Identifying Appropriate High-Performance Building Environmental Control Technologies for Commercial Code Enhancement in Montana

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Jaya Mukhopadhyay
Montana State University
Bozeman, Montana

Commercial Codes Training
For Montana

INTEGRATED IDL DESIGN LAB
offering daylight and energy efficiency analysis to Montana’s architects
OVERVIEW

OVERVIEW OF THE COMMERCIAL CODE ENHANCEMENT PROCESS

ROAD MAP FOR THE REPORT

HIGH PERFORMANCE BUILDINGS IN MONTANA

CASE-STUDIES

INCENTIVE PROGRAMS FROM NORTHWESTERN ENERGY

HIGH PERFORMANCE SYSTEMS

SUMMARY
Commercial Code Enhancement Initiative Relationship to NEEA Codes Program
OVERVIEW OF MONTANA CCE REPORT

STEP 1: Identifying examples of high-performance commercial buildings in Montana

- List of High Performance Building case studies in Montana
- Certification? (LEED, CHPS, Others)
- Resources:
  - Montana State A&E
  - Montana UGRC
  - Architecture & Engineering Firms

STEP 2: Identifying case studies in which the design & construction practices have been successfully demonstrated

- Identify case-study buildings
- Document & categorize HP HVAC system technologies in these case-studies:
  - Air distribution & control
  - Hydronic distribution & control
  - Central equipment
  - Motor control
  - Performance monitoring

STEP 3: Evaluating impact of these practices on increase in first costs, energy savings & O&M challenges

- Identify & assess selected HP technologies:
  - Energy savings
  - Compatibility w/ energy code
  - First & installation cost increase
  - O&M practices & challenges

STEP 4: Rate technologies for market readiness

- Identify & assess emerging HP technologies:
- Evaluate technologies using criteria proposed by NEEA
- Consultation w/ SME MEB, A&E Firms
- Resources:
  - Measured & simulated data
  - First, Installation, O&M costs & energy code

Road map for CCE Report
FOR THE REPORT...

- 72 commercial buildings in Montana were documented & high performance systems typical in commercial buildings were identified
- 5 case studies selected for a detailed evaluation

**List of Identified HP Systems & Equipment for Commercial Buildings in Montana**

<table>
<thead>
<tr>
<th>PROJECT</th>
<th>YEAR</th>
<th>LOCATION</th>
<th>TYPE</th>
<th>CERTIFICATION</th>
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<td>2019</td>
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List of High Performance / Energy Efficient Systems

- **Hydronic distribution and control**
  - Chilled beams
  - Radiant floor system
- **Air distribution and control**
  - Dedicated outdoor air system
  - Demand control ventilation system w/ CO2 monitoring
- **Central systems**
  - Variable refrigerant flow system (VRF)
  - Evaporative cooling system
  - Underfloor air distribution system
  - Open loop ground source heat pump system

List of High Performance / Energy Efficient Equipment

- Condensing boilers
- Heat recovery
  - Run around heat recovery loop
  - Heat recovery ventilators
- Enthalpy wheels
- Heat-pump water heaters
- Variable frequency drives on pumps and fans

List of Renewable Systems

- Photovoltaic array
- Solar transpired collectors
- Solar hot water heating

List of High Performance Commercial Buildings in Montana

Note: Rows marked in *RED* represent buildings situated on Montana State University campus.
FOR THE REPORT...

- 72 commercial buildings in Montana were documented & high performance systems typical in commercial buildings were identified
- 5 case studies selected for a detailed evaluation

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List of High Performance Commercial Buildings in Montana

- DSA Architects
- StudiFORMA Architects
- Reid Smith Architects
- NBBJ
- will bruder+PARTNERS
- Schlenker McKittrick Architects
- Comma-Q Architecture
- Overl+Partners
- Gordon Whirry Architecture
- L'Heureux Page Werner
- A&E Architects
- Instrink Architecture
- Think One Architects
- GH2 Architects
- Dowling, S&holm Architects
- High Plains Architects
- HGFA Architects
- Hennebery Eddy Architects
- Richard M. Shanahan Architects, Inc.
- Collaborative Design Architects
- Nelson Architects
- MMW Architects
- Hoyer Wysocki Architects
- ThinkOne
- Mithun
- Slate Architects
- CWG Architects
- Architects Design Group
- Mosaic Architects
- Daniel J Glenn Architect
- CTA Architects Engineers
- SMA Architects
- MulvannyG2
- OZ Architects

HP COMMERCIAL BUILDINGS IN MONTANA

List of Identified Architectural & Engineering Firms in Montana

- DSA Architects
- StudiFORMA Architects
- Reid Smith Architects
- NBBJ
- will bruder+PARTNERS
- Schlenker McKittrick Architects
- Comma-Q Architecture
- Overl+Partners
- Gordon Whirry Architecture
- L'Heureux Page Werner
- A&E Architects
- Instrink Architecture
- Think One Architects
- GH2 Architects
- Dowling, S&holm Architects
- High Plains Architects
- HGFA Architects
- Hennebery Eddy Architects
- Richard M. Shanahan Architects, Inc.
- Collaborative Design Architects
- Nelson Architects
- MMW Architects
- Hoyer Wysocki Architects
- ThinkOne
- Mithun
- Slate Architects
- CWG Architects
- Architects Design Group
- Mosaic Architects
- Daniel J Glenn Architect
- CTA Architects Engineers
- SMA Architects
- MulvannyG2
- OZ Architects
ORANGE CRUSH BUILDING
Great Falls, MT

Location: Great Falls MT
Building Type: Renovation
Total Area: 25,000 ft²
Architects: Cushing Terrell
Engineers: Cushing Terrell
Certification: LEED Gold

High Performance Systems:
Open loop GSHP, radiant heating & cooling, solar preheated outdoor ventilation air
ORANGE CRUSH BUILDING
Great Falls, MT

Conceptual diagram of mechanical systems for the Orange Crush office, Great Falls Montana
CASE STUDIES

JABS HALL, MSU CAMPUS
Bozeman, MT

Location: Bozeman, Montana
Building Type: Higher Education
Total Area: 50,830 ft²
Architects: HE Architects
Engineers: Morrison - Maierle, Inc.
Certification: LEED Gold

High Performance Systems:
GSHP, transpired solar collector, enthalpy wheel, radiant floor hydronic system, VAV
CASE STUDIES

JABS HALL, MSU CAMPUS
Bozeman, MT
CASE STUDIES

NORM ASBJORNSON INNOVATION HALL
Bozeman, MT

Location: Bozeman, Montana
Building Type: Higher Education
Total Area: 110,000 ft²
Architects: ZGF Group
Engineers: ACE Inc.
Certification: LEED Platinum

High Performance Systems:
Water-to-air heat pumps, transpired solar collectors, natural ventilation, dedicated outdoor air system (DOAS), economizers, natural ventilation
Transpired solar collectors on the south side of the building

The geothermal system uses adjacent ground as a giant battery to store excess heat for use later in the day or year.
NEW BOZEMAN HIGH SCHOOL
Bozeman, MT

Location: Bozeman, Montana
Building Type: K-12 School
Total Area: 303,000 ft²
Architects: CTA Group
Engineers: CTA Group
Certification: CHPS

High Performance Systems:
VRF systems, Ground source water-to-water heat pumps, Dedicated Outdoor Air System (DOAS)
CASE STUDIES

NEW BOZEMAN HIGH SCHOOL
Bozeman, MT

FOR HVAC

- Dedicated Outdoor Air System (DOAS)
- Variable Refrigerant Flow System (VRF)
- Chilled Beam System
- Open-loop Ground Source Heat Pump System
- Closed-loop Ground Source Heat Pump System
- Transpired Solar Collector
- Radiant Heating & Cooling System

FOR SHW HEATING

- Heat Pump Water Heater (HPWH)

FOR LIGHTING

- Dynamic Lighting
- Luminaire Level Lighting Controls

FOR ENVELOPE

- Highly Insulating (HI) Windows
- Dynamic Windows
- Building Integrated Photovoltaics
Web-based survey was developed

Currently disseminated among the engineering community in Montana

Link: http://ou.montana.edu/idl/cces.html

The results of the survey are in the process of being collected & assessed

7 experts were consulted & responses recorded

Given the small sample size of the responses, results should NOT be considered indicative of the trends in technology adoption practices for Montana

Sample Survey Questionnaire
INCENTIVES FROM NWE

NorthWestern Energy Efficiency Plus (E+) Program

- **E+ Commercial Electric Rebates**
  - Equipment type and associated rebate amounts are provided by the program guidelines
  - Applicants need to be eligible to take advantage of these rebates
  - Technologies include: VSDs, ECMs, high-efficiency chillers, high-efficiency DX units, high-efficiency ASHPs, hot water pipe insulation, HPWHs & DCV.

- **E+ Commercial Lighting Rebate**
  - Replace indoor and exterior lighting products with high efficiency technologies. LED Tubes, LED lamp and fixtures, and switch-mounted occupancy sensors installations may apply.

- **E+ Business Partners Program**
  - Projects must demonstrate the cost-effectiveness of specific conservation and/or load management measures or a group of measures.
  - Must also demonstrate reliability & availability of equipment, while demonstrating the availability of qualified design services, contractors, and maintenance services.

**DOAS** uses separate equipment to condition outdoor air brought into a building for ventilation.

**Characteristics:**
- Improving temperature & humidity control
- Reducing energy use due to reduced air flow rates
- Simplification of ventilation design & control
- Used in conjunction with equipment that does not provide ventilation (i.e., radiant panels, chilled beams)
- Use of an inverter technology to control the compressor & modulate speed to provide a turndown ratio that matches the load very closely improves efficiency

**Applications:**
- Can be implemented in almost any type of commercial, institutional, industrial or multifamily building
- Building types with strict indoor air quality, ventilation, humidity, or energy efficiency requirements benefit immensely

**Reference:**
VRF systems are a version of a simple split system AC that utilizes variable speed compressors, multiple zone refrigerant distribution, heat recovery, & low energy fan coil units to condition commercial buildings.

Characteristics:
- Distribution of heating & cooling using refrigerant instead of air
- Small footprint
- Eliminating the reheating of air by providing only needed heating & cooling
- Potential for heat recovery from cooling zones to heating zones

Applications:
- Educational facilities, office buildings, health care facilities & historic renovation projects

REFERENCE:
Active & passive Chilled Beams are room air recirculation devices that transfer sensible heat to & from the space using water.

Characteristics:
- Higher chilled water temperatures,
- Delivery of sensible cooling directly to space
- Reduction in ventilation energy
- Reduction in energy expended for reheating of cooled air
- Smaller plenum spaces & mechanical room footprints

Applications:
- Office buildings, schools, hospital patient rooms & laboratories
- Building types are associated with sensible heat generated from equipment
- Not recommended for buildings with high latent loads such as theatres, restaurants or health clubs

REFERENCE:
In an Open-loop GSHP system, groundwater is pumped into the system at ground temperature & passed through a heat pump. If the building system requires cooling, heat is rejected into the groundwater from system hydronics, & vice versa.

Characteristics:
- Low operational cost
- Environmental benefits
- System efficiency
- Compactness
- Mature technology

Applications:
- Commercial, & industrial applications
- Rely on the presence of a large, accessible aquifer or other water source
- Require an appropriate location to discharge the water brought in through the system

REFERENCE:
**Closed-loop GSHP System** consist of a network of heat pumps linked to a closed heat exchanger buried in the ground which acts as an efficient heat source or sink.

**Characteristics:**
- Low operational cost
- Environmental benefits
- System efficiency
- Mature technology

**Applications:**
- Residential, commercial, industrial applications
- Climates characterized by high daily temperature swings & where winters are cold & summers are hot
- In areas where electricity costs are higher than average & in areas where natural gas costs are higher than the cost of electricity

**Scorecard**

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<tr>
<td>Currently Incentivized by Utility Programs</td>
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</table>

**Examples of closed-loop GSHP**

REFERENCE:
Transpired Solar Collector consist of a dark colored perforated metal skin on the south facing exposure that creates a plenum through which air moves & gains heat absorbed by the metal from the sun. An intake duct connects the collector to the air handling system.

Characteristics:
- First cost effective
- Reliable & low maintenance
- Favorable conditions can result up to 30 - 100°F air temperature gain above ambient, significantly decreases the energy required to heat OA

Applications:
- Commercial, industrial, or educational buildings which require large amounts of outdoor air
- Most useful in climates with large amounts of solar radiation & long heating seasons

REFERENCE:
Radiant Heating & Cooling actively provide heating & cooling by radiant transfer of heat from the hydronic element to the surrounding surfaces.

Characteristics:
- Energy & system efficiency
- Reduced system horsepower
- Improved indoor environmental quality
- Reduced mechanical footprint
- Improved system hygiene

Applications:
- Hospitals, schools, data centers, offices

Scorecard

Example of a Radiant floor system installation

REFERENCE:
Luminaire Level Lighting Control (LLLC) refers to a lighting system that incorporates a complete set of sensors into each luminaire. This creates semi-autonomous zones that can respond to small changes below each unit.

Characteristics:
- Each fixture can be reprogrammed as needed.
- Ability for fine discrimination.
- Performance doesn’t need to be interpolated over a large zone area.
- Luminaire embedded components make commissioning easier.

Applications:
- Elementary schools
- Offices
- Working environments with individual desk spaces.

REFERENCE:

Wireless lighting controls used LLLC systems
**Dynamic Lighting** refers to a lighting system programmed to fluctuate in color temperature & illuminance while adjusting to varying color temperatures of natural daylight.

**Characteristics:**
- Use of LED & daylighting sensor technologies increased energy efficiency
- Can be calibrated based on the task required
- Effective in windowless environments
- Can promote a circadian rhythm to improve productivity

**Applications:**
- Elementary schools
- Offices
- Industrial setting, in windowless environments

**Scorecard**
- Energy Savings Opportunity: 2
- Cost Effectiveness: 3
- Measurability: 3
- Defined and Available: 4
- Market Ready: 1
- Market Friendly: 3
- Code Ready: 3
- Industry support: 4
- Compatibility with Utility Programs: 1
- Currently Incentivized by Utility Programs: 1

**REFERENCE:**
**Dynamic Windows** can change the qualities of the glazing depending on either the outdoor environment or occupant needs.

**Characteristics:**
- Variety of possible tints
- Can change colors
- Switch between translucent & transparent
- Can help mitigate glare, reduce solar heat loads, & increase occupant comfort
- Can be used to control amount of daylight entering a space.
- Some function as privacy windows.

**Applications:**
- Commercial buildings
- Some types restricted to residential uses

**Scorecard**

<table>
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<tr>
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<tr>
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</table>

**REFERENCE:**
Building Integrated Photo-voltaics (BIPV) is a system which integrates photovoltaics into the building’s envelope.

**Characteristics:**
- Less required area for energy generation
- Reduced photovoltaic system costs
- Envelope functions as both shading & energy generation
- Can replace traditional windows
- Can hide degrading parts of an old building
- Used as roofing materials

**Applications:**
- Commercial buildings
- Retrofit situations
- Skylights
- Green Houses

REFERENCE:
HIGH PERFORMANCE TECHNOLOGIES: Summary

For High-Performance HVAC Technologies:

- When considering ENERGY SAVING OPPORTUNITIES, COST EFFECTIVENESS, & MEASURABILITY:
  - Closed-loop GSHPs, open-loop GSHPs & VRF technologies:
    - Medium to high energy savings
    - Marginally cost effective
    - Savings readily quantifiable
    - GSHP systems characterized with minimal maintenance
    - VRF systems require substantial involvement from O&M staff
  - CB, TSC & RHC technologies:
    - Low to medium energy saving potential
    - Marginally cost effective
    - Savings quantifiable w/ detailed measurement & evaluation
  - HPWH technologies:
    - HPWH provide low energy saving opportunities in Montana climates
    - Savings for HPWH are quantifiable
    - HPWH technology has marginal cost effectiveness

LEGEND:

GSHP: Ground source heat pump
VRF: Variable refrigerant flow
CB: Chilled beams
TSC: Transpired solar collectors
RHC: Radiant heating & cooling
HPWH: Heat pump water heater
For High-Performance HVAC Technologies:

- When considering a technology being **DEFINED & AVAILABLE, MARKET READY & MARKET FRIENDLY**:
  - VRF, HPWH, GSHP & DOAS technologies:
    - VRF, HPWH & DOAS available from numerous manufacturers
    - The heat-pump equipment of the GSHPs available from numerous manufacturers
    - Installation of the ground / water HEX in GSHPs is site-specific & requires customization
    - Ready for both design & construction market
    - Implementation of technologies in between medium & high cost
    - Some non-energy benefits & meet code requirements
  
  - TSC technology:
    - Available from a single manufacturer
    - Well researched, simple to install & maintain
    - Ready for the design & construction market
    - Low-cost & has significant non-energy benefits

**LEGEND:**

- **GSHP:** Ground source heat pump
- **VRF:** Variable refrigerant flow
- **CB:** Chilled beams
- **TSC:** Transpired solar collectors
- **RHC:** Radiant heating & cooling
- **HPWH:** Heat pump water heater
For High-Performance HVAC Technologies:

- When considering a technology being **DEFINED & AVAILABLE, MARKET READY & MARKET FRIENDLY:**
  - **RHC & CB technologies:**
    - Mature technologies
    - Available in the market from at least three sources
    - Design & construction ready
    - Lower costs than all-air HVAC systems due to the elimination of ductwork
    - Significant non-energy benefits
    - Additional dedicated ventilation systems required
    - Widely accepted in the cold-dry climates of Montana as humidity control is not a concern

**LEGEND:**

- GSHP: Ground source heat pump
- VRF: Variable refrigerant flow
- CB: Chilled beams
- TSC: Transpired solar collectors
- RHC: Radiant heating & cooling
- HPWH: Heat pump water heater
For High-Performance HVAC Technologies:

- When considering program support in terms of **CODE READINESS, INDUSTRY SUPPORT, COMPATIBILITY WITH UTILITY PROGRAMS & INCENTIVES PROVIDED BY UTILITY PROGRAMS**:
  - All technologies can be implemented on voluntary basis
  - Industry support for all technologies can either be considered indifferent or supportive
  - HPWH has compatibility with utility programs & provided with some incentives
  - Certain technologies such as GSHPs have better incentivized better than others
  - Technologies such as VRF, TSC & DOAS the incentives are not big enough to convince the purchase & installation of these technologies

**LEGEND:**
- GSHP: Ground source heat pump
- VRF: Variable refrigerant flow
- CB: Chilled beams
- TSC: Transpired solar collectors
- RHC: Radiant heating & cooling
- HPWH: Heat pump water heater
For High Performance Envelope & Lighting Technologies:

- When considering **ENERGY SAVINGS**:
  - DL & BIPV technologies provide sound cost effectiveness & measurability
  - BIPV provide high energy saving opportunities
  - No unitized energy savings currently available for DL
  - DW technologies not associated with high energy saving opportunities, cost effectiveness & measurability
For High Performance Envelope & Lighting Technologies:

- **When considering MARKET POTENTIAL:**
  - DL, LLC & BIPV technologies:
    - Are defined & available
    - High costs
    - Numerous non-energy benefits of DL
    - Pre-commercialization stage for BIPV
    - Low market readiness for BIPV
  - DW technologies:
    - Available through unique sourcing
    - Nascent stages of commercialization
    - High costs
    - Few non-energy benefits – not market friendly
    - Low market readiness

**LEGEND:**
- LLLC: Luminaire level lighting control
- DL: Dynamic lighting
- DW: Dynamic windows
- BIPV: Building integrated photovoltaic
For High Performance Envelope & Lighting Technologies:

- When considering **COMPATIBILITY WITH CODE & UTILITY PROGRAMS**:
  - The DL, LLLC, BIPV & DW technologies:
    - Can be implemented in voluntary requirements
    - Have significant industry support
    - DL, BIPV and DW are not incentivized

**LEGEND:**
- LLLC: Luminaire level lighting control
- DL: Dynamic lighting
- DW: Dynamic windows
- BIPV: Building integrated photovoltaic
HIGH PERFORMANCE TECHNOLOGIES: Summary

GROUND SOURCE HEAT PUMPS (GSHPs) UNEARTH SIGNIFICANT ENERGY SAVINGS

GSHPs are adaptable to a variety of Montana building types and applications.

A ground source heat pump (GSHP) is a central heating and/or cooling system that transfers heat to or from the ground. As ground temperatures in Montana tend to be stable at 55°F, there is almost always a temperature difference between the ground and the air. GSHPs exploit this natural differential for heating and cooling purposes to provide energy savings in the range of 20–40% for typical efficiency GSHPs, and 45–50% for high-efficiency GSHPs.1

GSHPs are available in both open-loop (in which groundwater is pumped at ground temperature and passed through a heat pump) and closed-loop systems (which consist of a network of heat pumps that are linked to a buried, closed heat exchanger). Both system types can be tailored to fit residential, commercial, and industrial applications.

Closed-loop systems are particularly cost-effective in certain scenarios including new construction; climates with high daily temperature swings; climates with cold winters and hot summers; areas with high electricity costs; and areas where gas costs are more than electricity.2 In general, open-loop systems are more efficient due to lower resistance to heat transfer between piping and water3 but they rely on a large, accessible aquifer or other water source and an appropriate location to discharge the water they bring in.

2Renth and Sorensen (2011)

CASE STUDY: Jabs Hall, Montana State University

Built using a $25 million gift from MSU alumnus Jake Jabs, Jabs Hall at Montana State University was designed with efficiency in mind. Using a GSHP, Jabs Hall conditions its space using 52 geothermal loops that provide thermal storage at a ground temperature of nearly 55°F. These pumps move water through closed loops that reach 300 feet in depth and then through a plate and frame heat exchanger connected to the heat pump system.

CASE STUDY: Orange Crush CTA Office

The 10,000 sq. ft. Orange Crush CTA Office building in Great Falls, Montana, underwent a retrofit project to install a 675-foot water-source vertical well to capture energy from the earth's water. Using high-efficiency heat pumps, their open-loop GSHP system extracts energy from the near-constant 55°F underground water and distributes it to the building's custom-designed radiant floor system. By running the 55°F water through the radiant floor panels installed throughout the building, the system provides space cooling without requiring compressors.

To learn more about this and other high-efficiency commercial technologies, visit betterbricks.com.
Questions

Jaya Mukhopadhyay
jaya.mukhopadhyay@montana.edu

Presentation available on NCAT website:
www.ncat.org/energy-code-trainings/