

## Green by Design '09

### Reducing Your Risk with Green Rehab: A Systems-Guided Approach

Pat Huelman  
University of Minnesota Extension  
&  
Steve Klossner  
Advanced Certified Thermography

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## Program Learning Objectives

- Understand the “house as a system”.
- Understand key building science principles.
- Recognize why “green” rehab can be risky.
- Appreciate the need to move from prescriptive requirements to performance outcomes.
- Appreciate the critical importance of “testing in and testing out”.

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## Reducing Your Risk with Green:

- Part 1 of 2: A Systems-Guided Approach
  - “House as a System”
  - Building Science Basics
  - Top 10 Rehab Concerns
  - An Approach to Reduce Your Risk
- Part 2 of 2: Testing In & Testing Out
  - Paul Morin, The Energy Conservatory
  - Jimmie Sparks, The Neighborhood Connection

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## A Systems 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!

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## A Systems Approach

- 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.

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## Reducing Your Risk with Green: A Systems-Guided Approach

- Housing rehab 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

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## Reducing Your Risk with Green: A Systems-Guided Approach

- The "Cliff" (metaphor for a performance failure)
  - Health or safety issue
  - Poor material or building durability
  - High operation and maintenance costs
- 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.

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## Reducing Your Risk with Green: A Systems-Guided Approach

- 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,
  - Houses today are becoming more fragile.
  - It takes smaller changes to make bigger impacts.
    - It is getting easier to move towards "the cliff" quicker.

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## Reducing Your Risk with Green: A Systems-Guided Approach

- 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?
  - Will it be towards or away from the cliff?
  - Where will it be when I'm done?

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## Reducing Your Risk with Green: A Systems-Guided Approach

- 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

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## The Top 10 Risky Rehabs

- 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

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## Getting the Sequence Right: A Lesson Learned the Hard Way

- Combustion Safety ⇒ Safe & Health
- House Ventilation ⇒ Good Indoor Air
- Building Airtightness ⇒ Building Durability
- Increased Insulation ⇒ Energy & Resource Efficient

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## A Strategic Plan: Order Matters!!!

- 1. Take care of people (safe & healthy homes)
- 2. Take care of our buildings (durable homes)
- 3. Take care of our planet (efficient homes)

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## Take Care of People First

- 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

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## Next 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

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## Then, 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

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## The Rules of Building Performance

- Moisture moves from more to less
- Moisture moves from warm to cold
- Heat flows from warm to cold
- Air flows from higher to lower pressure
- CFM (air) out must equal CFM (air) in
- Things always get wet - let them dry
  - But let's minimize the wetting!
  
- In the end, heat, air & moisture are one!

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## Building Performance: Pressures, Holes, and Flow

- Positive or negative pressure ...
  - What does it signify?
  - What does it mean?
  - What are our concerns?
- How, what and where does house or zone tightness fit in?
  - No pressure change can signify significant leaks, not insignificant air flow imbalances.
  - High pressure changes without holes may not be a significant problem.

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## Building Performance: Success and Failure in Houses

- Air Failures
  - 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 climate

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## Building Performance: Success and Failure in Houses

- Air Successes
  - 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

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## The Top 10 Risky Rehabs

- Indiscriminate, inappropriate, or improperly guided air-sealing.
- Why is this risky?



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## The Top 10 Risky Rehabs

- Summary: Guided Air Sealing
  - Always focus on the big leaks (bypasses) first
  - Air sealing should start at the top and move down
    - So your house doesn't compete with your chimney/vent
  - 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 without removing the air (moisture)
    - May limit future ability to properly air seal

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## The Top 10 Risky Rehabs

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



- Why is this risky?

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## The Top 10 Risky Rehabs

- Summary: Increasing Attic or Wall Insulation
  - You can'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

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## The Top 10 Risky Rehabs

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



- Why is this risky?

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## The Top 10 Risky Rehabs

- Winter Conditions – 5” to 8” vent to outdoors
  - Off-Cycle (cold chimney)
    - 0 to 50cfm
  - Off-Cycle (warm chimney)
    - 50 to 150 cfm
  - On-Cycle
    - Depending on furnace size = 150 to 600 cfm

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## The Top 10 Risky Rehabs

- Summary: Furnace Change-Out
  - This is probably the biggest single change you can make in an existing house.
  - It changes everything!
    - Major change in the air exchange rate (esp. mid-winter)
    - Major change in house pressures (lowers the NPP)
  - 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

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## The Top 10 Risky Rehabs

- Adding exhausting devices
  - range hoods
  - clothes dryers
  - central vacs
  - ASD (if not done well)
- Why is this risky?



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## 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

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## Passive Make-up Air Opening

- Make-up air: CFM provided by smooth ductwork\*

Duct Diameter	Atmospheric	Power-vented	Sealed
3 inches	15	35	50
4 inches	30	60	90
5 inches	45	100	140
6 inches	65	140	200
7 inches	85	190	270
8 inches	110 x 1	250 x 2	350
9 inches	140	320	450 x 1
10 inches	180 x 2	400	570

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## The Top 10 Risky Rehabs

- Summary: Adding Exhaust Devices
  - 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

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## The Top 10 Risky Rehabs

- Finishing or renovating basement space



- Why is this risky?

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## The Top 10 Risky Rehabs

- 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

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## The Top 10 Risky Rehabs

- Minnesota Challenges Basements
  - 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.

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## The Top 10 Risky Rehabs

- 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

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## The Top 10 Risky Rehabs

- Summary: Finishing or Renovating Basements
  - Just say no!
    - No reverse grading, landscape irrigation, rain gardens, 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")

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## The Top 10 Risky Rehabs

- Converting or renovating attic space



- Why is this Risky?

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## The Top 10 Risky Rehabs

- Summary: Converting/Renovating Attic Space
  - 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)

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## The Top 10 Risky Rehabs

- Changes in ventilation rates and/or equipment



- Why is this risky?

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## The Top 10 Risky Rehabs

- Summary: Changes in Ventilation
  - 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

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## The Top 10 Risky Rehabs

- Window replacement without proper air sealing and moisture management



- Why is this risky?

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## The Top 10 Risky Rehabs

- Summary: Window Replacement
  - 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

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## The Top 10 Risky Rehabs

- Exterior grade changes
  - Reverse grade
  - Landscape irrigation
  - Hose bibs
  - Rain gardens



- Why is this risky?

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## The Top 10 Risky Rehabs

- Summary: Exterior Grade Changes
  - 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, beds, edgers
    - avoid trees and bushes adjacent to foundation
  - Water storage/recharge must be low and remote
    - ideally below the footing drain level

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## Developing a Rehab Strategy Prescriptive vs. Performance

- Prescriptive vs. Performance Approaches
- A Modified Prescriptive Approach
  - Green Light
  - Yellow Light
  - Red Light
- A Systems-Guide 5 Step Plan

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## Developing a Rehab Strategy Prescriptive vs. Performance

- Prescriptive-Based Approach
  - Simpler to implement; easier to verify
  - Frequently the process is visually-driven
  - Difficult to deal with multiple items and system interactions
  - Desired outcomes may or may not be achieved
- Performance-Based Approach
  - 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

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## Developing a Rehab Strategy 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

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## Developing a Rehab Strategy Prescriptive vs. Performance

- 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.

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## Developing a Rehab Strategy Prescriptive vs. Performance

- 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.

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## Developing a Rehab Strategy A Modified Prescriptive Approach

- Always begin by "testing in" to identify
  - Any preexisting conditions
  - Establish baseline performance
- Then move to a "green light, yellow light, or red light" approach based on level of impact.

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## A Modified Prescriptive Approach

- What does "testing in" mean?
  - Blower door (multi-point test)
  - Zonal Pressure Mapping
  - Worst Case Combustion Zone Depressurization\*
  - CO Production (all gas appliances)\*
  - Fan flows\*
  - Moisture assessment (surfaces and cavities)
    - visual with surface scan and pin meter
  - Short-term radon\*

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## 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

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## A Modified Prescriptive Approach

	Green	Yellow	Red
■ Test in	X	X	X
■ Plan			X
■ Verify			X
■ Test out		X	X
■ Monitor		?	X

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## A Modified Prescriptive Approach

- Once testing has provided an "all clear" from serious pre-existing conditions, a "green light" can be given for items with low risk due to limited systems interactions and low HAM impacts.
- 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

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## A Modified Prescriptive Approach

- A "yellow light" requires caution for items that might have some risk due to system interactions below them on the strategic order and/or possible HAM impacts.
  - These may require additional data or "testing out".
- Potential "Yellow Light" Items
  - Adding dehumidification
  - Adding central air filtration
  - Adding balanced ventilation
  - Adding active subslab depressurization (ASD)

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## A Modified Prescriptive Approach

- A "red light" means stop and fully evaluate items with likely system interactions and significant HAM impacts
  - These will require careful planning, oversight and "testing out".
- Potential "Red Light" Items
  - Any item that significantly changes
    - House tightness or pressures
    - Combustion venting
    - Exhaust flows
    - Duct tightness
    - Insulation levels

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## A Modified Prescriptive Approach

- Specific 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

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## A Systems-Guided 5 Step Plan

- 1. "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

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## A Systems-Guided 5 Step Plan

- 2. Create 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

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## A Systems-Guided 5 Step Plan

- 3. 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

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## A Systems-Guided 5 Step Plan

- 4. 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?

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## A Systems-Guided 5 Step Plan

- 5. 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 efficacy and efficiency over time.

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## 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

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## In Conclusion

- We can use a modified prescriptive approach.
  - "green light" is a go
  - "yellow light" is a caution; need more info or testing
  - "red light" demands a systems-guide approach
- A Systems-Guided 5 Step Plan for green rehab.
  - test in,
  - develop plan,
  - field verify,
  - test out, and
  - monitor.

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## 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!

\* This concludes the American Institute of Architects Continuing Education Program.

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## Reducing Your Risk with Green: A Systems-Guided Approach

Thank you for your attention and participation!

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