Expert Guidance on Cold-Climate Challenges

Buildings in arctic and subarctic climates face unique challenges, not only the cold, but also remoteness, limited utilities, permafrost, and extreme temperature shifts. Built structures must meet these challenges while maintaining occupant comfort and, if possible, minimizing impact on the environment. Harmonizing human comfort with the climatic realities of these environments can be a delicate balancing act. Strategic design is key to building, commissioning, and operating efficient and long-lasting cold-climate structures. This unified guide to cold-climate design provides expert knowledge on the issues commonly faced in arctic and subarctic climates.

In addition to cold-climate considerations in HVAC calculations and system design, this book’s chapters cover sustainability, controls, building design, and commissioning, all from this distinctive climatic perspective. The book also includes an appendix with seven case studies of buildings located in cold and extreme cold climates. These buildings are leaders in their field with regard to both efficiency and cold-climate design.

Aimed at each member of the building team, from the designer and architect to the commissioning authority, Cold-Climate Buildings Design Guide will serve as a valuable resource from the initial planning to completion of cold-climate buildings.
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Preface

The inspiration from this guide was the result of a working session held at the end of the 7th International Cold-Climate Design Conference held in Calgary in 2012, cosponsored by ASHRAE, SCANVAC, and REHVA.

Tom Watson and Bjarne Olesen were instrumental in the encouragement of ASHRAE hosting the Cold-Climate Design conference and conference and in ASHRAE developing this Guide.

A special thanks to the City of Calgary, Aqua Air, Convergint, Uponor, Scott Springfield Manufacturing, Erich Binder Consulting Limited, Government of the Northwest Territories, Low Carbon Design, and DLB Associates for their support and effort in making this design guide a reality.
The answer to the question “what is a cold climate?” might be as simple as, “anywhere you feel cold.” Of course, this feeling is different for each person and is not derived scientifically.

Historically, there have been many ways to quantify cold and define what a cold climate is such as lack of heat or weather cold enough to cause freezing. The Climatic Design Information chapter of the ASHRAE Handbook—Fundamentals (ASHRAE 2013a) divides the world into climate zones based on temperature, duration of low temperature periods, and whether the zone is humid or dry. Zones 5 to 8 are listed as cool to subarctic but may not encompass all zones that have some cold-climate features. Even the hottest climates having higher altitudes may need heat a few days of the year to maintain occupant thermal comfort.

Degree days are frequently used to compare location-specific weather in terms of severity. Heating degree days are useful for calculating energy savings, but do not present a definition for cold climates. Some areas of the world have relatively few heating degree days but can get very cold for just a short time of the year. Average temperature or design temperature are also considered in designating hot or cold climates, but some climates can experience both very hot and very cold temperatures; as such, average temperature is not always an accurate representation. Likewise, design temperature does not always clearly define the line between cold and noncold climates.

A cold climate is defined by a combination of factors that together create a unique set of building design challenges. This guide touches on each of these factors and identifies strategies on how to meet the design challenges created by them. Most of these must be considered for any building, but additional consideration is needed to provide a successful building in a cold climate.
Cold-Climate Factors

Temperature. Many areas of the world sometimes experience temperatures below the freezing point of water. Water located throughout construction materials, support systems, and equipment is susceptible to freezing if not protected. To function reliably at low temperatures, equipment must be robust and well maintained.

Frozen Precipitation. Snow, ice, vapor, and freezing rain can wreak havoc on any building, especially when it is not designed for those conditions. Roofs need extra support to accommodate snow loads. Pitched roofs can cause miniature avalanches next to buildings. Snow can also provide additional insulation to improve the building envelope.

Wind. Pressure differentials caused by wind cause infiltration, create snow drifts, drive snow into louvers, and rip roofs and siding off buildings. Cold-climate designers must take into account air velocities and pressures in and around buildings.

Humidity. Humidity is necessary for some building occupancies in all climates, but in cold climates, higher humidities cause extra complications. Cold envelope temperatures make materials susceptible to rising relative surface humidities and surface condensation.

Thermal Comfort. Cold interior surfaces, temperature stratification, and drafts can make space conditions difficult for occupant thermal comfort. The stack effect from aggressive temperature differences across the envelope can cause infiltration, resulting in undesirable air velocities throughout the building. A combination of envelope design, compartmental strategies, and heating systems arrangement is required to establish conditions suitable for occupant thermal comfort in a cold-climate building.

Thermal Envelope (Thermal Enclosure). Thermal envelopes for cold climates are specialized and have distinct needs. Being a largely passive element, the design and thermal performance of the envelope must be integrated with the design and installation of the heating systems.
systems. Refer to Chapter 8 of this guide for more information on envelope design and performance considerations.

**Maintainability.** Building systems must be maintained to keep the building operational. In cold climates, this can be especially difficult when encountering freezing temperatures, wind, and frozen precipitation. Various strategies are explored to enable equipment maintenance in cold climates.

**Permafrost and Frozen Ground.** Frozen ground can limit the construction season, choice in construction materials and methods, impact foundations, and cause utility damage. In some areas, permafrost (permanently frozen ground) can be especially difficult to build foundations on. Refer to Chapter 8 of this guide for more information on this topic.

**Remote Building Locations.** Remote locations are areas where, during certain events or at certain times of the year, transportation to the building is limited or restricted. There may be limited or reduced maintenance, a higher chance of power interruption, or the building may not be regularly occupied or monitored.

Remote buildings are typically built to be more robust and stand alone. Often, equipment repairs must wait for staff and/or parts to be flown in. Remote building considerations are covered throughout this guide.

If the considered building is exposed to any of the listed cold-climate factors, this book provides insight on how to deal with problems that can be encountered in the planning, design, construction, and commissioning phases of the project.

Figure 1.2  ASHRAE climate zones for states and counties in the United States.

*Reproduced from ASHRAE Standard 169-2013*
Figure 1.3  Polar bear, Manitoba, Canada.

Figure 1.4  Winter operation and maintenance challenges.
Figure 1.5  Ice road, Northwest Territories, Canada.

Figure 1.6  Remote, arctic industrial facility.

HOW COLD IS IT?
It is so cold ... my hot cup of cappuccino turned into a cappufreeze!
Sustainability in the Context of Cold-Climate Design

Human industry causes changes that affect the earth and its natural systems, frequently for the worse. However, products and processes thought to have a more benign or even beneficial effect on the natural world over their total life cycle are called sustainable. The phrase *environmentally appropriate* is sometimes interchangeably applied. Buildings and other engineered facilities are a form of product—one with large and long-lasting effects on environmental quality, utility supply networks, and stakeholder-neighbors’ quality of life. These effects may be favorable or unfavorable.

*Figure 2.1* Frozen source, low-temperature geothermal energy. *Courtesy Resource Professionals Group*