities other than that of the scientists themselves. CHARS will be a unique scientific, technical and social integration endeavor; both positive and negative impacts to the community have to be carefully identified, assessed, and managed. Impacts are not limited to the construction period. The Station's activities during operation will affect the community and this transformation needs to be socially and technically sustainable.

The design of the CHARS facility was managed in close collaboration with community stakeholders. The most significant request put forth by the community was for the design team to use Inuit Qaujimajatuqangit (IQ) (which can be translated as "which is known by Inuit") to help create CHARS. IQ is related to the spirit of IDP in that it is a holistic approach. IQ is a sort of compendium of all aspects of traditional Inuit culture including values, world-view, language, social organization, knowledge, skills, perceptions and expectations. IQ was formalized as a tool at the time of the creation of Nunavut to help address the challenge of preserving, articulating, and integrating Inuit beliefs and principles in the contemporary world [4].

IQ reminds us that decisions must be taken by considering the impact on the land, the animals, and future generations' needs. Consequently, IQ principles have been guiding Inuit lives generations before 'sustainable development' concepts were written.

When considering the introduction of CHARS to Ikaluktutiak, the community did not want to see another "southern import" dropped down into its midst. This desire to *decolonize* architecture, moving it squarely into *indigenizing* architecture, is in fact in the true spirit of sustainable development, where protection of cultural diversity is as important as that of protection of biodiversity. To move into this largely uncharted territory the design team needed the guidance and repeated feedback of community members. This was achieved through a series of consultations, discussion sessions and design iterations. The resulting community buy-in ensured continued support throughout the development of the project.

Concurrent to community consultations, the design team conducted multiple design iterations characteristic of IDP, including energy modeling and life cycle cost analysis. The IDP helps ensure a seamless integration between architecture and engineering, and ensures the various disciplines work together rather than at cross purposes. Air flow (natural and mechanical), lighting (natural and artificial), and heating (passive solar and mechanical) are fundamental bioclimatic principles requiring close coordination. Optimization of building orientation, interior volumes, doors, window sizes and operability requires the input of all members of the design team.

4. Energy Modeling and Life Cycle Cost Analysis During Schematic Design

To design a high performance building such as CHARS, the energy profile of the building must be known early in the design process. Although benchmarking with other comparable building is often used, since each building is unique, energy simulations are preferred as they provide more detailed information.

A preliminary energy analysis commissioned by the client during the feasibility study was provided to the design team. This study helped to identify major energy cost targets and preliminary design options. The design team then developed a more detailed simulation model during the schematic design stage, to assess the impact of different Energy Efficiency Measures (EEMs).

At early stages of design, when the architecture of the building was not yet defined, a “simple box” simulation was developed. This model was realized by using the building functional program’s floor surfaces and typical ratios for exterior walls, roofs and fenestration. Figure 2 shows a computer rendering of the building, extracted from the energy model software at early stages of design. This type of model provides enough precision to analyze energy consumption of various load types and to guide design choices.

Moreover, energy simulations at the schematic design phase sometimes yield counter-intuitive results. For example, in Ottawa, relatively low electrical rates (0.13 $/kWh) support the use of heat pumps for space heating and cooling. In Ikaluktutiak however, because electricity is produced by diesel generators, the cost of electricity is prohibitive to heat pump operation. (Refer to Table 4 in Section 5 for detailed utility rates comparison.)

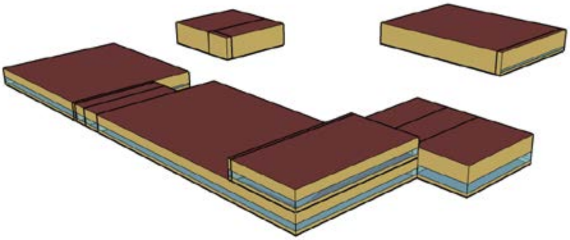

Figure 2: Rendering of the Simulated Volume at Schematic Design

Since the client aims at obtaining a LEED Gold certification for CHARS, the 'reference building' simulation model was constructed as per the Model National Energy Code for Building 1997 (MNECB 97). This model forms the basis for comparison to potential or 'proposed building' designs that incorporate various EEMs. The reference building projected energy costs extracted from the energy simulation at the schematic design stage are presented in Table 2.

Table 2: Annual Energy and Cost Comparison of Reference Building

	Energy		Cost	
	MJ	Ratio	$CAD	Ratio
Heating Oil	17,050,774	70%	529,597	31 %
Electricity	7,252,843	30%	1,164,299	69 %
Total	**24,303,616**	**100 %**	**1,693,896**	**100 %**

The outlined comparison above demonstrates the importance of fuel costs when considering design choices. In this particular case, electricity consumption of the reference building represents 69% of the total cost while only representing 30% of the total energy consumption. This result may be counter-intuitive to anyone who is not familiar with diesel electricity prices.

Further study of the load profile of the reference building showed that 30% of the overall energy costs were related to laboratory equipment use on which the electromechanical team had little or no influence. That fact highlighted that our design team had to reach its goal by acting on only 70% of the building load profile.

The Pareto Principle implies that 80% of the solution to a problem can be achieved by focusing on 20% of the cause of the problem. This guided the design team's focus on major loads – heating, lighting, and fans – using a Life Cycle Cost Analysis (LCCA) method. The LCCA was performed first by simulating the proposed building with various EEMs bundled together in order to account for simultaneous and cumulative effects.

For each option, energy cost reductions were compared to estimated capital costs with a 30 year lifecycle, taking into account inflation costs of fuels and maintenance. At the end of the schematic design phase, approved EEMs were integrated in the proposed building energy simulation. Table 3 presents the proposed building projected costs.

Table 3: Annual Energy and Cost Comparison of Proposed Building

	Energy		Costs	
	MJ	ratio	$CAD	ratio
Heating Oil	4,786,406	55%	148,666	19%
Electricity	3,868,500	45%	621,010	81%
Total	**8,717,125**	**100%**	**769,676**	**100%**

Compared to the reference building, the proposed building achieves a reduction of **55%** in energy costs at the schematic design phase. An integrated approach, in which EEMs are evaluated as a system rather than individually, yields a more optimal outcome in terms of system and component sizing and cost. The main reason is that some EEMs are potentially overlooked when studied individually due to high cost and low return on investment. Bundled with other EEMs however, the overall objectives can be achieved and acceptable paybacks are reached. This method also tends to optimize the sizing of systems, generally resulting in smaller equipment sizes and hence lower capital costs. This combination of higher efficiency design with lower operational and capital costs is what should make this method so attractive to clients and owners.

5. Advantages of Building Performance Monitoring

As described in Section 4, the design team made extensive use of energy modeling throughout the design phase. Simulation results were also used by the client to estimate operational costs and to inform analyses of potential alternative energy technologies that could be tested at CHARS. Since energy and water use is heavily influenced in practice by actual operational schedules, equipment loads, and weather variability, a comprehensive building performance monitoring (BPM) scheme is being implemented.

The BPM system at CHARS measures heating (fresh air, perimeter, domestic hot water), equipment loads categorized by end-use, lighting, and water consumption. The communication protocol is Building Automation and Control Network (BACnet), an open protocol defined by ASHRAE Standard 135. The use of this standard helps prevent interoperability issues and ensures a vendor-neutral approach.

Post-construction building monitoring is useful for any building, and can contribute to greater rigor in determining energy savings, troubleshooting during operations and maintenance (O&M), and demonstrating reduced emissions from energy efficiency and renewable energy measures [5]. BPM is also aligned with the objectives of CHARS as a research facility.

Confirmation of energy savings is critical for CHARS to ensure design goals were met, for commissioning of the facility, and for on-going operations. Utility costs in the Canadian Arctic are very high compared to southern Canada, and every dollar spent on energy is a dollar not available for research. Table 4 shows typical costs in Ikaluktutiak for electricity [6], heating oil, and water [7], with costs in Ottawa shown for comparison [8, 9, 10]. Natural gas, which is significantly less expensive than heating oil, is not available in Ikaluktutiak.

Table 4: Utility Rates in Ikaluktutiak and Ottawa

	Unit Rate ($CAD)		Rate / MJ	
Utility	Ottawa	Ikaluktutiak	Ottawa	Ikaluktutiak
Electricity (kWh)	$0.1345	$0.6607	$0.0373	$0.1835
Heating Oil (litre)	$1.041	$1.2120	$0.0267	$0.0311
Water/Sewage (litre potable)	$0.0037	$0.0750	N/A	N/A

Electricity production in Ikaluktutiak occurs through diesel generators, for which fuel is resupplied by ship in late summer, when transit through the Northwest Passage is possible. While reliable, the use of diesel generators is expensive, creates greenhouse gas emissions and localized pollution, and is subject to fuel price volatility and the risk of spills. The price of heating oil, which is ubiquitous across Nunavut for space heating and domestic hot water, is comparable to southern prices due to government subsidies; however, heating loads and therefore the quantity of fuel consumed is higher in the Arctic than in a southern location due to the colder climate.

Water and sewage costs are about twenty times higher in Ikaluktutiak than in the south. Water metering has thus been identified as a major feature for CHARS in order to maintain the water reduction objectives. Moreover, water consumption is measured by usage type (kitchen, laboratory, domestic and emergency). This data could be useful in developing benchmarks for other buildings in the future.

Beyond monitoring energy savings, the goals of CHARS and the associated research program suggest further opportunities for performance monitoring, such as the Green Education Program as specified by LEED or integration of alternative and renewable energy systems at the campus.

The intent of the Green Education Program is to provide an active, instructional program that will educate users and visitors of the green aspects of the building [11]. This could include a live feed of energy use to a website or interactive display located in the public space, and touch-screens that educate users about efficient design approaches utilized for the station. While still under development, the BPM system supports a wide variety of approaches to meeting this LEED credit.

The BPM system will also support the integration of alternative energy sources in to the Station’s infrastructure. For example, as a demonstration project, renewable energy generators such as wind turbines could be optimized based on time-of-use demand at the Station. Further community integration could be supported by engaging local businesses and training workers to help deliver these projects.

6. Conclusion

This paper presented a case study of the design of the Canadian High Arctic Research Station (CHARS), currently under construction in Ikaluktutiak (Cambridge Bay), Nunavut. Supporting world-class science and technology, integrating into the host community, and being a leader in green and sustainable technologies for the Arctic were three main objectives for the project.

The design team utilized an integrated design process (IDP) to ensure these objectives were met. In addition to addressing technical challenges, significant engagement of the host community helped foster a sense of ownership of the Station, provided a forum for the community to express their priorities to the design team, and supported the goal of integration of CHARS into the community.

CHARS is targeting a LEED Gold certification, with an estimated 55% reduction in energy use compared to a reference building. Combined with rigorous building performance monitoring, this approach will reduce operational costs and greenhouse gas emissions, and support the use of CHARS as a platform to test and adapt sustainable energy technologies for the Arctic.

Finally, the IDP has resulted in a flexible, multidisciplinary design that will enable researchers at CHARS to deliver world-class science and technology research, to the benefit of Northerners, all Canadians, and the world.

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