



COLD CHANGES

Courtesy of CCHRC

BY MOLLY RETTIG AND NATHAN WILTSE

Winter days with little to no sunlight, frigid temperatures and reliance on expensive fuel oil for heat might seem to be insurmountable obstacles to building sustainable, energy-efficient structures in Alaska. But the Cold Climate Housing Research Center (CCHRC) in Fairbanks, Alaska, proves otherwise. The Research and Testing Facility, housed in the farthest north LEED Platinum building in the world, is a living laboratory for arctic building science and energy research.

The 15,000 ft² Research and Testing Facility sits on the edge of the University of Alaska Fairbanks campus. Experiments are embedded throughout the building in the form of innovative wall assemblies, creative energy storage and multiple heating and distribution systems.

CCHRC was formed in 1999 by members of the Alaska home building community to address the challenges and costs of building in this climate. Its mission is to make housing more energy efficient, healthy, affordable and durable throughout Alaska and circumpolar regions. CCHRC is supported by the state-owned Alaska Housing Finance Corporation, which finances more than 40% of all new residential construction in Alaska, as well as other funding sources.

The team researches building techniques and materials, tests heating and energy systems and designs sustainable prototype houses for rural Alaska. This research is disseminated to building professionals, regulators, housing agencies, policymakers and homeowners through publications, education and outreach. For instance, CCHRC developed a wall system for Interior Alaska that saves homeowners thousands on energy costs and designed prototype homes for rural Alaska that

cost far less than conventional homes and use one-tenth the energy.

The facility, built in 2006, integrates proven technologies—such as a super-tight thermal envelope and a highly efficient stone masonry heater—with innovative ideas—such as an adjustable foundation and experimental wall designs. The structure is laced with hundreds of sensors monitoring temperature, humidity, light, carbon dioxide and more. It is designed to prove that sustainable, affordable building is possible even in the world's coldest places.

Energy Efficiency

Fairbanks swings from −50°F and three hours of daylight in the winter to 80°F and nearly 23 hours of sunlight in the summer. It has a six-month cold season and nearly 14,000 heating degree days, almost three times the national average.

In addition, Interior Alaska has no access to low-cost natural gas or

BUILDING AT A GLANCE

Name	Cold Climate Housing Research Center
Location	Fairbanks, Alaska
Owner	Cold Climate Housing Research Center
Principal Use	Research center
Employees/Occupants	26
Gross Square Footage	15,000
Conditioned Space	15,000
Distinctions/Awards	LEED Platinum
Total Cost	\$5.2 million
Cost Per Square Foot	\$346
Substantial Completion/Occupancy	2007

electric heat and therefore relies on oil (at roughly \$4 a gallon) as its main heating fuel. The extreme climate and high cost of heating have pushed Alaska to the front edge of energy efficiency design and innovation.

The facility was built for \$346/ft², less than the cost of typical

Opposite The Cold Climate Housing Research Center (CCHRC) building in Fairbanks, Alaska, is located on a brownfield site with underlying permafrost. It is surrounded by black spruce and birch forests.

Right The Research and Testing Facility is in the world's farthest north LEED Platinum building. CCHRC plans to move the heating system off fossil fuels by adding a ground source heat pump and greater thermal mass.



Courtesy of CCHRC



Courtesy of COHRC

commercial construction in this region at \$400/ft². It uses roughly half the energy resources of a typical commercial building its size in Fairbanks.

The building combines high-efficiency oil boilers, as well as experimental solar thermal and wood boiler systems into an integrated hydronic

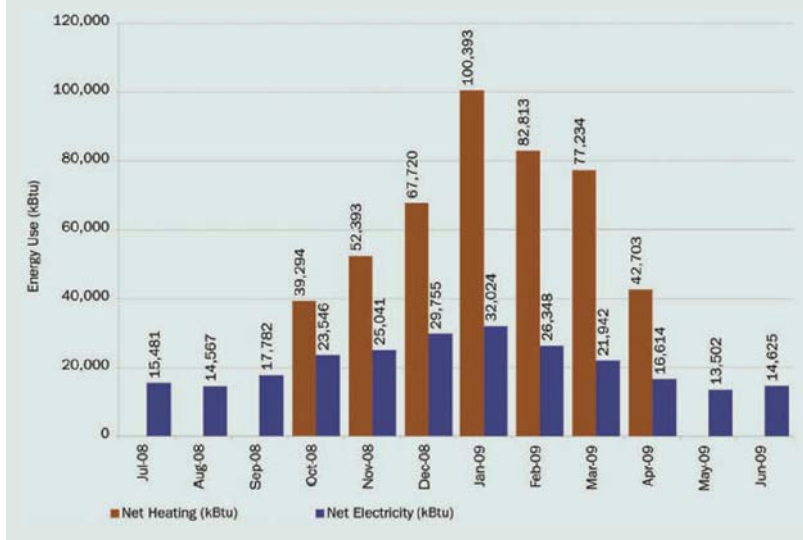
heating system. But the thermal envelope is the heavy lifter, delivering a majority of the energy savings. The building has a warm, airtight envelope with an R-60 roof, R-40 to R-45 walls, and 0.15 to 0.20 U-value triple-pane, argon gas-filled windows.

The masonry heater is made of 12,000 local rocks that absorb heat from exhaust gases and radiate it slowly into the building. With a 2,000°F fire in the firebox, the heater produces an extremely hot, clean burn, exhausting 300°F gas out of the flue.

Wall assemblies are comprised of combinations of materials and insulation. The west wing, which houses the labs and design office, mimics commercial construction with a structural steel frame wrapped with 2 × 4 light gauge steel stud curtain walls, interior cellulose insulation (R-21) and layered EPS exterior foam insulation (R-26). The east administrative wing simulates residential construction with 2 × 6 wood framing, interior fiberglass insulation (R-19), and exterior foam (R-26).

Both systems use a construction method called REMOTE (Residential Exterior Membrane Outside-insulation TEchnique) that was developed to prevent moisture problems in the wall cavities, a widespread issue in the severe cold of Interior Alaska. The method moves the majority of the insulation and the air barrier to the outside of the wall sheathing, keeping dew point

NET ENERGY USE FOR ELECTRICITY AND HEATING JULY 2008–JUNE 2009 *



*Net heating includes fuel oil, wood and solar thermal. Solar thermal accounts for less than 1.5% of space heating. Net electricity includes purchased electricity only. Gross annual electricity use (including electricity generated on site) is about 85,000 kWh (290,032 kBtu).

condensation outside the cavity and allowing walls to dry to the inside.

The REMOTE system also eliminates thermal bridging, another contributor to building heat loss. The REMOTE wall has become a popular new construction and retrofit method in the Interior, with an estimated one-half of new homes using this technique.

On a standard 2 x 6 wall in a 1,900 ft² home, adding 6 in. of EPS foam to the outside will add \$3,700 in materials cost and will pay back in energy savings in about 4.5 years. Energy savings over 10 years equal more than \$8,000 (assuming heating oil prices of \$5 a gallon).

Heating. The building absorbs all its heat for space heating and domestic hot water from passive solar and solar thermal from April through September. In the winter, it relies on two of its three oil-fired boilers (designed to be interchangeable for testing purposes).

The CCHRC library is filled with resources for builders and homeowners, including a wide array of texts, technical journals, industry publications and CCHRC research. It is frequented by walk-in visitors as well as CCHRC staff and research partners.



Courtesy of CCHRC



Courtesy of CCHRC

Top The facility relies almost entirely on daylight from May through August.

Above Steel railing art was designed by a local artist to create an outdoorsy, homey feel.

The current top performer is a 92% AFUE (annual fuel utilization efficiency) condensing boiler because it's able to squeeze more Btus out of the flue gas than standard non-condensing boilers. The boiler feeds water through the radiant in-floor slab, which is separated into 16 control zones throughout the facility.

CCHRC plans to replace the building's remaining fossil fuel heating entirely with a ground source heat pump in 2012. Seasonal solar

thermal will recharge the soil with heat that is extracted in the winter.

Ventilation. Instead of one central air-handling system, the building has six highly efficient residential heat-recovery ventilators (HRVs) throughout the building. The system tests the three most popular brands of HRVs in the region and improves whole building efficiency by ventilating specific zones on demand.

The HRVs operate based on outdoor air temperature and interior carbon dioxide concentrations and can be manually activated. They also redistribute heat through ducting from warm areas, like near the

WATER AT A GLANCE

Annual Water Use 31,392 gallons

ENERGY AT A GLANCE JULY 2008–JULY 2009

Annual Energy Use Intensity (Site)
45.37 kBtu/ft²

Fuel Oil 11.1 kBtu/ft²

Purchased Electricity 19.46 kBtu/ft²

Solar PV 2.76 kBtu/ft²

Wood (estimated) 11.1 kBtu/ft²

Masonry Heater 2.096 kBtu/ft²

Wood Boiler 9.004 kBtu/ft²

Solar Thermal (estimated)

0.95 kBtu/ft²

Annual Source Energy 87 kBtu/ft²

Annual Energy Cost Index (ECI) \$1.11/ft²

Annual Net Energy Use Intensity*
30.56 kBtu/ft

Savings vs. Standard 90.1-2004
Design Building 49.2%

Heating Degree Days 13,982

Cooling Degree Days 132

*Annual Net Energy Use Intensity excludes wood. The CCHRC only burns wood that is approved as an on-site resource by LEED. (Several cords were harvested from and donated by the University of Alaska Fairbanks, the CCHRC's landlord and neighbor. The CCHRC submitted a letter from UAF with the LEED application and the wood was approved as an on-site resource.)



Courtesy of CCHRC



Top Rainwater is collected from the roof and used for the sprinkler system, the toilets and the sewage treatment plant. CCHRC collects about 15,000 gallons of rainwater per year.

Above The south lab houses research projects such as a firewood analysis, a study of various wall systems and a passive refrigeration experiment.

masonry heater, to cooler areas. A large central air handler could possibly be more efficient if it were as sophisticated as the current zoned system; it would need a damper control system and pressure feedback system to respond

to ventilation needs throughout the building.

Lighting. The building is lit with a mix of sunlight, T-8 fluorescent lamps and LEDs. Lights are controlled by motion sensors and ambient light sensors that gauge the amount of light coming in the windows.

The controls reduce artificial lighting levels based on the availability of natural light and turn off lights when a zone is vacant. Few interior lights are needed from May through August.

Resources and Renewables

Researchers are studying solar, biomass and thermal storage to see how the resources perform in this climate and whether they can provide 100% of the facility's energy in the future. Currently, approximately 25% of the energy use is offset by on-site renewable sources.

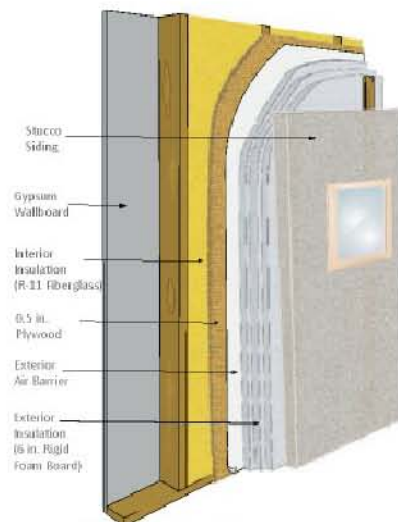
Two types of solar thermal panels—flat plate and evacuated tube collectors—are mounted on the roof to study which technology works best with the low-angle sun and heavy frost accumulation of Fairbanks winters. The collectors provide heat for the labs' radiant floor system during low heat demand periods, saving oil consumption for colder and darker times of the year.

While the evacuated tube collectors have produced more total Btus over the past five years, they tend to work best in the spring and fall shoulder seasons, while flat plate collectors outperform them in the summer.

Another key energy source is the masonry heater, an old-world technology designed to hold and emit heat for long periods of time. Masonry heaters are one of the cleanest ways to burn wood, which is still a significant heating fuel in Alaska.

The heater is made from stone with a refractory brick combustion chamber and flue passage. Each morning during the heating season, it is loaded with about 60 lb of wood and burns as a hot, fast fire, which is a far cleaner combustion than a long, smoldering fire.

As hot flue gases meander through the heater's 30 ft of winding flue passage, the heat is absorbed by 12,000 lb of mass and radiates



One wall section of the Research and Testing Facility demonstrates the REMOTE technique with 2 × 6 studs filled with R-11 batt insulation and 6 in. of expanded polystyrene (EPS) foam board on the outside of the sheathing.

slowly into the building over 16–24 hours.

The masonry stove heats one-third of the building in the winter and burns through less than two cords of wood a season, far less than a typical building this size and comparable to an energy-efficient residence in Fairbanks. Researchers are testing how emissions levels are affected by variables of

wood burning—such as wood species, wood moisture content and firewood storage methods—for the municipality’s public education program.

CCHRC also is testing the potential of storing heat with water to bridge long periods with no solar gain. (Fairbanks receives virtually no usable sun from late November through mid-February.) The north lab contains a 1,500 gallon water tank hooked to a wood-fired boiler. This hot water resource supplements the oil-fired low-temperature hydronic system.

Researchers are comparing the efficiency of the system to the oil-fired boiler system. They are also studying whether burning an efficient fire, and saving the heat for later use, reduces particulate pollution—a severe problem in Fairbanks caused in part by inefficient wood burning. No initial results are available because the project is not funded.

Solar PV. CCHRC also taps the sun for electricity with a 12-kW photovoltaic array. A fickle resource



Courtesy of CCHRC

Top In the topmost photo, designers installed three tracking arrays and one fixed array to research the efficiencies and pay-backs of each system. A 10 kW photovoltaic array provides roughly one-third of the building’s power during the summer.

Above The locally manufactured, self-contained sewage treatment plant breaks down sewage using an aerobic process and ultraviolet light. The clean discharge flows into a storm water pond.

Left The gallery in the west wing of the building has a double-height ceiling, allowing in greater daylight. The space provides collaborative office space for architectural designers.

Courtesy of CCHRC



at this latitude, the sun shines excessively in summer months (providing 30% of the building’s power) and scantily in winter months (kicking out just 2 kWh in January).

When the building is not demanding power, the panels feed power into the local electric grid or charge the

on-site 24-hour battery bank. The system includes three panel technologies arranged in three arrays that track the sun and one fixed array.

The greater output from the tracking arrays resulted in the same nine-year payback as the fixed array, despite a nearly 40% higher installation cost. The payback equation also is impacted by the tracking arrays'



Courtesy of CCHRC

The south roof is landscaped with native grasses and includes summer meeting space and a weather station.

KEY SUSTAINABLE FEATURES

Urban Redevelopment of Brownfield Site

Alternative Transportation Refueling Stations More than 30 plug-in stations for electric vehicles

Stormwater Management

Green Roof

Light Pollution Reduction With LED Outdoor Motion-Sensing Lighting

Water Conservation Native landscaping, rainwater catchment, low-flow showerheads and dual-flush toilets

Solar Thermal Panels

Solar PV

Materials Locally sourced, low emitting

Daylighting

HEATING ENERGY USE BY SOURCE *

Fuel Oil (Btu)	190,374,391	41%
Solar Thermal (Btu)	6,726,000	1.5%
Stone Masonry Heater (Btu)	31,450,370	7%
Wood Boiler (Btu)	234,000,000	51%
Total	462,550,761	

ELECTRICITY USE BY SOURCE *

	Electricity Coming to Building (kWh)	Solar PV Generation (kWh)	Net Electricity Purchased (kWh)
July	6,120	1,584	4,536
August	6,040	1,772	4,268
September	6,040	830	5,210
October	7,440	541	6,899
November	7,400	63	7,337
December	8,720	2	8,718
January	9,420	37	9,383
February	8,080	360	7,720
March	7,800	1,371	6,429
April	6,760	1,892	4,868
May	5,880	1,924	3,956
June	6,040	1,755	4,285
Total	85,740	12,131	73,609
Percent of Total Electricity Consumed		14%	

*Heating energy data includes heating season (March–September). Data for heating and electricity sources was recorded from multiple years (2008–2011) and mapped to the 2008–09 heating season. Energy data is compiled from various years because individual building systems have been monitored as research funding allowed.

ability to collect the high level of diffuse light and reflected solar gains from snow cover, which amounts to one-third of collected solar energy in March, April, and May.

Brownfield Redevelopment. The facility is located on a 2.5 acre brownfield site with a history of groundwater contamination and poor soils that is still being monitored by state environmental regulators. The site was previously cleared and

was being used as an experimental farm by the University of Alaska Fairbanks until 30 years ago.

The location was selected to demonstrate how to design and build successfully on a lower quality site rather than develop additional land. The site is near an old gas station that is thought to have leaked gasoline, solvents, and waste oil into the groundwater, creating a benzene plume one-quarter mile from the facility.



To avoid the contaminated groundwater, CCHRC uses a system of delivered water, rainwater harvesting and remediation. Designers revegetated the land, preserved open space, developed a wetland habitat and restored native grassy fields.

Water. Half of the water consumed within the building (about 15,000 gallons a year) comes from the sky. This rainwater is collected during nonwinter months from the roof and stored in two 2,500 gallon cisterns in the basement. It is used to flush toilets and supply the sprinkler system.

Seasonally harvested rainwater also irrigates vegetable and flower gardens around the building and on the roof. The facility reduces water use with dual-flush toilets, waterless urinals and low-flow showerheads.

This rainwater harvesting system had an increased up-front cost, roughly \$7,000 including tanks, plumbing and pumps. Half the water is delivered at a cost of 6 cents per gallon. But the rainwater collection and water delivery are the best long-term options, as drilling a well was not possible (because of the site's history) and hooking up to municipal water would have been cost prohibitive.

The frozen soils of the site are not compatible with a standard wastewater system—an underground septic tank and leach field. Instead, the building uses a locally made self-contained sewage treatment plant, rated for -50°F . At about \$15,000, the sewage treatment plant cost approximately 40% more than a standard leach field system, but was required to build on this site.

It contains three chambers that separate the solid waste, break down the sewage through an aerobic process, disinfect the liquid effluent with a UV lamp and ultimately discharge the treated effluent. The treated water flows through a swale to a storm water pond that provides wetland habitat for ducks and other wildlife.

Through adjusting the system's fan, lights and sensors, researchers have cut its original energy use nearly in half. CCHRC researchers have adapted the sewage treatment plant to building projects in rural Alaska with equally challenging soils.

Foundation. CCHRC has a one-of-a-kind adjustable foundation that allows it to respond to possible movements in the frozen soils (or permafrost) that lay 15 to 30 ft

BUILDING ENVELOPE

Roof

Type Cellulose
Overall R-value R-60

Walls

Type Cellulose and extruded polystyrene foam board
Overall R-value South wall: R-19 cavity, R-26 sheathing
North Wall R-13 cavity, R-26 sheathing

Basement/Foundation

Slab Edge Insulation R-value R-20
Basement Wall Insulation R-value R-30
Under Slab Insulation R-value R-20

Windows

U-value 0.15–0.20
Solar Heat Gain Coefficient (SHGC) 0.19–0.27
Visual Transmittance 0.33–0.4

Location

Latitude 64.83°N
Orientation South



Top left Employees harvest (and sample) the sugar snap pea crop on the north green roof.

Above Two 2,500 gallon tanks in the basement hold rainwater, which provides half of the facility's annual water. It takes about three days of good rain to fill them up.

Below The building has six residential-sized heat recovery ventilators (HRVs) that respond by zone to ventilation needs throughout the building.



Courtesy of CCHRC

Above A fire is built in the masonry heater every morning in the cold season, burning hot and fast for a few hours and warming stones to about 100°F. The stones slowly emit radiant heat over 16–24 hours.

Right The energy and electricity use of the building ranges from more than 130,000 kBtu in January to fewer than 15,000 kBtu in June.

beneath the building. The foundation includes concrete footings that can be pushed into the ground to help level the building in the event that permafrost melts or shifts.

The foundation contains more than 50 concrete jacking points. If the building experiences differential settling, hydraulic jacks can be installed to lift the structure against the footing, and load-bearing



foam can be injected to stabilize the adjustment.

The well-insulated foundation (R-30 below-grade walls, R-20 slab) is designed to reduce heat loss through the building foundation that would accelerate thawing of permafrost under the site. After three years and

periodic internal surveys, the building has yet to shift, a fact that brings both grins and grimaces to its designers eager to prove all aspects of its design.

Materials. The building is made from local resources (63% regionally extracted, 22% regionally

LESSONS LEARNED

More Low-Temperature Radiant Heat, Less Radiant Baseboard Heat. CCHRC has a mixed heat distribution system with about one-third radiant floor slab and two-thirds baseboard heat. In-floor heating is much more efficient because it requires lower-grade heat, allowing the building to take greater advantage of low-temperature sources such as solar thermal or a ground source heat pump. The addition to the CCHRC Research and Testing Facility planned for 2012 will incorporate more in-floor radiant heat as well as radiant panels in the walls and ceiling.

More Solar Thermal, More Thermal Mass. Researchers and builders are still exploring the vast potential of solar thermal in this climate, where many underestimate the sun's potential to provide reliable heat. Our research shows that usable solar thermal can be harvested in Fairbanks as early in the year as March, improving the viability of the resource.

Key to this approach is thermal storage, using mass to capture and hold heat from the sun, biomass and other sources.

CCHRC will add greater thermal mass to the building addition in 2012.

Ventilation System. The idea of zonal ventilation was successful; installing six HRVs was more cost-effective upfront and uses less energy than a central air-handling system. However, monitoring has indicated that controlling the HRVs by carbon dioxide sensors has resulted in over-ventilation and lower humidity levels. Alternate indicators are being considered while adjustments to raise indoor humidity are ongoing.

Heating Load Evaluation. When designers focus on electric loads and heating loads as separate components rather than as a system, the heating contribution from large electric appliances can often be overlooked. Such is the case with the server room in the basement, which provides more than enough heat for that zone. Monitoring of the building's zone demands has shown that no call has ever been needed for this zone, even at -50°F.

BUILDING TEAM

Building Owner/Representative, Architect/Designer, General Contractor, Landscape Architect CCHRC

Mechanical, Electrical Engineer Design Alaska

Energy Modeler Donald W. Cott, PhD, PE., LEED AP; Thermal Systems Engineering, North Pole, Alaska

Structural Engineer PDC Engineering

LEED Consultant O'Brien & Company

manufactured) that minimize its footprint. The heart of the building is the masonry heater that sits inside the entrance. Made from a half ton of local river rocks, the heater exudes cozy radiant heat all day.

Doors and windows are trimmed in milled Alaskan birch, logged 20 miles away. The walls are constructed with Forest Stewardship Council-certified plywood and the entire structure contains 16% recycled material, including steel columns and beams, asphalt paving, fly ash concrete, cellulose insulation, carpeting, cork flooring and stone.

An open floor plan and strategically placed windows ensure that every workspace receives natural light, either direct or reflected, and views. Argon-filled, double low-e coated triple-pane windows minimize heat

loss while providing benefits of passive solar and daylight—especially nice during long, dark winters.

Green Roof. The green roof provides outdoor meeting space as well as an employee garden. The roof and surrounding landscape, covered in native vegetation, were designed to reduce heat-island effect and protect permafrost.

Upcoming Innovations. A 7,500 ft² addition to the Research and Testing Facility planned for 2012 will incorporate a ground source heat pump, greater thermal storage and more radiant heat. By adapting today's technologies to a cold climate and pushing toward net-zero energy, CCHRC is striving to transform the future of housing in Alaska. ●

ABOUT THE AUTHORS

Molly Rettig is communications coordinator at the Cold Climate Housing Research Center.

Nathan Wiltse is a project manager and building energy economist at the Cold Climate Housing Research Center.



Courtesy of CCHRC

Above In the spring, the north roof is dotted with wildflowers, poppies and geraniums.



ISIS[®]

A Ceiling Fan That Actually Works.

Isis uses its immense size, aerodynamic airfoils and uncompromised engineering to create a wall to wall breeze. In fact, this air moving machine does the work of 9 small ceiling fans while using just 1/3 of the energy. Unlike gear-driven fans, the effect of Isis is seen and felt - not heard. And although it's whisper quiet, Isis makes a bold visual statement about a commitment to sustainable design.

www.BigAssFans.com | (877) BIG FANS 244-3267





Ask how Big Ass Fans contribute to LEED[®] credits in:
Optimized Energy Performance; Enhanced Refrigerant Management;
Minimum Indoor Air Quality Performance; Increased Ventilation;
Thermal Comfort – Design; Innovation in Design

May be covered by one or more of the following U.S. Patents:
6,244,821; 6,589,016; 6,812,835; 6,939,108; 7,252,478;
7,284,960; 6,587,799; 6,607,988 and other patents pending.
©2011 Delta I Corporation dba the Big Ass Fan Company.
All rights reserved.



BIG ASS FANS[®]

No Equal.

HPB.hotims.com/37997-9