Welcome to Smart Remodeling

Opening Remarks
Erin Barnes-Driscoll / Laura Millberg

Workshop Feedback Instructions
Roberta Gibbons
MPCA Stakeholder Advisory Committee

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- Kevin Brauer, Center for Energy & Environment
- Angela Demonte, Green Designs and Supply
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- Jay Stills, Urban Rebuilders
- Samantha Strong, Metamorphosis Design-Build
- Terry Webster, MN Office of Energy Security
- Janneke Schaap, MN GreenStar

The Smart Remodeling Team

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Training Evaluation
Roberta Gibbons
Key Themes for Today’s Workshop

• Remodeling requires an integrated, “systems-guided” approach to design and construction.
• Remodeling decisions should be informed by testing and guided by building science.
• Remodeling a house can have significant impacts on heat, air, and moisture flows …
  – so a deliberate and robust design, construction, and verification process must be followed.
• While green remodeling programs, prescriptions, and points can guide you, in the end it must be about process and performance.

Key Objectives for Today’s Workshop

• Recognize common remodeling changes that could pose a risk to the building or occupants.
• Understand the building science behind these changes.
• Use building science and testing protocols to optimize building performance.
• Learn how to implement a five-step process that will enhance performance and reduce risk.
Outline for Today’s Workshop

- Introduction
- Systems-Guided Approach to Remodeling
- Green Remodeling Programs in Minnesota
- Intro to Building Performance & Building Science
- Top 10 Risky Remodels
- Going Green with a Focus on Process & Performance
- Developing a Whole Building Strategy for Remodeling
- Best Practices, Risky Practices, & Missed Opportunities
- Wrap-up

Overview of Today’s Workshop

- Presentations
  - Electronic copies will be available at:
    - [www.pca.state.mn.us/greenbuilding](http://www.pca.state.mn.us/greenbuilding)
    - in left column click on “Presentations and Resources”
    - should be online sometime after June 15th

- Handouts
  - Packet
    - Outline
    - Key Slides
    - Scenarios
    - Resource List
  - Workshop Feedback
Section 1: Introduction to Smart Remodeling

What hat are your wearing today?

• Remodeler or general contractor
• Architect or designer
• Material dealer/distributor/supplier
• Inspectors (code, building, home)
• HVAC contractor
• Insulation and/or air sealing contractor
• Other subcontractors (plumbing, electrical, etc.)
• Real estate (realtor, mortgage, etc.)
• Building performance contactor
• Program managers (government, private, utility)

What hat are your wearing today?

• Other hats you may need as a “smart remodeler”?
  – Risk manager
  – Educator
  – House doctor
  – Financial advisor
  – Building scientist
  – Guidance counselor
  – Salesperson
  – Coach
  – ???
Section 1: Introduction to Smart Remodeling

The Many P’s of Remodeling

Planning
Priorities
Protocols
Programs
Points
Prescriptions
Products
Processes
Performance

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This material is available in alternative formats upon request.
Direct requests to Pat Huelman, Associate Professor and Coordinator of the
Cold Climate Housing Program at 612-624-1286
Section 2: Systems Guided Approach to Remodeling

Smart Remodeling: Begins and Ends with Performance

Developing Best Practices for Home Performance

- Moisture
- Air-seal
- Insulation
- Ventilation
- Combustion Safety
Section Learning Objectives:
• Justification for science-based systems-guided remodeling.
• Solutions through planning based on performance testing.
• Identifying how systems interact – whole house assessment.
• Protocols for performance measurement

What is performance?
• Existing homes have pre-existing conditions.
• Remodeled homes have new performance conditions.
• Good performance requires control of process and outcomes at all times.
• Measuring and verifying
Why Performance?

We have only two pathways to walk:

1. Do it right
2. Not right

Key Question: Can we create a process, a knowledge base, and a best practices approach to doing it right?

Obvious reasons:

- Energy efficiency saves money and environment
- Moisture control ensures durability
- Air control ensures health and comfort

Key Question: Can we create a process, a knowledge base, and a best practices approach to doing it right?
**Systems Guided Approach to Remodeling**

**Why Performance?**

As professionals, we must be in control of performance outcomes we must know the answer to:
- 1. If we alter the performance of an existing house will it help or will it hurt?
- 2. Who is “in charge” of performance in a remodel?

Key Question: Can we create a process, a knowledge base, and a best practices approach to doing it right?

**Doing it right means:**
- Accountability – Who’s in control?
- Measurement – Did it work?

Key Question: Can we work together to control the outcomes of our work?
Remodeling is more complicated than new construction

Some say:
“The home has been working fine for 50, 70 or even 80 years!”
How do you know it is “working?”

Why do many older homes seem to “work”?  

• Robust materials (plaster, solid wood)  
• Lots of air flow (leakage)  
• Lots of energy (heat)

They leak air and eat energy.
Section 2: Systems Guided Approach to Remodeling

5 Fundamental Changes to Buildings

1. Increased thermal resistance.
2. Changing of the permeability of the linings put on inside and outside of enclosure.
4. Ability of bldg to store and redistribute moisture – going down.
5. Complex, 3-dimensional airflow networks that inadvertently couple the bldg enclosure to the breathing zone of the occupied space.

Remember Building Science Basics:

3 key elements: air, water, heat.

- Performance requires extensive air management.
- Air is always moving: from indoors to outdoors, from outdoors to indoors, through ducts and vents attached to appliances, between rooms in the house and within and between framing voids and other cavities in the building structure.
- Changing one aspect of this airflow will always affect other aspects of the airflow and airflow changes may affect energy and moisture flows throughout the house.
Water

Remember Building Science Basics:
Moisture or water vapor moves in and out of a home in three ways:

- By diffusion through materials
- With air currents
- By heat transfer (dew point)

2/3 pint per season

1/8" hole, 50 pints of water per season

Heat

Remember Building Science Basics:

Systems Guided Approach to Remodeling

Section 2: Systems Guided Approach to Remodeling
Existing Homes Present More Risks

- Unlike new construction, existing homes come with pre-existing conditions. (many are unknown)
- Adding more insulation, new windows, and efficient heating can introduce variables that change performance and result in “unintended consequences.”
- Older homes are often “leaky” (more forgiving) with higher drying capacity and air exchange.
  - Increasing energy consumption, i.e., more heat, air movement, and dehumidification can produce a similar drying effect at a higher cost.
- Building science principles applied to rehab methodology can provide safer, healthier, more durable, and less costly homes **while reducing energy consumption.**

Pre-Existing Issues

- Energy hog: little insulation, lots of air leaks
- Poor moisture control: interior and/or exterior
- Unhealthy: pollutants, ventilation management
- High maintenance cost
- Deteriorating conditions
- Foundation: not waterproof, no insulation
- Aesthetic & floor plan changes needed

Key Question: How do we determine critical issues that must be addressed for each house prior to rehab?
Common Changes or Upgrades:
- New furnace
- More insulation
- Air seal
- New windows, doors
- New roof and siding
- New ventilation
- New interior finishes
- New equipment

Key Question: How do we identify and prioritize the changes or upgrades that are appropriate for each home?

Performance Requires Priority Planning
Systems Guided Approach to Managing Risk

Brakes failed:

Budget Priorities:
1. re-paint
2. replace upholstery
3. tune up engine
4. replace brakes

Key Question: How do we identify and prioritize the changes or upgrades that are appropriate for each home?

Seven building scientists riding in a boat.
High Risk Changes in Existing Homes

- Air sealing without guidance and managed ventilation.
- Furnace change-out to sealed combustion without addressing changes in ventilation.
- “Orphaned” water heater and combustion safety.
- Increased insulation without proper air sealing and moisture management.
- Window replacement without proper moisture management.
- Poor ventilation design, installation and use.
- Most basements were not built to contain living space without water proofing and insulation.

How can we find solutions and plan for success?
Section 2: Systems Guided Approach to Remodeling

Find out basic information:
What are the desired whole house performance outcomes?

– Energy efficiency?
– Healthy indoor air quality?
– Long term durability?
– Low budget?
– “Light” environmental footprint?

How do we achieve good performance?

By Testing!

Combustion Safety
Existing homes can have massive amounts of air leakage.

Air can carry heat, moisture and pollutants.

Find air leakage in building enclosure
Section 2: Systems Guided Approach to Remodeling

Testing ducts for air leakage.

1. PROCESS

Can we develop a best practices approach?
  – Critical assessment: test in
  – Systems planning: develop plan/design
  – Execution oversight: is it right?
  – Commissioning and testing: measure it!
  – Evaluation: what worked, what was cost
Section 2: Systems Guided Approach to Remodeling

1. Process
2. Priority Planning

How do we determine which changes?

Prioritize by systems guided analysis:

First
Second
Third
Fourth
Fifth

Combustion
Ventilation
Insulation
Air seal
Moisture

PP + P = PERFORMANCE

• PRIORITY PLANNING PLUS PROCESS EQUALS PERFORMANCE
Section 2: Systems Guided Approach to Remodeling

Whole House Systems Approach

Building Envelope
Equipment
HVAC
Occupant Choices
Materials

Performance Success

Desired Outcomes

Energy Conservation Efficiency
Water Management
IAQ Health
Durability
Maintenance
Section 2: Systems Guided Approach to Remodeling

Whole House Systems Approach

Building Envelope
- Insulation
- Wall Assembly
- Foundation, slab
- Roofing, attic
- Siding
- Windows, doors

Equipment
- Energy
- HVAC
- Ducts
- Air Conditioning
- Ventilation
- Use fans
- Bath fan
- Dryer

Occupant Choices
- Choices
- Equipment
- HVAC
- Furnace Type
- Ducts
- Air Conditioning
- Use fans
- Bath fan
- Dryer

Materials
- Flushing
- Windows, doors
- Insulation
- Wall Assembly
- Foundation, slab
- Roofing, attic
- Siding
- HVAC
- Ducts
- Air Conditioning
- Use fans
- Bath fan
- Dryer

Water Management
- Durability
- Maintenance
- IAQ
- Health
- Use fans
- Bath fan
- Dryer

Energy Conservation Efficiency
- Furnace Type
- Ducts
- Air Conditioning
- Use fans
- Bath fan
- Dryer

Remodel changes

Change impact on outcomes
Mandates for energy reduction and performance metrics are being considered across the country.

States and municipalities are beginning to develop energy and green based codes and requirements.

The federal government is gearing up for energy targets in all sectors that require measurement.

Testing for performance that will reduce health risk is being researched.

Time to plan for these changes is now.
Walk out Rambler, 3900 sq. ft. Remodel mostly cosmetic, new kitchen, baths and deck. New sealed combustion furnace & A/C.

Opened some walls. House has 16 in. of attic insulation, B vented water heater, and no bath fans. Has ice dams.
Systems Guided Approach to Achieving Performance

Performance Measures and Metrics

1. Health and Safety
2. Indoor Environmental Quality
3. Building Durability
4. Energy Efficiency
5. Environmental Impact
Systems Guided Approach to Achieving Performance

Performance Measures and Metrics

1. Health and Safety
   - Carbon Monoxide
   - Combustion Zone Depressurization

2. Indoor Environmental Quality
   - Pollutants
   - Ventilation
   - Filtration

3. Building Durability
   - Water management
   - Indoor Humidity control
   - Building tightness
   - Materials
Performance Measures and Metrics

4. Energy Efficiency
   - Heating
   - Cooling
   - Duct tightness
   - Water heating
   - Appliances
   - Lighting
   - Misc plug loads

5. Environmental Impact
   - Water efficiency
   - Resource efficiency & materials
   - Site & community
   - Consumer awareness, education, & behavior
A Systems Guided Approach to Performance

PROCESS
Critical assessment: test in
Systems planning: develop plan/design
Execution oversight: is it right?
Commissioning and testing: measure it!
Evaluation/monitor: what worked, what was cost

PROTOCOL
Performance Measures and Metrics
Health and Safety
Indoor Environmental Quality
Building Durability
Energy Efficiency
Environmental Impact

Priorities Planning

Moisture
Air-seal
Moisture
Insulation

Ventilation

Combustion

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Smart Remodeling

It Begins and Ends with Performance

Introduction to

Green Remodeling

Programs in

Minnesota
### Sustainable Housing Guidelines

- **LEED for Homes**
  - www.usgbc.org

- **NAHB Green Home Building Guidelines**
  - www.nahbrc.org/greenguidelines/

- **Green Communities Program**
  - www.greencommunitiesonline.org

- **Austin Energy Green Building**
  - www.austinenergy.com

- **Minnesota GreenStar**
  - www.mngreenstar.com/

### Green Remodeling Programs

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**Section 3: Introduction to Green Remodeling Programs in Minnesota**
Section 3: Introduction to Green Remodeling Programs in Minnesota

Green Remodeling Programs in Minnesota

What is Green? Sustainability?

ecology
economics
equity

Section 3: Introduction to Green Remodeling Programs in Minnesota

Residential Impact.

Section 3: Introduction to Green Remodeling Programs in Minnesota
Why think about Green? Health

90% of time spent Indoors
(up to 70% at home for women and small children)

Built in or Built Out
- mold
- carbon monoxide
  92 Minnesotans died (2002–2006)
- asthma
  6.6 – 10% of children in Minnesota have asthma
- radon
  2nd leading cause of lung cancer in the U.S.
- lead
  Estimated that 310,000 children have elevated levels in the U.S.

Why think about Green? Market Advantage

Certified Green Homes
- Sold 9.1% premium per square foot
- On the market 24% less time

“Deep” Green Homes
- Sold 23.5% premium per square foot
- On the market 10% less time
Green Remodeling Programs in Minnesota

Section 3: Introduction to Green Remodeling Programs in Minnesota

National w/local affiliate
new and gut-rehab
single family, multi-family, mid-rise

Local
renovation, gut-rehab and new
single family

National w/local affiliate
renovation, gut-rehab and new
single family, multi-family, mid-rise

LEED for Homes - USGBC

organization:
United States Green Building Council
mission:
To transform the way buildings and communities are designed, built and operated, enabling an environmentally and socially responsible, healthy, and prosperous environment that improves the quality of life.

Section 3: Introduction to Green Remodeling Programs in Minnesota
LEED for Homes - USGBC

project types:
market rate single family, multi-family, and mid-rise multi-family;
new and renovation
used by people seeking...
certification with national recognition

Section 3: Introduction to Green Remodeling Programs in Minnesota

LEED for Homes - USGBC

How it works.
criteria organization
1. Innovation and Design Process
2. Location and Linkages
3. Sustainable Sites
4. Water Efficiency
5. Energy and Atmosphere
6. Materials and Resources
7. Indoor Environmental Quality
8. Awareness and Education

LEED for Homes Provider and LEED for Homes Rater
LEED for Homes Accredited Professional

Section 3: Introduction to Green Remodeling Programs in Minnesota
Minnesota GreenStar

organization:

Minnesota GreenStar

mission:

Driving positive impact to our environment by transforming residential building practices

Section 3: Introduction to Green Remodeling Programs in Minnesota

project types:

market rate single family renovation and new construction

used by people seeking...

certification while working with a builder or remodeler

Section 3: Introduction to Green Remodeling Programs in Minnesota
Minnesota GreenStar

How it works.

5 Principles of Green
- Energy Efficiency
- Resource Efficiency
- Water Conservation
- Indoor Environmental Quality
- Site and Community Impact

Section 3: Introduction to Green Remodeling Programs in Minnesota

Overall Requirements
1. Pre-Construction Design Standards
2. Site and Landscape
3. Improvements to Existing Floor, Wall and Roof Assemblies
4. New Floor, Wall and Roof Assemblies
5. Mechanicals
6. Electrical
7. Water Plumbing Systems and Fixtures
8. Finish Materials and Coatings
9. Waste Management
10. Education
11. Innovation

Minnesota GreenStar Building Science Professionals
Minnesota GreenStar Train Professional
Minnesota GreenStar

Remodeling Certification

Minnesota GreenStar’s Remodeling program has four types of projects:

- **Type 1:** Renovations that do not add conditioned space
- **Type 2:** Renovations that add conditioned space without changing exterior shell of building
- **Type 3:** Renovations that change exterior shell of building but use only existing foundation
- **Type 4:** Renovations that add a foundation

Section 3: Introduction to Green Remodeling Programs in Minnesota
Green Communities

organization:
Enterprise Community Partners &
Minnesota Housing

mission:
Enterprise’s vision through Green Communities is to fundamentally transform the way we think about, design and build affordable homes.

Section 3: Introduction to Green Remodeling Programs in Minnesota

Green Communities

project types:
- single and multi-family new and renovation
- used by people seeking...
- state housing funding and grant funds
Section 3: Going Green: Focusing on Process and Performance

Green Communities

criteria organization
1. Integrated Design
2. Site, Location and Neighborhood Fabric
3. Site Improvements
4. Water Conservation
5. Energy Efficiency
6. Materials Beneficial to the Environment
7. Healthy Living Environments
8. Operations and Maintenance
Green Remodeling Programs in Minnesota

3rd Party certification
moderate to extensive documentation
Four levels of Certification

3rd Party certification
moderate to extensive documentation
Three levels of Certification

3rd Party certification on energy
limited
Pass/Fail

Section 3: Introduction to Green Remodeling Programs in Minnesota

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<th>Remodeling Type</th>
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A Systems-Guided Approach

- A house is a dynamic system of interconnected parts and components.
- It is driven by the climate, site, indoor conditions, and the laws of physics.
- And depending on how it is designed, constructed, and operated, it may perform ...  
  - very well,  
  - very poorly, or  
  - anywhere in between!
Remodeling Reality

• Building a home or remodeling today is ...
  – not just materials, but methods;
  – not just products, but process.

• A high performance home is ...
  – Not just components, but connections;
  – Not just actions, but interactions.

Remodeling Reality

• Home remodeling is a risky business!
  – Pre-existing conditions
  – Limited budgets
  – Surprises at every turn

• Rehab of vacant, foreclosed house is riskier!
  – Limited data on past performance
  – No occupants to interview / share insights
  – Unknown conditions during vacancy
  • we use energy to manage moisture
Introduction to Building Performance and Building Science Review

Building Performance Review

• Introducing the “Cliff”
  – Health or safety issue
  – Poor material or building durability
  – High operation and maintenance costs
  – Environmental impacts

• In general,
  – Most homes today are getting closer to the cliff.
  – As we change them, they frequently move closer.
    • It is usually easier, cheaper, quicker to move them towards the cliff, than away from the cliff.

Building Performance Review

• Is the house “Robust or Fragile”?
  – Robust: strong, healthy and hearty in construction; able to recover from unexpected conditions
  – Fragile: weak and easily broken; unlikely to withstand severe stresses and strains

• In general,
  – Existing houses are becoming more fragile.
  – It takes smaller changes to make bigger impacts.
    • It is getting easier to move towards “the cliff” quicker.
Building Performance Review

• Your goal is to find out
  – How close the house is to the cliff?
  – How robust or fragile is the house?

• So you can predict
  – How far will you move it?
  – How fast will it move?
  – Will it be towards or away from the cliff?
  – Where will it be when I’m done?

Building Performance Review

• Do you have a fragile house near the cliff?
  – Pre-existing conditions
    • CO problems
    • water intrusion/wet basement/mold
    • lead & asbestos
    • radon
  – Special design concerns
    • fireplace (or wood stove)
    • 1-1/2 story houses
    • tuck under (and attached) garages
    • crawl spaces
Can closing a bedroom door push a fragile house over the cliff?

The Order Matters: A Lesson from the Past

• Combustion Safety ⇒ Safe & Healthy
• House Ventilation ⇒ Good Indoor Air
• Moisture Sources ⇒ Moisture Management
• Building Airtightness ⇒ Building Durability
• Increase Insulation ⇒ Energy & Resource Efficient
**The Order Matters**

- Take care of people
  - provide safe & healthy homes

- Take care of our buildings
  - enhance long-term durability of homes

- Take care of our planet
  - produce resource and energy efficient homes

**Take Care of People**

- We must ensure that our homes are safe and restorative!
  - a. Provide uncompromised combustion safety
  - b. Execute a sound ventilation/filtration strategy
  - c. Provide deliberate pollutant management from both exterior and interior sources
Take Care of the Building

• We must protect the integrity and longevity of the original building and the resources we have already invested in it.
  – a. Protect the building from both exterior and interior water (including vapor)
  – b. Provide a warm and dry foundation
  – c. Make the house as tight as possible

Take Care of Our Planet

• We must be vigilant guardians against excessive energy, water, and resource consumption.
  – a. Improve building thermal integrity, including high-performance windows
  – b. Install high-efficiency equipment, lights, and appliances
  – c. Develop a sound water conservation strategy
  – d. Use low-impact materials, where appropriate
Building Science Review

• Study of the physical forces that act on houses
  – Gravity, wind, etc.
  – Heat transfer
  – Moisture transport
  – Air flows

• Application of that knowledge to provide houses that are
  – Structurally sound
  – Comfortable and efficient
  – Durable and long-lasting
  – Healthy to live in
  – Friendly to our environment

Introduction to HAM

• Heat Flows
  • transmission losses/gains
  • air exchange losses/gains
  • solar and internal gains

• Air Flows
  • paths
  • pressures

• Moisture Flows
  • liquid
  • vapor
Heat Flow

- Heat always goes from more (hot) to less (cold).

- Three modes of pure heat transfer
  - conduction
  - convection
  - radiation

Heat Flow in Buildings

- Transmission
  - always from warm to cold
  - rate is a function of R-value, area, and temperature difference
  - through opaque ceilings, walls, floors, windows & doors

- Air flow
  - always from higher to lower pressure
  - rate is a function of hole size and pressure difference
  - through infiltration/exfiltration, ventilation, combustion venting, exhaust devices
Heat Flow in Buildings

- Building Envelope Losses/Gains (Loads)
  - transmission
  - air exchange
  - solar gains
    - helps in winter, hurts in summer
  - internal gains
    - people, equipment, appliances, lights

Moisture Flow

- Always moves from more to less
  - Both liquid & vapor

- Three phases
  - Solid
  - Liquid
  - Gas
Section 4: Introduction to Building Performance and Building Science Review

Moisture Basics

• States of moisture

• Moisture transport
  – liquid
  – Vapor

• Wetting vs. Drying

Moisture Basics

• Moisture States

  Solid

  Liquid => Absorbed

  Vapor => Adsorbed
Moisture Basics

• Ice is generally not an issue in residential construction, except for:
  – wind-driven snow in attics,
  – attic frost,
  – water entry resulting from ice dams, and
  – freeze-thaw action in absorbent materials.

Moisture Basics

• Liquid water sources and transport are usually the most damaging in residential construction, both above and below grade, and can cause:
  – initiation of biological deterioration,
  – initiation of mold/mildew growth,
  – staining, leaching, efflorescence,
  – dimensional changes in materials, and
  – enhanced freeze-thaw damage
Moisture Basics

• Water vapor will rarely create a problem, as long as it stays in the vapor state.
• However,
  – it frequently contributes to durability and indoor air quality problems when it migrates and condenses on susceptible materials,
  – it can raise the moisture content of materials by adsorption and cause dimensional changes, and
  – at very high relative humidity it can sustain mold growth.
• But don’t forget,
  – vapor drying is the main method of removing moisture from materials.

Water Vapor Basics

• How much water vapor does air hold at saturation?
Water Vapor Basics

• What is relative humidity?

Relative humidity is a percentage of the amount of water air can hold at a given temperature.

<table>
<thead>
<tr>
<th>Temperature (°F)</th>
<th>Absolute Humidity (pounds of water per cubic foot of air)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10° R.H.</td>
<td>100%</td>
</tr>
<tr>
<td>10° R.H.</td>
<td>100%</td>
</tr>
<tr>
<td>30° R.H.</td>
<td>100%</td>
</tr>
<tr>
<td>50° R.H.</td>
<td>100%</td>
</tr>
<tr>
<td>70° R.H.</td>
<td>50%</td>
</tr>
<tr>
<td>90° R.H.</td>
<td>27%</td>
</tr>
</tbody>
</table>

Water Vapor Basics

• What happens as air is cooled from 70 degrees?

As 70° air at 50% R.H. is cooled, the air becomes saturated at 50° and condensation occurs below 50°.

<table>
<thead>
<tr>
<th>Temperature (°F)</th>
<th>Absolute Humidity (pounds of water per cubic foot of air)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10°</td>
<td>Condensation</td>
</tr>
<tr>
<td>10° R.H.</td>
<td>100%</td>
</tr>
<tr>
<td>30° R.H.</td>
<td>100%</td>
</tr>
<tr>
<td>50° R.H.</td>
<td>100%</td>
</tr>
<tr>
<td>70° R.H.</td>
<td>50%</td>
</tr>
<tr>
<td>90° R.H.</td>
<td></td>
</tr>
</tbody>
</table>
Water Vapor Basics

• What happens as air is heated from 30 to 70 degrees?

As saturated 30°F air is heated, the relative humidity is reduced.

Water Vapor Basics

• What happens as air is cooled from 90 to 70 degrees?

As 90°F air at 90% R.H. is cooled to 70°F, the air becomes saturated and condensation occurs.
Moisture Transport

• The Basics of Liquid Water Transport
  – Gravity
    • downward flow
  – Pressure-driven (hydrostatic, wind)
    • accelerated by water or air pressure
  – Capillary action
    • wicking through porous materials

Moisture Transport

• Gravity (Bulk Water)
  – Above Grade
    • roof leaks
    • window/door leaks
    • wall penetrations
    • saturated materials
  – Below Grade
    • surface drainage
    • saturated soils

Courtesy of Building Science Corporation
Moisture Transport

• Pressure Driven Flow
  – Above grade
    • wind-driven rain
  – Below grade
    • rising water table

Moisture Transport

• Capillary Action
  – Above grade
    • seams/joints
    • flashing
  – Below grade
    • soils
    • footing/foundation
    • slab
Moisture Transport

• The Basics of Water Vapor Transport
  – Air flow
    • from higher to lower pressure
    • rate is a function of hole size, pressure difference, and moisture content of the air
  – Diffusion
    • from higher to lower vapor concentration
    • rate is a function of permeability, area, and concentration difference

Moisture Transport

• Air Flow
  – Above grade
    • interior/exterior moisture
    • air barrier integrity
    • indoor-outdoor pressures
  – Below Grade
    • interior & soil moisture
    • air barrier integrity
    • basement-outdoor pressures
Moisture Transport

- Diffusion
  - Above grade
    - vapor pressure gradient
      - outward in heating
      - inward in cooling
  - Below grade
    - vapor pressure gradient
      - lower wall and slab is usually inward
      - upper wall is similar to above grade
Moisture Basics

• You can’t always be wetting and you can’t always be drying.

• Over some critical period
  – drying must exceed wetting and
  – safe material storage provides the buffer.

Moisture Basics

• Material Storage as a Buffer
  – Because a perfect envelope is not realistic, wetting will occur. Ample storage must be provided until drying can be completed.
    • concrete/masonry walls provide a lot of storage
    • steel frame and fiberglass provide almost no storage
    • wood framing and sheathing provide limited storage
    • some evidence that cellulose board or insulation can act as a hygric buffer for short wetting periods
  – Remember, water stored (adsorbed or absorbed) must leave as a vapor!
Air Flow Basics

- Flow is driven by a pressure difference and always moves from higher to lower pressure.

- Flow must occur through openings, holes, pathways, and ducts.

- In a home, air flow in must equal air flow out.

Air Flow Basics

- Paths
  - Unintentional – leaks and holes
  - Intentional – windows, ports, & ducts

- Pressures
  - Natural
    - wind
    - stack
  - Mechanical
    - combustion venting
    - exhaust fans/devices
    - supply fans/devices
    - forced air systems
Section 4: Introduction to Building Performance and Building Science Review

The Stack Effect

Air Flow Basics

- Pressure Triangle

- House Pressure

- Exhaust or Supply Flow

- House Tightness
Building Science Review

• What’s the best predictor of overall building performance?
  – Answer: Air flows and pressures
    • as a group – unplanned, unintentional, and unmanaged
      airflows are the primary cause of performance failures.
    • air flow can carry with it a great deal of heat and moisture
    • air pressures can easily compromise mechanical systems

• Air management is critical for comfort, energy efficiency, durability, and indoor air quality!

Building Science Review

• But the greatest challenge is airflow control!

• Efficient, durable, healthy homes require carefully managed airflows,
  – both holes and pressures.

• And to some extent, until we get this right we can’t move on!
Air Failures in Houses

- Building not tight enough
- Duct system not tight enough
- Ventilation system not sized, continuous, or distributed properly
- Filtration system not efficient or air tight
- Inability of consumer to control indoor climate

Air Successes in Houses

- Air tight & weather tight construction
- Duct leakage limited to 10% of flow
- Ventilation properly sized, proper system and proper distribution
- High efficiency filter system, with air tight enclosure
- Smart systems, filter, humidifier, and ventilation
IAQ Basics

• The Basics of Indoor Air Quality
  – Sources
    • Outdoors
    • Building
    • Occupancy
  – Transport Mechanisms
    • Air flows
  – Removal
    • Dilution (ventilation)
    • Filtration

• Indoor pollutant concentration is a function of
  – source strength (type, emissions rate, transport)
  – removal rate (ventilation, filtration, sinks)

• Indoor air quality has been demonstrated to be many times worse than outdoor air quality.
IAQ Basics

- External
  - Outdoor air
    - Particulates
    - Biologicals
  - Attached garages
  - Loading docks
  - Soil gas

- Internal
  - Building materials
  - Combustion equipment
  - Occupant
  - Occupant activities
    - Cooking
    - Cleaning
    - Hobbies
  - Furnishings
  - Mold and other biologicals

IAQ Basics

- Pollutant avoidance strategies
  - Elimination
    - Don’t bring it in
    - Remove it
  - Encapsulation
    - Seal
      - Another material
      - Paint, varnish, sealer
IAQ Basics

• Pollution removal strategies
  – Dilution
    • Mixing
    • Point source removal
    • General ventilation
  – Filtration
    • Spot filtration (free standing units)
    • General filtration (through air handling systems)

Building Science Review

• Energy (Heat Transfer)
  – Transmission losses and gains
  – Air exchange losses and gains
  – Solar and internal gains
• Moisture Movement Mechanisms
  – Gravity (or bulk water)
  – Capillary flow
  – Air transport
  – Vapor diffusion
• Requirements for Airflow
  – Pressure
  – Path
• Indoor Air Quality
  – Source strength and transport
  – Dilution and/or filtration
Building Science Review

- Heat always moves from warm to cold
- Moisture moves from more to less
- Moisture moves from warm to cold
- Air flows from higher to lower pressure
- CFM (air) out must equal CFM (air) in
- Drain the rain (and the soil)
- Most of the action is at surfaces and connections
- Gas concentration is a function of source strength and removal rate

=> In the end, heat, air & moisture will drive the performance of the system!
The Top 10 Risky Remodels

- **Building Envelope**
  - Air sealing
  - Adding/changing wall or attic insulation
  - Finishing/renovating basement spaces
  - Converting/renovating attic spaces
  - Window replacement
  - Exterior grade changes

- **Mechanical Systems**
  - Furnace change out (and orphaned water heater)
  - Adding exhaust devices (range hoods, clothes dryers)
  - Adding or changing ventilation rates/equipment
  - Duct changes and/or duct sealing
1. Indiscriminate Air Sealing

- Indiscriminate, inappropriate, or improperly guided air-sealing.

- Why is this risky?

What ballpark you are in?

[Graph showing the relationship between building pressure and leakage (cfm).]
1. Guided Air Sealing Summary

- Always focus on the big leaks (bypasses) first
- Air sealing should start at top and move down
  - so your house doesn’t compete with your chimney
- Air sealing changes everything
  - house air exchange rate (ventilation)
  - house pressure regime (backdrafting, radon)
- Air sealing is a prerequisite to insulation
  - don’t remove the heat before removing the moisture
  - may limit future ability to properly air seal
2. Adding Attic or Wall Insulation

- Increasing attic or wall insulation without proper air sealing and moisture management.

- Why is this risky?

Too much moisture; not enough heat!
Section 5: Top 10 Risky Remodels

Too much moisture; not enough heat!

Do you need to inspect insulation?
2. Adding Attic or Wall Insulation Summary

- Don’t slow the heat flow until you have slowed the moisture flow (especially via air flow).
- Adding or changing insulation may make it more difficult or expensive to air seal later.
- For insulation to do its job it must ...
  - fill the entire cavity
  - have no air flow through it or around it
  - remain dry

3. Furnace Replacement

- Furnace change-out
  - from chimney-vented to power-vented or sealed combustion
  - with an “orphaned” water heater

- Why is this risky?
3. Furnace Replacement Summary

- This is probably the biggest single change you can make in an existing house.
- It changes everything!
  - major change in air exchange rate (esp. mid-winter)
  - major change in house pressures (lowers the NPP)
  - may change duct flows & pressures; zonal pressures
- Don’t orphan the chimney-vented water heater
  - it may not be capable of venting on its own
  - especially as the house gets tighter or exhaust devices are added
4. New Exhaust Devices

- Adding large exhausting devices
  - range hoods
  - clothes dryers
  - central vacs
  - ASD (if not done well)

- Why is this risky?
Section 5: Top 10 Risky Remodels

CO Production Under Backdraft

Make-up Air Requirements

- Bathroom fan
- Clothes dryer
- Kitchen fan
- 2 at 50 CFM
- 1 at 150 CFM
- 1 at 200 CFM
- Total Exhaust flow
  = 450 CFM
Section 5: Top 10 Risky Remodels

Make-up Air Requirements

Passive Make-up Air Opening

- Make-up air: CFM provided by smooth duct*

<table>
<thead>
<tr>
<th>Duct Diameter</th>
<th>Atmospheric</th>
<th>Power-vented</th>
<th>Sealed</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 inches</td>
<td>15</td>
<td>35</td>
<td>50</td>
</tr>
<tr>
<td>4 inches</td>
<td>30</td>
<td>60</td>
<td>90</td>
</tr>
<tr>
<td>5 inches</td>
<td>45</td>
<td>100</td>
<td>140</td>
</tr>
<tr>
<td>6 inches</td>
<td>65</td>
<td>140</td>
<td>200</td>
</tr>
<tr>
<td>7 inches</td>
<td>85</td>
<td>190</td>
<td>270</td>
</tr>
<tr>
<td>8 inches</td>
<td>110 x 1</td>
<td>250 x 2</td>
<td>350</td>
</tr>
<tr>
<td>9 inches</td>
<td>140</td>
<td>320</td>
<td>450 x 1</td>
</tr>
<tr>
<td>10 inches</td>
<td>180 x 2</td>
<td>400</td>
<td>570</td>
</tr>
</tbody>
</table>
4. Adding Exhaust Devices Summary

- Can create significant negative pressures
- Can create backdraft conditions for chimney-vented appliances
  - especially as the house get tighter
- Must provide adequate make-up air to minimize troublesome negative pressures
  - passive opening for sealed combustion and small exhaust
  - active make-up air for chimney-vented and large exhaust
5. Basement Remodeling

- Finishing or renovating basement space

- Why is this risky?

---

Basement Renovation Touches It All!

- Combustion safety
- Foundation moisture
- Radon (& other soil gases)
- Biologicals (mold, dust mites, etc.)
- Garage gases (if attached)

- And front and center are uncontrolled...
  - negative pressures in basements
  - below grade moisture transport
Baseline Challenges

- Foundations get wet from three sides by all four moisture transport mechanisms.
  - bulk water, capillarity, diffusion, and air flow
- Foundations can only dry to the inside.
  - generally by diffusion only
- That means you must keep it dry from all three sides
  - or come up with an approach that promotes inward drying better than outward wetting.

The Big, Bad, Boogie Men in the Basement

- Carpet on the slab
- Insulating the walls (from the interior)
- Adding an egress window
- Changing out the furnace
- Changing the ductwork
- Drywalling the ceiling
- Rim (or extended) joists to the garage
5. Basement Remodeling Summary

• Just say no!
  – no reverse grading, landscape irrigation, etc.
  – no carpet
  – no interior wall insulation
  – no chimney-vented combustion

• Just say yes to ...
  – ventilation
  – aggressive humidity control (dehumidification or AC)
  – radon mitigation
  – paperless drywall (off the floor at least 1”)

6. Converting Attic Spaces

• Converting or renovating attic space

• Why is this Risky?
6. Converting Attic Spaces Summary

- Challenging to light w/o skylight or dormers
- Challenging to air seal thoroughly
  - must get to wall top plates
- Challenging to insulate sufficiently
  - to reduce heat loss
  - to avoid ice dams (minimum of R-30 or 40)
- Challenging to ventilate (if needed)

7. Ventilation Changes

- Changes in ventilation rates and/or equipment

- Why is this risky?
7. Ventilation Changes Summary

- Don’t rely on natural infiltration/exfiltration
  - it might not be there when you need it.
- Use current codes and standards as guidance for sizing, distribution, and controls
  - New MN Energy Code
  - ASHRAE 62.2
- How will the ventilation system impact ...
  - house pressures
  - air temperature & humidity

8. Window Replacement

- Window replacement without proper air sealing and moisture management
- Why is this risky?
8. Window Replacement Summary

- Be certain the new window will be better than the old one!
- Buy the best window you can afford
  - you only need to recover the incremental costs
- Make certain it is installed properly
  - plumb, level, and square
  - sill is pan flashed to drain out
  - properly flashed on sides and top
  - air sealed

9. Exterior Grade

- Exterior grade changes
  - reverse grade
  - landscape irrigation
  - hose bibs
  - rain gardens

- Why is this risky?
9. Exterior Grade Summary

- Correct grade problems (if possible)
- Minimize surface water quantity & time near house
  - proper slope = 1’ in first 10 feet
  - gutters with downspout and permanent extensions
  - avoid damming surface water with sidewalks/edgers
  - avoid trees and bushes adjacent to foundation
- Water storage/recharge must be low and remote
  - ideally below the footing drain level

10. Ductwork Changes

- Duct changes & duct sealing

- Why is this risky?
### 10. Ductwork Changes Summary

- Always seal returns (and filter slots) in the CAZ
  - sealing supplies in CAZ can increase negative pressure
- Always try to reduce duct leakage to outside
  - but it can change pressures and will change air exchange
- Always recheck zonal pressures after significant duct modifications.

### House Scenario 2

- Classic Bungalow (1940)
  - Unfinished walk-up attic
  - 1st floor fireplace
  - Fan-assist furnace
  - Atmospheric water heater
  - No ventilation

- Client wants to finish the attic space for an art studio
House Scenario 2

- **Client interview/concerns**
  - Hard to heat
  - Basement is very cold
  - Frequent ice dams

- **Testing Results**
  - Moderately tight
    - 1365 cfm @ 50Pa
  - Carbon monoxide ?
  - Basement pressures ?

- **This house is very close to the cliff for health and safety!**
  - pre-existing combustion issues
  - no ventilation
- Can’t address attic renovation until pre-existing conditions are resolved.
- **Ventilation situation must be fixed.**
  - bath fans
  - range hood
- **Stove must be repaired or replaced**
- **Fireplace will necessitate a make-up air strategy or change out of water and furnace.**
- **Art studio may require additional ventilation.**
- **Will need to develop strategy to adequately insulate roof slope.**
A Closing Thought

- While it is quite possible to do the right thing in the wrong way, there is no right way to do the wrong thing!
Smart Remodeling

It Begins and Ends with Performance

Presented by
Minnesota Pollution Control Agency

Sponsored by

Developed by
University of Minnesota EXTENSION

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Going Green:
Focusing on Process and Performance
Where’s the science in the program?

Training Required
HERS Rating w/3rd Party Verification

Training Required
HERS Rating w/3rd Party Verification

Non-required
HERS Rating 3rd Party Verification Recommended

Section 6: Going Green: Focusing on Process and Performance

Provider Structure - Science

LEED for Homes Provider
LEED for Homes Rater
LEED for Homes Accredited Professional

Minnesota GreenStar Building Science Professionals
Minnesota GreenStar Train Professional

Section 5: Going Green: Focusing on Process and Performance
CRITERIA
5. Energy Efficiency
5.1b Energy Use: Moderate & Substantial Rehabilitation
Perform an energy analysis of existing building conditions, estimate costs of improvements, implement measures that will improve building energy performance by 15 percent from pre-renovation figures.

GOAL
Reduce heating energy by 15 percent from pre-renovation figures.
STRATEGY
Explore alternatives to reduce energy related to heating by 15%.

1. Reduce overall loads - air sealing
2. Meet loads efficiently – install high efficiency boiler

CHAMPION
Mechanical Engineer (leader)
Architect and Developer

METRIC
Kbtu/sf/yr or HERS index score

Provider Structure - Science
Section 5: Going Green: Focusing on Process and Performance
Where’s the science in the program?

Across programs areas that address building science issues are:

- Integrated design process
- Energy Efficiency
- Ventilation Requirements
- Material selection
- Moisture control
- And more...

Criteria Types

Prescriptive based – do this.
Use low and no VOC paint

Performance based – achieve this.
Achieve or exceed the Energy Star Standard
Criteria Type? Prescriptive or Performance

Minnesota GreenStar - 2F-5

Install French drains to manage rainwater and to keep storm water on site.

Prescriptive
Minnesota Green Communities – 7.5c

Install power vented fans or range hoods that exhaust to the exterior.
Criteria Type? Prescriptive or Performance

Minnesota Green Communities – 7.12 (LH)

Garage Isolation: Provide a continuous air barrier between the conditioned (living) space and any unconditioned garage space. In single-family houses with attached garages, install a CO alarm inside the house on the wall that is attached to the garage and outside the sleeping area, and do not install air handling equipment in the garage.

Prescriptive
LEED for Homes – 2.3

Reduce Overall Irrigation Demand by at Least 45% (maximum 4 points).
<table>
<thead>
<tr>
<th>Criteria Type?</th>
<th>Prescriptive or Performance</th>
</tr>
</thead>
</table>

**LEED for Homes – EA 3.1 thru 3.3**

Reduce Envelope Leakage. Meet the air leakage requirements shown in Table 17. The air leakage rate must be tested and verified by an energy rater.

**Performance**
Material Impact on IAQ

Avoiding adverse impact on air quality due to materials
1. Eliminate sources of indoor air pollution
2. Encapsulate unavoidable sources of indoor air pollution
3. Ventilate and exhaust for pollution control

Material Impact on IAQ

Sealant
1. acetic acid content
2. acetic acid decay
Material Impact on IAQ

Varnish
1. Elapsed time
2. Air change Rate

Science across criteria types

Topic Criteria Areas
1. Integrated Design
2. Site, Location and Neighborhood Fabric
3. Site Improvements
4. Water Conservation
5. Energy Efficiency
6. Materials Beneficial to the Environment
7. Healthy Living Environment
8. Operations and Maintenance
Section 5: Going Green: Focusing on Process and Performance

5. Energy Efficiency

5.1b Energy Use: Moderate & Substantial Rehabilitation
Perform an energy analysis of existing building conditions, estimate costs of improvements, implement measures that will improve building energy performance by 15 percent from pre-renovation figures.
Science across criteria types

5. Energy Efficiency
5.1b Minnesota Overlay adds the requirement for single family to follow the Minnesota Weatherization Guide Process.

test-in & test-out
(with life safety checks)

Section 5: Going Green: Focusing on Process and Performance

Criteria are interconnected.
Acting on Energy Efficiency will impact other parts of the system.

Green Communities Criteria EE 5.1b
Efficient Energy Use: Moderate and Substantial Rehabilitation.
Met for rehab by following the Minnesota Weatherization Guidelines.
Criteria are interconnected.
Acting on Energy Efficiency will impact other parts of the system.

**Common Actions:**
1. Air Sealing – improved tightness to the envelope
2. Insulation – adding insulation to attic or walls
3. Window Replacement – this could be done for energy or health (lead).

**Consequences**
1. Moisture levels increase
2. Mold
3. Other?
Green Communities Criteria
Efficient Energy Use: Moderate and Substantial Rehabilitation should trigger thinking in these areas.

Healthy Living Environment

And Others…
Other related and involved criteria.

EE 5.2 Energy Star Appliances
EE 5.3a&b Efficient Lighting Interior and Exterior

HLE 7.5a Exhaust Fans – Bathroom
HLE 7.5c Exhaust Fans – Kitchen
HLE 7.6a Install fresh air ventilation
HLE 7.7 HVAC sizing
HLE 7.13 Clothes Dryer Exhaust
HLE 7.18 Combustion Equipment

Secondary Issues
HLE 7.1 Low/No Volatile Organic Compounds (VOC) Paints and Primers; HLE 7.2 Low/No VOC Adhesives and Sealants; HLE 7.3 Urea Formaldehyde-free composite wood; etc.

Process for Performance

LEED for Homes Durability Guidelines

1. Collect Site and project-specific data
2. If you have quality management plan in place, review documents and records for callbacks, etc.
3. Identify issues of particular interest or concern and include these on the durability evaluation form
4. Characterize the degree of risk…for each high risk complete steps 5 thru 7.
5. Ensure the durability management plan includes a specific design and/or construction strategy.
6. Ensure that the strategy addresses each of the applicable building systems, assemblies, etc.
7. Ensure that each strategy is adequately drawn and/or described in the relevant project documents
(Interactive Demonstration of LEED durability checklist)

LEED and ASID (resource)

Section 5: Going Green: Focusing on Process and Performance
Process for Performance

Checklist - Step by Step Approach.

Line Item organization
Highly Prescriptive
Line Item Documentation

Checklist as Verification and Quality Assurance Process
Process and Performance

How it works.

5 Principles of Green
- Energy Efficiency
- Resource Efficiency
- Water Conservation
- Indoor Environmental Quality
- Site and Community Impact

Section 5: Going Green: Focusing on Process and Performance
Minnesota GreenStar

(Interactive Demonstration of GreenStar checklist as tool)
Developing a Whole Building Strategy

- Prescriptive vs. Performance Approaches

- A Modified Prescriptive Approach
  - Green Light
  - Yellow Light
  - Red Light

- A 5-Step “Systems-Guided” Approach
Section 7: Developing Whole Building Remodeling Strategies

Prescriptive-Based Approaches

• Simpler to implement; easier to verify

• Frequently the process is visually-driven

• Difficult to deal with multiple items and system interactions

• Desired performance outcomes may or may not be achieved

Performance-Based Approaches

• More cumbersome to implement; may have uncertainty

• Generally requires data to direct the process

• Can anticipate and evaluate for systems interactions

• Commissioning enhances likelihood of desired outcomes
Prescriptive vs. Performance

• Which should we use?
  – What is the current state of the house?
  – How much is being done?
  – What are the desired outcomes?
    • Updated aesthetics
    • Better space functionality/utilization
    • General care and maintenance
    • Enhanced durability of the structure
    • Healthier indoor air
    • Improved energy efficiency

• Use a prescriptive approach where
  – outcomes are generally cosmetic,
  – system interactions are limited, and
  – heat, air, moisture impacts are likely to be small.

• Use a performance approach where
  – outcomes are performance-oriented
  – systems interactions are likely, and
  – heat, air, moisture impacts are likely to be significant.
A Reminder: Everything is Connected

• Energy, durability, and air quality issues are interactive and must be solved simultaneously.
  – Generally better results will be achieved for these items with a performance-based approach.
  – A performance-based approach reduces the risk of improving one area at the risk of another area.
  – Performance testing reduces callbacks and liability.
  – With a good understanding of the existing condition and proper commissioning of changes, it is possible to positively affect all three.

A Modified Prescriptive Approach

• Always begin by “testing in” to identify ...
  – any preexisting conditions and
  – establish baseline performance.
A Modified Prescriptive Approach

• What does “testing in” mean?
  – Establishes the baseline
    • determine current performance levels
    • identify any pre-existing conditions
  – Comprehensive home performance assessment
    • visual inspection
    • owner/occupant interviews
    • testing & diagnostics
    • performance assessment report

House Performance Assessment

• Building Envelope
  – House tightness
    • blower door (multi-point test)*
    • infrared thermographic inspection
  – Insulation assessment
    • visual and/or intrusive inspection*
    • infrared thermographic inspection
  – Zonal pressure mapping
    • series leakage of buffer zones*
    • pressures between internal zones
House Performance Assessment

• Building Moisture
  – Moisture assessment (surfaces, cavities, & framing)
    • visual with surface scan*
    • pin meter
  – Water management inspection
    • visual*
    • intrusive or spray test
  – Moisture contributions
    • slab (or crawl floor)*
    • foundation

• Mechanical Systems
  – CO Production (all gas appliances)*
  – Worst Case Combustion Zone Depressurization*
    • closed house conditions
    • turn on each exhaust fan from smallest to largest
    • turn on air handler & test each door from
  – Fan flows*
    • all ventilation and exhaust fans
  – Duct tightness
    • total, supply and return leaks*
    • leakage to outdoors
  – Air handler flow
**House Performance Assessment**

- **Indoor Air Quality**
  - Temperatures*
  - Humidity*
  - Ambient CO*
  - Ambient CO$_2$
  - Radon*
  - Biologicals / Mold
  - VOCs
  - Particulates
    - total and size distribution (counts, mass)
    - allergens

- **Energy, Water, & Waste Consumption**
  - Utility bill analysis
    - simple bill review*
    - comprehensive analysis
  - Inventory
    - equipment*
    - appliances
    - lighting
    - fixtures
  - Modeling
    - using house and utility data
**House Performance Assessment**

- Homeowner Interview(s)
  - Overview (short form)*
    - critical to assess/establish current performance levels
    - helps to determine outcome expectations
  - Symptom analysis*
    - frequently this will point you to performance deficits
  - In-depth (long form)
    - as needed for more complex situations

**A Modified Prescriptive Approach**

- Always begin by “testing in” to ...
  - identify any preexisting conditions,
  - establish baseline performance, and
  - complete the house performance assessment.

- Then move to a “green light, yellow light, or red light” approach based on “level of impact”.
A Modified Prescriptive Approach

• What does “level of impact” mean?
  – Systems interactions
    • likelihood of significant connection/interactions
  – Strategic order
    • health and safety
    • durability
    • energy efficiency
  – HAM significance
    • heat flows
    • air flows
    • moisture flows

A Modified Prescriptive Approach

<table>
<thead>
<tr>
<th>Green</th>
<th>Yellow</th>
<th>Red</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

• Test in  X  X  X

• Plan  X
• Verify  ?  X
• Test out  X  X
• Monitor  ?  X  X
Green Light

• Once testing has provided an “all clear” from serious pre-existing conditions, a “green light” can be given for items having low risk due to ...
  – limited systems interactions and
  – low heat/air/moisture impacts.

Green Light

• Potential “Green Light” Items
  – Cosmetic changes (interior or exterior finishes)
  – Installing a room air filtration device
  – Change out incandescent lights to CFLs
  – Replace appliances with high efficiency
    • refrigerator or freezer
    • dishwasher or washing machine
Yellow Light

• A “yellow light” requires caution for items that might have some risk due to ...
  – system interactions below them on the strategic order and/or
  – may have possible heat/air/moisture impacts.
• Possible cautionary steps
  – These may require additional data or “testing out”.
  – It might be a good idea to monitor for unanticipated changes.

Potential “Yellow Light” Items
  – Adding dehumidification
  – Adding central air filtration
  – Adding balanced ventilation
  – Adding active subslab depressurization (ASD)
Red Light

• A “red light” means stop and fully evaluate items with increased risk due to ...
  – likely system interactions and
  – significant heat/air/moisture impacts.
• These items will require careful planning, oversight and “testing out”.

Red Light

• Potential “Red Light” Items
  – Any item that significantly changes
    • House tightness or pressures
    • Combustion venting
    • Exhaust (or supply) flows
    • Duct tightness
    • Insulation levels
Section 7: Developing Whole Building Remodeling Strategies

**Red Light**

- Potential “Red Light” Items
  - Air sealing
  - Adding or changing insulation
  - Furnace change out
  - Window replacement
  - Ductwork changes
  - Adding exhaust equipment (range, dryers, etc.)
  - Adding or modifying ventilation equipment
  - Adding new conditioned area

**Developing a Whole Building Strategy**

- A 5-Step, Systems-Guided Approach
  - Test In
  - Plan
  - Verify
  - Test Out
  - Monitor
**Step 1. Test In**

- “Test In” is always the first step.
  - Identify pre-existing conditions
  - Basis for developing a plan and scopes of work
  - Baseline for evaluating completed work

**Step 2: Develop Plan**

- Develop a Customized Rehab Plan
  - Each house is different
    - Where it starts => existing conditions
    - Where it ends up => desired outcomes
  - Each action will have different interactions
    - Use the “test in” data to guide the work plan
  - Develop clear work scopes, specs, and expectations
    - Tell them what will be expected at “test out”
  - This will be your roadmap to successful performance.
Step 3: Field Inspection

• Verify Compliance in the Field
  – Proper materials/equipment
    • Is the right stuff on the job site?
  
  – Proper means and methods
    • Are they following the plan, codes, and standards?
    • Pay close attention to sequence issues
    • Follow the hand-off between multiple contractors
  
  – Properly document the end product

Step 4. Test Out

• The Job’s Not Done Until You “Test Out”
  – Compare results to the initial baseline

  – Compare results to established guidelines and/or criteria set in rehab plan

  – Were performance outcomes met?
Step 5. Feedback

- Monitor Performance
  - Feedback is a required component for continuous improvement.
  
  - This is especially critical when we are trying to get maximum results with minimum dollars.
  
  - It is the only way to increase our effectiveness and efficiency over time.

House Scenario 3

- Modern Two Story (1994)
  - highly insulated
  - airtight construction
  - sealed combustion
  - balanced ventilation

- Client is considering a basement remodel
  - finished walls
  - carpet on slab
  - adding a wood stove
House Scenario 3

- **Client interview/concerns**
  - Seems like negative pressure
  - Occasional CO Readings

- **Testing Results**
  - Very tight 360 cfm @ 50Pa
  - Large negative w/ exhaust
  - Ventilation ?
  - Carbon monoxide ?

- **This house is very close to the cliff for indoor air quality!**
  - pre-existing combustion issue
  - pre-existing ventilation problem

- Walls should be built without adding foundation insulation.

- Due to slab insulation, carpet might work, but should be discouraged.

- Don’t put a wood stove in this house without a serious make-up air strategy.
In Conclusion

• Before you can change (or improve) the “system”, you must know the “system”.
  – Where is the home relative to the “cliff”?  
  – How robust or fragile is the home?

• “Testing In” is absolutely essential!
  – To identify pre-existing conditions
  – To provide a basis for assessment
  – To provide a baseline for evaluation
In Conclusion

• We can use a modified prescriptive approach.
  – “green light” is a go
  – “yellow light” is a caution;
    • may need more info, testing, or follow-up monitoring
  – “red light” demands a systems-guide approach

• 5-Step System-Guided Plan for a Smart Remodel
  – test in,
  – develop plan,
  – field verify,
  – test out, and
  – monitor.
A COMMON SCENARIO FOR REVIEW
Where in this sequence of events would you get called in to help?

On a cold winter day, the furnace stops running and there is an acrid odor. The blower motor made a screeching noise and then the bearings seized up.
WHAT ARE THE OPTIONS?

OPTION 1
Keep Old Furnace + Install New Blower Motor = Relatively Inexpensive and No Changes to the Existing System Whole House Performance Audit Recommended

OPTION 2
Install New High Efficiency Furnace = More Expensive and Risky Many Systems in the House could be Affected:
Carefully Review the Following Cautions Before Making this Change

WHY IS THIS RISKY?
This type of furnace replacement is probably one of the most complex changes you can make in an existing house.

IT CHANGES EVERYTHING!

• May orphan the chimney-vented water heater (a safety issue)
• Major change in the air exchange rate (especially in winter)
• Major change in house pressures (lowers the Neutral Pressure Plane)
• May change duct flows & pressures (a comfort issue year-around)
• May change zonal pressures within the house (health & durability)

LET’S LOOK AT A COUPLE OF THOSE ISSUES
WHAT IS AN ORPHANED WATER HEATER?

An orphaned water heater has been left alone to use the chimney that also used to serve the furnace that has been changed out to a new high-efficiency unit.

Why can an orphaned water heater be risky?
It may not be capable of venting on its own in a chimney designed for a much larger appliance.

IT MAY BACKDRAFT

When an atmospherically vented water heater cannot establish a draft, combustion byproducts exhaust into the house.

Backdrafting creates an UNSAFE CONDITION for the people in the house.

WHAT CAN BE DONE TO RESTORE A SAFER CONDITION?

WHAT ARE THE OPTIONS?

OPTION 1
Keep the Old Water Heater
An atmospherically vented water heater may perform better if a properly sized metal FLUE LINER is installed inside the old chimney flue.

After installation, the appliance and flue should be Tested for Safety by a Building Performance Professional.

OPTION 2
Replace the Water Heater

power-vented sealed combustion electric
WHAT IS A CHANGE IN THE AIR EXCHANGE RATE?

The old furnace was probably the largest “exhaust fan” in the house and regularly removed moist, stale air from the house when it was running. The new sealed combustion furnace takes its air from outside so there is less air being exhausted from the house than there used to be.

The moist air that the old furnace exhausted was replaced by colder and drier fresh air that entered the house through leaks in the exterior walls. That reduced the Relative Humidity inside the house and the windows did not get wet too often.

THAT JUST CHANGED

WHAT NEEDS TO BE DONE NEXT?

DO THE WINDOWS NEED TO BE REPLACED?

WOULD A NEW EXHAUST FAN REDUCE THE MOISTURE?

WILL INCREASED HUMIDITY AFFECT OTHER PLACES?

HOW MANY DIFFERENT PARTS AND SYSTEMS OF THE HOUSE DOES EACH OF THESE CHOICES TOUCH?
HOW DO WE MANAGE THE DECISIONS?

What are the Guiding Principles?
• Plan changes to the home to ensure safety.
• Design, construct, and maintain homes for durability.
• Operate homes for health and comfort.

Here is the Priority List:
1. Combustion Safety - including attached garages (safety and health)
2. Ventilation and Indoor Environmental Quality (health and durability)
3. Water and Moisture Vapor Management (health and durability)
4. Building Shell Air-tightness (comfort and durability)
5. Insulation and Windows (comfort and energy efficiency)
6. Heating and Air Conditioning Design (comfort and energy efficiency)

Priorities are Listed In Order of Importance!
Apply the Priorities to Each Planned Change

SAFETY + HEALTH + DURABILITY + COMFORT + ENERGY EFFICIENCY = SUSTAINABLE
START WITH BASELINE PERFORMANCE TESTING

- Combustion Safety
- Building Leakage
- Infra-Red Thermography
- Duct Testing
- Ventilation Flows

EVIDENCE OF AIR LEAKAGE IN THE PARTY WALL
CLASSIC “OLDER STORY and a HALF” ICE DAMS

SURPRISING FOR A TWO YEAR OLD HOME
Testing reveals air leakage at top plates.

Walls should have top plates.
IMPORTANCE of ATTIC KNEEWALL BACKER

BLOCKED AND AIR-SEALED AT THE TRANSITION
ATTENTION TO EVERY AIR-SEALING DETAIL

WHAT’S MISSING and WHAT’S NOT
VENTS, SHEATHING, and AIR SEALING

LOOK FOR CLUES – INTERIOR GABLE WALL
‘EXTERIOR’ SHEATHING MISSING ON GABLE WALL

COLD BATHROOM INSIDE ATTIC KNEEWALL
THERMAL AND PRESSURE BUILDING DEFECTS

A RELIABLE WAY TO TREAT THE ATTIC SPACES
AIR IN = AIR OUT

A SYSTEMS APPROACH FOR ALL BUILDING TYPES
EFFICIENCY, COMFORT, and PRESSURE PROBLEMS
SEAL ALL DUCTS AND BALANCE SYSTEMS

IS THIS A GOOD IDEA?
EVIDENCE OF PREVIOUS WATER LEAKS

UNIFORM ICE DAM AND ICICLES
ICE DAM CROSS SECTION

LOOK FOR CLUES THAT EXPLAIN THE DIFFERENCE
OPEN ALL THE WAY TO THE BASEMENT

RIGID WIND WASH BLOCKING IS BETTER
AS FOUND CONDITION – WHAT IS IT?

UNSEALED ELECTRICAL PENETRATIONS
INCOMPLETE SEALING

INTERIOR WALL BYPASS
PROPER AIR SEALING METHODS

ATTIC BYPASSES TO CHECK FOR
OPEN DUCT AND PLUMBING CHASES

OPEN TOPS ON HIDDEN CHASES
CHASE HAS BEEN BLOCKED AND SEALED

SECTION 8 – BEST PRACTICES, RISKY PRACTICES, AND MISSED OPPORTUNITIES

USING THE BLOWER DOOR + INFRA-RED THERMOGRAPHY TO IDENTIFY BY-PASS ISSUES

What are They?
DROPPED SOFFIT BYPASS

INTERIOR WALL OPEN TO ATTIC
SEAL THE LID BEFORE INSULATING

CHANGING THE BUILDING VENTILATION RATE

12 CFM
RATED, NOT TESTED IN PLACE

DON’T FORGET THIS EXHAUST FAN

100 CFM – 200 CFM
WHAT ARE THE REASONS FOR VENTILATION HERE?

VENTILATION CHANGES = PRESSURE CHANGES
ANOTHER REPLACEMENT AIR PATHWAY

THE LAST LINE OF DEFENSE – FRESH BATTERIES?

SECTION 8 – BEST PRACTICES, RISKY PRACTICES, AND MISSED OPPORTUNITIES
OUTSTANDING DECK ATTACHMENT SYSTEM

SPACE TO DRAIN AND DRY
NO APPEARANCE PROBLEMS

DRAIN AND DRY MASONRY VENEER FINISHES
ANOTHER METHOD TO DRAIN AND DRY

STRAPPED TO PROVIDE DRAINAGE AND DRYING
EXTRA PROTECTION AT A KNOWN PROBLEM AREA

SHINGLE FASHION AND KICKOUT IN PLACE
VINYL SIDING TRIMMED AROUND A KICKOUT

KICKOUT INTEGRATED WITH STUCCO FINISH
OUTSIDE – EVIDENCE OF FLASHING FAILURE

INSIDE – CONSEQUENCES OF FLASHING FAILURE
FULLY INTEGRATE FLASHINGS AND WEATHER BARRIER

SECTION 8 – BEST PRACTICES, RISKY PRACTICES, AND MISSED OPPORTUNITIES

TOP AND SIDES SEALED – BOTTOM OPEN TO DRAIN

SECTION 8 – BEST PRACTICES, RISKY PRACTICES, AND MISSED OPPORTUNITIES
CAULKING TRAPS THE WATER INSIDE THE WALL

SO DOES TAPE
SLOPE AWAY AND USE LONG CONDUCTOR PIPES

SLOPED INTO SWALE AND DRAINED TO STREET
ONE SOURCE OF ALL THAT MOISTURE

SEAL OFF MOISTURE TRANSPORT PATHWAYS
OPENING CREATED A NEW PATHWAY AND WET SPOT

INSTALLLED TO DRAIN WATER INTO THE SOIL
WHICH WAY IS THE MOISTURE ACTUALLY MOVING?

MOISTURE TRAPPED INSIDE BUILDING ASSEMBLY
WHERE IS THE WATER TABLE?

A LARGE, HIDDEN SOIL MOISTURE CONNECTION
SEAL ALL OPEN SOIL MOISTURE CONNECTIONS

DON’T FORGET TO SEAL UNDER THE SHOWER BASE
OPEN SUMP CROCKS ARE A MOISTURE SOURCE

COVERED BUT NOT SEALED
INSULATE AND AIR SEAL COMPLETELY

HOLD STUDS OUT – INSULATE AND SEAL IN ONE STEP
INSULATION ON THE EXTERIOR IS BEST

LEDGER AND COVERING INSULATION ARE CHALLENGES
GROUND BREAKER IS ONE EASY SOLUTION

WORKS ON SLOPES, TOO
MINNESOTA RADON ZONES

Zone 1
Highest Potential

Zone 2
Moderate Potential

SHORT AND LONG TERM TESTING SYSTEMS
ADDING A SYSTEM TO AN EXISTING HOME

IDENTIFY SYSTEM AND MONITOR PRESSURE
FAN SHOULD BE ACCESSIBLE FOR SERVICING

DEHUMIDIFICATION IN SUMMER
What factors should the insulation decisions for Above Grade Walls and Foundation Walls be based on?

Check the options against the list again.
Open Questions & Answers

- Systems-Guided Approach to Remodeling
- Green Remodeling Programs in Minnesota
- Intro to Building Performance & Building Science
- Top 10 Risky Remodels
- Going Green with a Focus on Process & Performance
- Developing a Whole Building Strategy for Remodeling
- 5-Step Process for Smart Remodeling
- Best Practices, Risky Practices, & Missed Opportunities
The Challenge

• What are you going to do different tomorrow?

The Challenge

• Are you leaving with any new hats?
The Smart Remodeling Team

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Thank-you for your attention and participation and
Have a safe trip home!
University of Minnesota Extension is an equal opportunity educator and employer.

This material is available in alternative formats upon request.
Direct requests to Pat Huelman, Associate Professor and Coordinator of the Cold Climate Housing Program at 612-624-1286

Smart Remodeling
*It Begins and Ends with Performance*
House Performance Assessment

Why do you need to test?
1. You want to know how the building is currently performing.
2. You don’t want to miss pre-existing conditions.

The “home performance assessment” has four key components.
1. Visual inspection
2. Owner / Occupant interview(s)
3. Testing & Diagnostics (testing in)
4. Performance Assessment report

<table>
<thead>
<tr>
<th>Common Building Tests</th>
<th>Always</th>
<th>Conditional</th>
</tr>
</thead>
<tbody>
<tr>
<td>House Tightness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single point (@50 Pa)</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Multi-point (with house curve)</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Duct Tightness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Leakage (supplies &amp; returns)</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Leakage to outdoors</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Air Handler Flow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estimated (from rated)</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Measured</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Zonal Pressure Diagnostics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attic</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Garage</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Basement/Crawl space</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Soil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mechanical room</td>
<td></td>
<td>X (wcd)</td>
</tr>
<tr>
<td>Carbon Monoxide</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Appliance</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Worst Case Depressurization</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fan Flows (or pressures)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bath fans</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Range hoods</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Clothes dryer</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Whole house ventilation</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Radon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central vacuum</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Attic fan</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
### Insulation Assessment
- **Visual**
- **Intrusive inspection**
- **Infrared thermography**
  - Natural conditions
  - With blower door

### Energy
- **Simple bill review**
- **Bill analysis**
- **Equipment inventory**
- **Lighting & Appliances**
- **Modeling (with house data)**

### Water Management
- **Visual**
- **Intrusive**
- **Spray test**

### Materials (moisture content)
- **Ceilings/Attic Framing**
- **Walls (framing & sheathing)**
- **Basement Framing**
- **Windows**
- **Floor slab**
- **Foundation**

### Mold
- **Visual**
- **Air sampling (ambient vs. aggressive)**
- **Tape lifts**

### Indoor Air Quality
- **Temperatures**
- **Relative Humidity**
- **Radon**
- **CO2**
- **CO (ambient)**
- **Formaldehyde**
- **TVOC**
- **Biologicals**
- **Particulates**

### Water Use
- **Bill review**
- **Fixture inventory**

### Homeowner interview
- **Short form**
- **Symptom analysis**
- **Long form**
**Customer Home Data Collection Form: Case Study**

**House Story:** Home was purchased last fall and interior remodeling was to begin immediately. A new sealed combustion furnace and A/C was installed a week before closing. The B vented water heater was 2 years old. Owner added 3 bath fans where there were none. Kitchen exhaust was doubled to 280 cfm. Attached double garage. Previous owner recently added 12 inches of attic insulation (5 in. prior)

<table>
<thead>
<tr>
<th>Building Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Age</td>
</tr>
<tr>
<td># of Stories</td>
</tr>
<tr>
<td>Sq. Ft Conditioned</td>
</tr>
<tr>
<td>Rental?</td>
</tr>
<tr>
<td>Foundation Type</td>
</tr>
<tr>
<td>Siding Type</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pre-Test, Assessment and Blower Door</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre Blower Dr Test</td>
</tr>
<tr>
<td>Air Changes Per Hr @50</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Air Leakage Sites (Check all that applies)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X Chimneys</td>
</tr>
<tr>
<td>_ Plumbing Penetrations</td>
</tr>
<tr>
<td>_ Mechanical Chase</td>
</tr>
<tr>
<td>__ Windows</td>
</tr>
<tr>
<td>__ Porch Ceiling</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Insulation Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Insulation area</strong></td>
</tr>
<tr>
<td>Open Joist Attic</td>
</tr>
<tr>
<td>Sloped Ceiling</td>
</tr>
<tr>
<td>Knee Wall attic</td>
</tr>
<tr>
<td>Cantilever</td>
</tr>
<tr>
<td>Sill Box</td>
</tr>
<tr>
<td>Windows: Area: Type: U Value:</td>
</tr>
</tbody>
</table>
Heating, A/C, Water Heating Equipment (existing)

Heating Type FA   Fuel type  gas   Age 5 mons AFUE 95%  Sealed Combustion? yes
A/C    SEER   Tons
Other heating types:   Fire Places   Wood   Gas   X
Space Heaters   X   Fuel Type   Gas
Water Heating:   1   Fuel Type:   gas   Age 2y   Gallons   50
Atmospheric vented   Yes   Power vented   Sealed Combustion

Combustion Safety Testing
It is critical to test combustion equipment and ventilation to determine ventilation changes.

<table>
<thead>
<tr>
<th>Appliance</th>
<th>Draft Test</th>
<th>Carbon Monoxide</th>
<th>Spillage Y/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Heater</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heating System</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Space Heater</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fire place</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Ventilation

House Depressurization

<table>
<thead>
<tr>
<th>Type</th>
<th>Baseline</th>
<th>Kit Exhaust</th>
<th>Bath Exh.</th>
<th>Dryer</th>
<th>Air Hndl</th>
<th>Hrv/Erv</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFM</td>
<td>0</td>
<td>280</td>
<td>20</td>
<td>140</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure (+/-)</td>
<td>7</td>
<td>7.5</td>
<td>12</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Tested Flow</th>
<th>Vent. Equipment Type</th>
<th>Rated Fl</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Utility Bill Data

<table>
<thead>
<tr>
<th>Last 12 months:</th>
<th>Gas (CCF):</th>
<th>Electric (Kwh):</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A. Monthly outdoor temperature (NOAA)
B. Monthly heating degree days (HDD) and cooling degree days (CDD) from the weather station (NOAA).
# Customer Home Data Collection Form: Case Study

**House Story:** This is a classical walk-up bungalow with an unfinished attic. The client wants to convert this attic space to an art studio.

They have asked you to come in and give them a bid on finishing off the attic. Any thoughts or concerns from the homeowner comments and testing results?

## Customer Information

<table>
<thead>
<tr>
<th>Name</th>
<th>St. Paul, MN</th>
</tr>
</thead>
<tbody>
<tr>
<td>City</td>
<td>St. Paul, MN</td>
</tr>
<tr>
<td>Customer Concerns</td>
<td>1 House is hard to heat</td>
</tr>
<tr>
<td></td>
<td>2 Basement is cold</td>
</tr>
<tr>
<td></td>
<td>3 Frequent ice dams</td>
</tr>
</tbody>
</table>

## Building Data

<table>
<thead>
<tr>
<th>Building Age</th>
<th>1940</th>
<th># of Occupants</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td># of Stories</td>
<td>1.5</td>
<td>Ceiling Hgt</td>
<td>8’</td>
</tr>
<tr>
<td>Sq. Ft Conditioned</td>
<td>1225 sf</td>
<td>House Volume</td>
<td>10,800 cf</td>
</tr>
<tr>
<td>Rental?</td>
<td>Y</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Building Type</td>
<td>Single family</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foundation Type</td>
<td>Cinder block</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Siding Type</td>
<td>Stucco &amp; Brick</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Pre-Test, Assessment and Blower Door

<table>
<thead>
<tr>
<th>Pre Blower Dr Test</th>
<th>1365</th>
<th>CFM50</th>
<th>Post Blower Dr Test</th>
<th>CFM50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Changes Per Hr @50</td>
<td>Pre</td>
<td>7.6</td>
<td>Post</td>
<td></td>
</tr>
<tr>
<td>Air Leakage Sites (Check all that applies)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>x</em> Chimneys</td>
<td><em>x</em> Soil Stacks</td>
<td>___ Electrical Penetrations</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>x</em> Plumbing Penetrations</td>
<td>___Pocket Doors</td>
<td>___ Drop soffit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>___Mechanical Chase</td>
<td><em>x</em> Void Around Stairwell</td>
<td><em>x</em> Open Partition, top plate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>_x_Windows</td>
<td>___ Other</td>
<td>___________________________</td>
<td></td>
<td></td>
</tr>
<tr>
<td>___Porch Ceiling</td>
<td>___ Other</td>
<td>___________________________</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Insulation Values (not completed at this time)

<table>
<thead>
<tr>
<th>Insulation area</th>
<th>Sq. Ft to Insul</th>
<th>Pre R Value</th>
<th>Post R Value</th>
<th>Insulation Area</th>
<th>Sq. Ft to Insulate</th>
<th>Pre R-Value</th>
<th>Post R Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Joist Attic</td>
<td>20</td>
<td>Side walls</td>
<td>??</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sloped Ceiling</td>
<td>Interior Fdn</td>
<td>none</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knee Wall attic</td>
<td>Exterior Fdn</td>
<td>none</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cantilever</td>
<td>Floor</td>
<td>none</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sill Box</td>
<td>11</td>
<td>Other</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Windows: Area: Type: Single pane w/ Storm</td>
<td>U Value: 0.55 est.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Heating, A/C, Water Heating Equipment (existing)**

<table>
<thead>
<tr>
<th>Heating Type_ FA_</th>
<th>Fuel type_ NG_</th>
<th>Age_ 12 yr._</th>
<th>AFUE_ 78%_</th>
<th>Sealed Combustion?_ N_</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/C</td>
<td>SEER_ 10.0_</td>
<td>Tons_ 3.0_</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Other heating types: Fire Places_ 1_ Wood_ X_ Gas________

Space Heaters______ Fuel Type________

Water Heating: _Tank_ Fuel Type: _NG_ Age_ 5_ Gallons_ 30________

Atmospheric vented_ X_ Power vented_______ Sealed Combustion_______

**Combustion Safety Testing**

It is critical to test combustion equipment and ventilation to determine ventilation changes.

<table>
<thead>
<tr>
<th>Appliance</th>
<th>Draft Test</th>
<th>Carbon Monoxide</th>
<th>Spillage Y/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Heater</td>
<td>5 pa</td>
<td>20 ppm after 2 min</td>
<td>N</td>
</tr>
<tr>
<td>Heating System</td>
<td>Fan-assist</td>
<td>35 ppm after 2 min.</td>
<td>N</td>
</tr>
<tr>
<td>Space Heater</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fire place</td>
<td>not tested</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other – Oven</td>
<td></td>
<td>&gt; 1000 ppm at 5 min.</td>
<td></td>
</tr>
</tbody>
</table>

**Ventilation**

**House Depressurization**

<table>
<thead>
<tr>
<th>Type</th>
<th>Baseline</th>
<th>Kit Exhaust</th>
<th>Bath Exh.</th>
<th>Dryer</th>
<th>Air Hndlr</th>
<th>Hrv/Erv</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFM</td>
<td>---------</td>
<td>0</td>
<td>0</td>
<td>120</td>
<td>1200</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Pressure (+/-)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-1</td>
<td>-4</td>
<td>NA</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Tested Flow</th>
<th>Vent. Equipment Type</th>
<th>Rated Fl</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Utility Bill Data**

<table>
<thead>
<tr>
<th>Last 12 months:</th>
<th>Gas (CCF):</th>
<th>Electric (Kwh):</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>2008</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A. Monthly outdoor temperature (NOAA)
B. Monthly heating degree days (HDD) and cooling degree days (CDD) from the weather station (NOAA).
Customer Home Data Collection Form: Case Study

House Story: High performance home built in 1994 – This home is highly insulated with airtight construction, sealed combustion, and balanced heat recovery ventilation.

This potential client wants to finish off their basement. They would like to finish the walls, put carpet on the slab, and add a woodstove. This client has called your company because you have done a number of basement remodels in the neighborhood. Any thoughts an how you might approach this one?

Customer Information

<table>
<thead>
<tr>
<th>Name</th>
<th>Lino Lakes, MN</th>
</tr>
</thead>
</table>

Customer Concerns

1. Seems to have negative pressure
2. CO detector in the lower level has occasional readings (10 to 50 ppm)
3. 

Building Data

<table>
<thead>
<tr>
<th>Building Age</th>
<th>1994</th>
<th># of Occupants</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td># of Stories</td>
<td>2</td>
<td>Ceiling Hgt</td>
<td>8’</td>
</tr>
<tr>
<td>Sq. Ft Conditioned</td>
<td>3100 sf</td>
<td>House Volume</td>
<td>26,000 cf</td>
</tr>
<tr>
<td>Rental?</td>
<td>N</td>
<td>Building Type</td>
<td>Single family</td>
</tr>
<tr>
<td>Foundation Type</td>
<td>Poured in place concrete</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Siding Type</td>
<td>Wood and vinyl</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Pre-Test, Assessment and Blower Door

<table>
<thead>
<tr>
<th>Pre Blower Dr Test</th>
<th>360</th>
<th>CFM50</th>
<th>Post Blower Dr Test</th>
<th>CFM50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Changes Per Hr @50</td>
<td>Pre</td>
<td>0.8</td>
<td>Post</td>
<td></td>
</tr>
</tbody>
</table>

Air Leakage Sites (Check all that applies)

- Chimneys
- Plumbing Penetrations
- Mechanical Chase
- Windows
- Porch Ceiling
- Soil Stacks
- Pocket Doors
- Void Around Stairwell
- Other
- Electrical Penetrations
- Drop sofit
- Open Partition, top plate
- Other

Insulation Values

<table>
<thead>
<tr>
<th>Insulation area</th>
<th>Sq. Ft to Insulate</th>
<th>Pre R Value</th>
<th>Post R Value</th>
<th>Insulation Area</th>
<th>Sq. Ft to Insulate</th>
<th>Pre R Value</th>
<th>Post R Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Joist Attic</td>
<td>1050</td>
<td>60</td>
<td></td>
<td>Side walls</td>
<td>1940</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Sloped Ceiling</td>
<td>NA</td>
<td></td>
<td></td>
<td>Interior Fdn</td>
<td>NA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knee Wall attic</td>
<td>NA</td>
<td></td>
<td></td>
<td>Exterior Fdn</td>
<td>776</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Cantilever</td>
<td>NA</td>
<td></td>
<td></td>
<td>Floor</td>
<td>1000</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Sill Box</td>
<td>260</td>
<td>20</td>
<td></td>
<td>Other - Doors</td>
<td>40</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Windows: Area: 400 sf</td>
<td>Type: Triple w/2 low-e, argon &amp; i.s. U Value: 0.21</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Heating, A/C, Water Heating Equipment (existing)**

<table>
<thead>
<tr>
<th>Heating Type: FA</th>
<th>Fuel type NG-WH</th>
<th>Age 16</th>
<th>AFUE: 94%</th>
<th>Sealed Combustion: Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/C</td>
<td>SEER: 13.0</td>
<td>Tons: 2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other heating types: Fire Places</td>
<td>Wood</td>
<td>Gas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Space Heaters</td>
<td>Fuel Type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Heating: HE-Tank</td>
<td>Fuel Type NG</td>
<td>Age 16</td>
<td>Gallons 50</td>
<td></td>
</tr>
<tr>
<td>Atmospheric vented</td>
<td>Power vented</td>
<td>Sealed Combustion: Y</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Combustion Safety Testing**

It is critical to test combustion equipment and ventilation to determine ventilation changes.

<table>
<thead>
<tr>
<th>Appliance</th>
<th>Draft Test</th>
<th>Carbon Monoxide</th>
<th>Spillage Y/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Heater</td>
<td>Seal combustion</td>
<td>1,800 ppm</td>
<td>???</td>
</tr>
<tr>
<td>Heating System</td>
<td>NA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Space Heater</td>
<td>NA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fire place</td>
<td>NA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Ventilation**

**House Depressurization**

<table>
<thead>
<tr>
<th>Type</th>
<th>Baseline</th>
<th>Kit Exhaust</th>
<th>Bath Exh.</th>
<th>Dryer</th>
<th>Air Hndlr</th>
<th>HRV/ERV</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFM</td>
<td>NA</td>
<td>160</td>
<td>NA</td>
<td>120</td>
<td>800</td>
<td>80 - 140</td>
<td></td>
</tr>
<tr>
<td>Pressure (+/-)</td>
<td>0</td>
<td>- 20</td>
<td>NA</td>
<td>- 35</td>
<td>- 35</td>
<td>- 45</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Tested Flow</th>
<th>Vent. Equipment Type</th>
<th>Rated Fl</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRV - ex</td>
<td>140</td>
<td>150 cfm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HRV - sup</td>
<td>60</td>
<td>150 cfm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>160</td>
<td>180 cfm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Utility Bill Data**

<table>
<thead>
<tr>
<th>Last 12 months:</th>
<th>Gas (CCF):</th>
<th>Electric (Kwh):</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>573</td>
<td>10,363</td>
</tr>
<tr>
<td>2008</td>
<td>557</td>
<td>12,184</td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A. Monthly outdoor temperature (NOAA)
B. Monthly heating degree days (HDD) and cooling degree days (CDD) from the weather station (NOAA).
Customer Home Data Collection Form: Case Study

House Story: The house is a raised-ranch split entry with the basement about 40% finished. The owners received an energy comparison letter from utility showing the energy consumption of their home to be in the worst third of homes in the neighborhood and feel guilty about the energy that they are wasting. They like the house and plan to stay for a while. The house already needs to be re-roofed and re-sided. They bring in a HERS rater to evaluate the home and produce a baseline rating and several options to address the results of the rating. Looking at the options, are they making choices in the right order for safety, health, and durability? What factors should the insulation decisions for Above Grade Walls and Foundation Walls be based on?

Customer Information

<table>
<thead>
<tr>
<th>Name</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>City</td>
<td>Roseville, MN</td>
</tr>
<tr>
<td>Customer Concerns</td>
<td></td>
</tr>
<tr>
<td>1 Energy costs</td>
<td></td>
</tr>
<tr>
<td>2 Windows</td>
<td></td>
</tr>
<tr>
<td>3 Ice dams</td>
<td></td>
</tr>
</tbody>
</table>

Building Data

<table>
<thead>
<tr>
<th>Building Age</th>
<th># of Occupants</th>
<th># of Stories</th>
<th>Ceiling Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td>2</td>
<td>2</td>
<td>8 feet main &amp; 8 feet basement</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sq. Ft Conditioned</th>
<th>House Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>2415</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rental?</th>
<th>Building Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>Single family Detached</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Foundation Type</th>
<th>Siding Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Pre-Test, Assessment and Blower Door

<table>
<thead>
<tr>
<th>Pre Blower Dr Test</th>
<th>CFM50</th>
<th>Post Blower Dr Test</th>
<th>CFM50</th>
</tr>
</thead>
<tbody>
<tr>
<td>2160</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Air Changes Per Hr @50</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.23</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Air Leakage Sites (Check all that applies)</th>
</tr>
</thead>
<tbody>
<tr>
<td>√ Chimneys</td>
</tr>
<tr>
<td>√ Soil Stacks</td>
</tr>
<tr>
<td>√ Electrical Penetrations</td>
</tr>
<tr>
<td>√ Plumbing Penetrations</td>
</tr>
<tr>
<td>√ Pocket Doors</td>
</tr>
<tr>
<td>√ Drop soffit</td>
</tr>
<tr>
<td>√ Mechanical Chase</td>
</tr>
<tr>
<td>√ Void Around Stairwell</td>
</tr>
<tr>
<td>√ Open Partition, top plate</td>
</tr>
<tr>
<td>Windows</td>
</tr>
<tr>
<td>Porch Ceiling</td>
</tr>
<tr>
<td>Other</td>
</tr>
</tbody>
</table>

Insulation Values

<table>
<thead>
<tr>
<th>Insulation area</th>
<th>Sq. Ft to Insulate</th>
<th>Pre R Value</th>
<th>Post R Value</th>
<th>Insulation Area</th>
<th>Sq. Ft to Insulate</th>
<th>Pre R-Value</th>
<th>Post R Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Joist Attic</td>
<td>1287</td>
<td>12</td>
<td></td>
<td>Side walls</td>
<td>1367</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Sloped Ceiling</td>
<td></td>
<td></td>
<td></td>
<td>Interior Fdn</td>
<td>1172</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Knee Wall attic</td>
<td></td>
<td></td>
<td></td>
<td>Exterior Fdn</td>
<td>1172</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Cantilever</td>
<td>52</td>
<td>19</td>
<td></td>
<td>Floor/Slab</td>
<td>1271</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Sill Box</td>
<td>156</td>
<td>19</td>
<td></td>
<td>Other</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Windows: Area: 210</td>
<td></td>
<td></td>
<td></td>
<td>Type: Wood Slider</td>
<td></td>
<td>U Value: 0.90</td>
<td></td>
</tr>
</tbody>
</table>
### Heating, A/C, Water Heating Equipment (existing)

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Fuel Type</th>
<th>Age</th>
<th>AFUE</th>
<th>Sealed Combustion?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating Type</td>
<td>Forced Air</td>
<td>1995</td>
<td>80</td>
<td>NO</td>
</tr>
<tr>
<td>A/C</td>
<td>SEER 10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel type</td>
<td>NG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>1995</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AFUE</td>
<td>80</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sealed Combustion?</td>
<td>NO</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other heating types</td>
<td>Fire Places</td>
<td>1-basement</td>
<td>Wood X</td>
<td>Gas</td>
</tr>
<tr>
<td>Space Heaters</td>
<td>Fuel Type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Heating</td>
<td>Conventional</td>
<td>Fuel Type</td>
<td>NG</td>
<td>Age 2006</td>
</tr>
<tr>
<td></td>
<td>Atmospheric vented</td>
<td>Power vented</td>
<td>Sealed Combustion</td>
<td></td>
</tr>
</tbody>
</table>

### Combustion Safety Testing

It is critical to test combustion equipment and ventilation to determine ventilation changes.

<table>
<thead>
<tr>
<th>Appliance</th>
<th>Draft Test</th>
<th>Carbon Monoxide</th>
<th>Spillage Y/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Heater</td>
<td>Not Tested</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heating System</td>
<td>Not Tested</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Space Heater</td>
<td>None</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fire place</td>
<td>Not used</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Ventilation

#### House Depressurization (cumulative-in sequence)

<table>
<thead>
<tr>
<th>Type</th>
<th>Baseline CFM</th>
<th>Kit Exhaust CFM</th>
<th>Bath Exh. CFM</th>
<th>Dryer CFM</th>
<th>Air Hndlr CFM</th>
<th>Hrv/Erv CFM</th>
<th>Other CFM</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFM</td>
<td>*</td>
<td>71</td>
<td>11</td>
<td>~150</td>
<td>n/a</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Pressure (+/-)</td>
<td>+0.9</td>
<td>-1.4</td>
<td>-1.8</td>
<td>-2.7</td>
<td>-2.2</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Tested Flow</th>
<th>Vent. Equipment Type</th>
<th>Rated Flow</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Bath</td>
<td>11 CFM</td>
<td>Exhaust Fan</td>
<td>50 CFM</td>
<td>3’ duct / roof jack</td>
</tr>
<tr>
<td>Bsmt Bath</td>
<td>Not tested</td>
<td>Exhaust Fan</td>
<td>50 CFM</td>
<td>Vented in bsmt</td>
</tr>
<tr>
<td>Kitchen</td>
<td>71 CFM</td>
<td>Micro/Exhaust Fan combo</td>
<td>Unknown</td>
<td>6’ duct / roof jack</td>
</tr>
</tbody>
</table>

### Utility Bill Data

<table>
<thead>
<tr>
<th>Last 12 months</th>
<th>Gas (CCF):</th>
<th>Electric (kWh):</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>1117</td>
<td>8403</td>
</tr>
<tr>
<td>2008</td>
<td>1179</td>
<td>8328</td>
</tr>
<tr>
<td>2007</td>
<td>1114</td>
<td>9795</td>
</tr>
<tr>
<td>2006</td>
<td>1072</td>
<td>7952</td>
</tr>
</tbody>
</table>

### A. Monthly outdoor temperature (NOAA)

### B. Monthly heating degree days (HDD) and cooling degree days (CDD) from the weather station (NOAA).
Roseville Home – Case Study Additional Information

All options assume leaving the slab floor un-insulated, doors with the same R-value, and a power vented water heater with the same Energy Factor. All options assume:

- Upgrading attic insulation from R12 to R50.
- Upgrading windows from U-0.90 to U-0.33.
- Upgrading cantilever insulation from R19 to R38.
- Upgrading furnace from 80 AFUE-80,000 Btu to 94 AFUE-32,000 Btu.
- Upgrading central AC from 10 SEER-2.5 ton to 14 SEER-1.5 ton.
- The infiltration will be reduced from 2160 CFM50 to 400 CFM50.

Five wall and Foundation insulation combinations are offered.

**Above grade Walls**  |  **12” CMU Found. Walls (4.5’ exposed, 3.5’ below grade)**
--- | ---
1) R13 cavity with R13 cont. ext  |  R10 full ht with R10 top 4.5 feet ext
2) R13 cavity with R13 cont. ext  |  R0 int with R10 top 4.5 feet ext
3) R13 cavity with R13 cont. ext  |  R12 full ht with R0 exterior
4) R11 cavity  |  R12 full ht int with R10 top 4.5 feet ext
5) R13 cavity with R6.5 cont. ext  |  R12 full ht int with R10 top 4.5 feet ext

**REM/Rate Action Report Energy Use**

<table>
<thead>
<tr>
<th>HEATING</th>
<th>As Found</th>
<th>Edit 1</th>
<th>Edit 2</th>
<th>Edit 3</th>
<th>Edit 4</th>
<th>Edit 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundation Walls</td>
<td>508</td>
<td>78</td>
<td>177</td>
<td>102</td>
<td>78</td>
<td>78</td>
</tr>
<tr>
<td>Infiltration</td>
<td>236</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Windows</td>
<td>230</td>
<td>72</td>
<td>69</td>
<td>71</td>
<td>69</td>
<td>71</td>
</tr>
<tr>
<td>Above Grade Walls</td>
<td>193</td>
<td>76</td>
<td>76</td>
<td>76</td>
<td>166</td>
<td>103</td>
</tr>
<tr>
<td>Ducts</td>
<td>173</td>
<td>41</td>
<td>53</td>
<td>44</td>
<td>52</td>
<td>44</td>
</tr>
<tr>
<td>Ceilings</td>
<td>169</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Slab Floors</td>
<td>-</td>
<td>56</td>
<td>56</td>
<td>56</td>
<td>56</td>
<td>56</td>
</tr>
<tr>
<td>Mechanical Ventilation</td>
<td>-</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>48</td>
</tr>
<tr>
<td>Other</td>
<td>-64</td>
<td>-32</td>
<td>-35</td>
<td>-33</td>
<td>-35</td>
<td>-33</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$1,445</td>
<td>$338</td>
<td>$443</td>
<td>$363</td>
<td>$434</td>
<td>$367</td>
</tr>
</tbody>
</table>

**COOLING**

| Internal Gains | 96 | 70 | 70 | 70 | 70 | 70 |
| Windows | 34 | 22 | 22 | 22 | 22 | 22 |
| Ceilings | 8 | 1 | 1 | 1 | 1 | 1 |
| Ducts | 8 | 8 | 7 | 8 | 8 | 8 |
| Other | -79 | -31 | -39 | -33 | -34 | -32 |
| TOTAL | $68 | $71 | $62 | $68 | $66 | $69 |

**Energy Cost and Feature Report Totals:**  
$2,441  $1,339  $1,436  $1,362  $1,431  $1,367
**Zero CO detector outside** (Follow manufactures instructions)  
**Record outdoor temperature:** ______ F

### Customer Information

<table>
<thead>
<tr>
<th>Name</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Address</td>
<td></td>
</tr>
<tr>
<td>City</td>
<td>State</td>
</tr>
<tr>
<td></td>
<td>Zip</td>
</tr>
<tr>
<td>Phone: ( )</td>
<td>Email:</td>
</tr>
<tr>
<td>Electric Provider</td>
<td>Account Number</td>
</tr>
<tr>
<td>Heating Fuel Provider</td>
<td>Account Number</td>
</tr>
</tbody>
</table>

### Customer Top Concerns:

1. 
2. 
3. 

### General Building Data

<table>
<thead>
<tr>
<th>Building Age</th>
<th># of Occupants</th>
<th>Weather Condition:</th>
</tr>
</thead>
<tbody>
<tr>
<td># of Stories</td>
<td>Ceiling Height</td>
<td>Building Type (check one)</td>
</tr>
<tr>
<td>Sq. Ft. Conditioned Floor Area</td>
<td>House Volume</td>
<td>Single Family Duplex Split Level Mobile Home</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rental Unit:</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landlord Name:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landlord Address:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Building Age Data

<table>
<thead>
<tr>
<th>Building Age</th>
<th># of Occupants</th>
<th>Weather Condition:</th>
</tr>
</thead>
<tbody>
<tr>
<td># of Stories</td>
<td>Ceiling Height</td>
<td>Building Type (check one)</td>
</tr>
<tr>
<td>Sq. Ft. Conditioned Floor Area</td>
<td>House Volume</td>
<td>Single Family Duplex Split Level Mobile Home</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Building Type (check one)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Family Duplex Split Level Mobile Home</td>
</tr>
</tbody>
</table>

### Foundation Type:

<table>
<thead>
<tr>
<th>Foundation Type:</th>
<th></th>
</tr>
</thead>
</table>

### Siding Type:

<table>
<thead>
<tr>
<th>Siding Type:</th>
<th></th>
</tr>
</thead>
</table>

### Blower Door Test Results & Air Leakage Sites

<table>
<thead>
<tr>
<th>Pre Blower Door Test</th>
<th>CFM50</th>
<th>Post Blower Door Test</th>
<th>CFM50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Changes Per Hour @50 Pa (CFM50*60/Volume)</td>
<td>Pre</td>
<td>Post</td>
<td>CFM 50</td>
</tr>
</tbody>
</table>

### Air Leakage Sites (check all that apply):

- Chimneys
- Plumbing Penetrations
- Mechanical Chase
- Windows
- Porch Ceiling
- Other:

- Soil Stacks
- Pocket Doors
- Void Around Stairwell
- Sill Plate
- Recessed lights
- Electrical Penetrations
- Tongue & Groove Ceiling
- Band Joist
- Drop Soffit
- Open Partition Wall at Top Plate

### Other:

- ____________________
## Insulation Values

<table>
<thead>
<tr>
<th>Insulation Area</th>
<th>Sq Ft to Insulate</th>
<th>Pre R-Value</th>
<th>Post R-Value</th>
<th>Insulation Area</th>
<th>Sq Ft to Insulate</th>
<th>Pre R-Value</th>
<th>Post R-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Joist Attic</td>
<td></td>
<td></td>
<td></td>
<td>Sidewalls</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Closed Floor Attic</td>
<td></td>
<td></td>
<td></td>
<td>Int. Foundation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sloped Ceiling</td>
<td></td>
<td></td>
<td></td>
<td>Ext. Foundation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gable End Walls</td>
<td></td>
<td></td>
<td></td>
<td>Floor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knee Wall Attic</td>
<td></td>
<td></td>
<td></td>
<td>Mobile Home Floor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cathedral</td>
<td></td>
<td></td>
<td></td>
<td>Mobile Home Wall</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sill Box</td>
<td></td>
<td></td>
<td></td>
<td>Mobile Home Ceiling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
<td>HUD label:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MN Pre-Fab Seal:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Equipment verification:

| Htg 1: ___________________________ Model #: ___________________________ AFUE: _______ ECM: _______ |
| Htg 2: ___________________________ Model #: ___________________________ AFUE: _______ ECM: _______ |
| A/C 1: ___________________________ Model #: ___________________________ SEER: _______ Tons: _______ |
| Evaporator Coil #: ________________ Condenser Coil #: ________________ |
| A/C 2: ___________________________ Model #: ___________________________ SEER: _______ Tons: _______ |
| Evaporator Coil #: ________________ Condenser Coil #: ________________ |
| Water Heater: ____________________ Model #: ___________________________ EF: _______ |

## Heating Equipment (Existing Unit)

<table>
<thead>
<tr>
<th>Heating System Fuel Type:</th>
<th>Natural Gas</th>
<th>Propane (LP)</th>
<th>Oil</th>
<th>Electric</th>
<th>Other:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating thermostat setpoint</td>
<td>_____ setback _____ Hours: ___</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heating System Type (check one):</td>
<td>Forced Air</td>
<td>Boiler (steam)</td>
<td>Boiler (water)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Existing Unit Age:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heating System Type:</td>
<td>Atmospheric</td>
<td>Condensing</td>
<td>Induced Draft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot Water measured temperature ________F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Water Heating Equipment (Existing Unit)

<table>
<thead>
<tr>
<th>Water Heater Fuel Type:</th>
<th>Natural Gas</th>
<th>Propane (LP)</th>
<th>Oil</th>
<th>Electric</th>
<th>Other:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Heater Type (check one):</td>
<td>Atmospheric</td>
<td>Power Vented</td>
<td>Electric</td>
<td>Other:</td>
<td></td>
</tr>
<tr>
<td>Water heater Fuel Type</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water heater Type (check one):</td>
<td>Atmospheric</td>
<td>Power Vented</td>
<td>Electric</td>
<td>Other:</td>
<td></td>
</tr>
<tr>
<td>Existing Unit Age:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Existing Gallons</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Optional Test: Pressure Drop Across A Coil

<table>
<thead>
<tr>
<th>Pressure Drop: w.c. or PA</th>
<th>Pressure Drop: w.c. or PA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature:</td>
<td>Temperature:</td>
</tr>
</tbody>
</table>
Combustion Safety Testing

Test Setup Procedures
Turn combustion appliance to pilot (Preventing operation during set-up)

**Record house ambient CO level. ______ ppm**
Put house in winter condition. (Including latching or locking windows)
Install hose; CAZ WRT (with respect to) Outside.
Check furnace filter, replace if dirty when possible.
Close all operable vents (Example -- Fireplace damper).
Clean lint filter in dryer.

**Combustion Appliance Zone Pressure / (CAZ) Pressures (Pa.)**

| 1. Baseline test: (Interior doors open, exhaust appliances off) | Pre test | Post test |
| 2. Turn on all exhaust appliances in Home | |
| 3. Turn on furnace air handler | |
| 4. Close interior doors and as you do so measure the pressure difference between main body and the room you are closing off. (If neg. leave door open, if pos. keep door closed.) | |

5. Close basement door (or door to CAZ) and determine position based on CAZ WRT outside (If the reading becomes more negative – leave door closed. If reading becomes more positive, open door).

6. Check CAZ wrt outside, determine if furnace fan contributes to depressurization.

7. Record worst case depressurization.

**NOTES:**
Make observation of any supply or return grills in the CAZ
Inspect integrity and design of venting system
Check for blocked supply or return registers
Remember to check for backdrafting at diverter of water heater when running furnace in combined test.
Recommend a CO detector in all homes when atmospherically vented appliances, gas ranges, or attached garages are present

**Backdraft and CO testing results of atmospherically vented appliances**
Cycle combustion appliances for 3min. then record, Draft, CO and if any Spillage occurs.

<table>
<thead>
<tr>
<th>Appliance</th>
<th>Draft Test</th>
<th>Carbon Monoxide</th>
<th>Spillage Y/N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stand Alone Test</td>
<td>Combined Test</td>
<td>Stand Alone Test</td>
</tr>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
</tr>
<tr>
<td>Water Heater</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heating System</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A combined test cycling heating system and water heater must be performed if both are tied together before the masonry chimney. Induced draft furnaces do not have to be tested for draft or CO but must be fired for the combined test.

5/14/2009
Combustion Safety Test Action Levels - Carbon Monoxide level is tested before the diverter
There are very specific references in the Mechanical Code as to who can shut down a heating system, unless the local authority has listed an Energy Auditor as someone who can do this, the action is not allowed. Notice of a heating system or Domestic Hot Water problem should be given to the local authority immediately.

<table>
<thead>
<tr>
<th>CO test results</th>
<th>And/Or</th>
<th>Draft Test Results</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;0</td>
<td>And</td>
<td>Fails</td>
<td>Work may not proceed. Arrangements must be made to correct drafting problems. Disclosure form must be signed</td>
</tr>
<tr>
<td>0 - 25ppm</td>
<td>And</td>
<td>Passes</td>
<td>System is OK</td>
</tr>
<tr>
<td>26 – 99 ppm</td>
<td>And</td>
<td>Passes</td>
<td>Recommend a clean and tune</td>
</tr>
<tr>
<td>&gt;100 ppm</td>
<td>Or</td>
<td>Fails</td>
<td>Arrangements must be made to correct high C0 levels and/or venting problem before work can proceed. Disclosure form must be signed</td>
</tr>
<tr>
<td>&gt;200ppm</td>
<td>And</td>
<td>Passes</td>
<td>Work may not proceed until the system is serviced and the problem is corrected. Shut off equipment Disclosure form must be signed</td>
</tr>
</tbody>
</table>

Minimum Acceptable Draft Readings

<table>
<thead>
<tr>
<th>Acceptable Draft Test Readings -- Outdoor Temperature:</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
</tr>
<tr>
<td>pa</td>
</tr>
<tr>
<td>w.c.i.</td>
</tr>
</tbody>
</table>

House depressurization: Record pressure in main body (w.r.t. outside) with a sequential series of mechanical fans operating.

<table>
<thead>
<tr>
<th>Location Tested flow</th>
<th>Ventilation equipment type</th>
<th>Rated flow</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type: □ Exhaust fan □ ERV/HRV □ Central Ex.</td>
<td></td>
<td></td>
<td></td>
</tr>
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<td></td>
</tr>
</tbody>
</table>

(From: CMCH Chimney Safety Users’ Manual (Reference #4 in Appendix A)
Note: Under summertime conditions, actual HDL’s may be lower than shown above.
Utility Billing Data:

1. Collect and record measured energy use data and influential variables for the pre-retrofit period. At a minimum, include the following for each month for which energy use data are collected and recorded:

   a. Monthly average outdoor temperature from the weather station (NOAA) most representative of the actual building site
   b. Monthly heating degree days (HDD) and cooling degree days (CDD) or cooling degree hours (CDH), as appropriate, from the weather station (NOAA) most representative of the actual building site.
Internet Reference Library
(Will be available to download from MPCA website)

Partners and Sponsors
MN Pollution Control Agency http://www.pca.state.mn.us/greenbuilding
(This site will contain the Power Points and other documents from the workshop)
Energy Info Center, MN Dept. of Commerce http://www.state.mn.us/portal/mn/jsp/home.do?agency=Energy
Minneapolis Building Performance Association http://www.mbpa.us/
MN Green Star http://www.mngreenstar.org/
NARI http://www.narimn.org/
CMBA http://www.cmbaonline.org/
BATC http://www.batconline.org/index.aspx
RBA http://www.rochesterareabuilders.com/
University of Minnesota Extension http://www.extension.umn.edu/HousingTech/

Home Energy Efficiency Testing and Evaluation
http://www.homenergyherstesting.com/
http://www.energystar.gov/index.cfm?c=home_improvement.hm_improvement_hpwes&layout=print
http://www.conservationtesting.com/index.htm
http://www.njhomediagnosics.com/
http://www.state.mn.us/portal/mn/jsp/content.do?subchannel=-536895037&id=-536893808&agency=Energy
http://www.greenbuildingadvisor.com/blogs/dept/energy-solutions/does-green-building-have-cost-more
http://www.nap.edu/openbook.php?record_id=10463&page=1
http://www.homegreenhome.us/
http://www.livingspacesdesign.biz/eps_report.html
http://www.efficiencyfirst.org/about/
http://www.hprcenter.org/

Energy Calculators
http://ase.org/uploaded_files/homeenergycheckup/home.html#climate
http://hes.lbl.gov/consumer

High Performance and Research
http://www.nrel.gov/buildings/res_building_design.html#performance_metrics
http://www.bpi.org/
http://www.wbdg.org/wbdg_approach.php
http://www.nrel.gov/docs/fy01osti/27745.pdf Building America Overview
http://www.nrc-cnrc.gc.ca/eng/ibp/irc.html
Green Building and Building Science
http://www.regreenprogram.org/ (this is a comprehensive design tool with system integration info)
http://buildingscience.com/
http://www.joelstiburek.com/topten/index.html
http://www.pca.state.mn.us/oea/greenbuilding
http://www.stopdraftscold.com/building-science-fundamentals.html
http://www.youtube.com/watch?v=D_InDR3p0c&feature=related  Great Video! Joe Lstiburek
http://www.bestofbuildingscience.com/ Training Videos from the best!

Building Product Specs
http://www.buildinggreen.com/menus/

Energy Data
http://www.eia.doe.gov/
http://www.eia.doe.gov/
http://www.aceee.org/press/e086pr.htm
http://www.energycodes.gov/implement/pdfs/Minnesota_rpt.pdf

US Dept of Energy-Building Technologies Program
http://www1.eere.energy.gov/buildings/building_america/
http://www1.eere.energy.gov/buildings/building_america/publications.html
http://www1.eere.energy.gov/buildings/building_america/publications.html
http://www1.eere.energy.gov/buildings/building_america/homeowners.html
http://www1.eere.energy.gov/buildings/building_america/systems_engineering.html
http://www1.eere.energy.gov/buildings/challenge/

Energy and Environmental Building Alliance
http://www.eeba.org/bookstore/default.aspx

Saturn Resource Management
http://srmi.biz/Bookstore.htm

Minnesota Department of Health
http://www.health.state.mn.us/divs/eh/air/index.htm
http://www.health.state.mn.us/divs/eh/indooorair/co/index.html (Carbon Monoxide)
http://www.health.state.mn.us/divs/eh/indooorair/voc/formaldehyde.htm (Formaldehyde)
http://www.health.state.mn.us/divs/eh/indooorair/mold/index.html (Moisture/Mold)
http://www.health.state.mn.us/divs/eh/indooorair/radon/index.html (Radon)
http://www.health.state.mn.us/divs/eh/indoorair/voc/index.htm (VOC’s)
http://www.health.state.mn.us/divs/eh/lead/index.html (Lead Poisoning)
http://www.health.state.mn.us/divs/eh/lead/prof/pre/index.html (Lead Renovation)

US Environmental Protection Agency (EPA) Lead and Renovation
http://www.epa.gov/lead/index.html
http://www.epa.gov/lead/pubs/renovation.htm#authorized (Lead/Renovation, Repair, and Painting)

The Energy Conservatory
http://www.energyconservatory.com/ (Building diagnostic equipment)
http://www.energyconservatory.com/links/links1.htm (Numerous valuable links)