MIT CONCRETE SUSTAINABILITY HUB

Quantifying building sustainability and resilience

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Infrastructure Working Group
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Sustainability: we want our world to last

These are interconnected systems

Measuring performance of systems

Functional

Environmental

Economic

Social

Measuring absolute sustainability is difficult

We tend to measure trends:
Are we moving towards or away from sustainability?

Measuring performance of systems

Functional

Environmental

Economic

Social

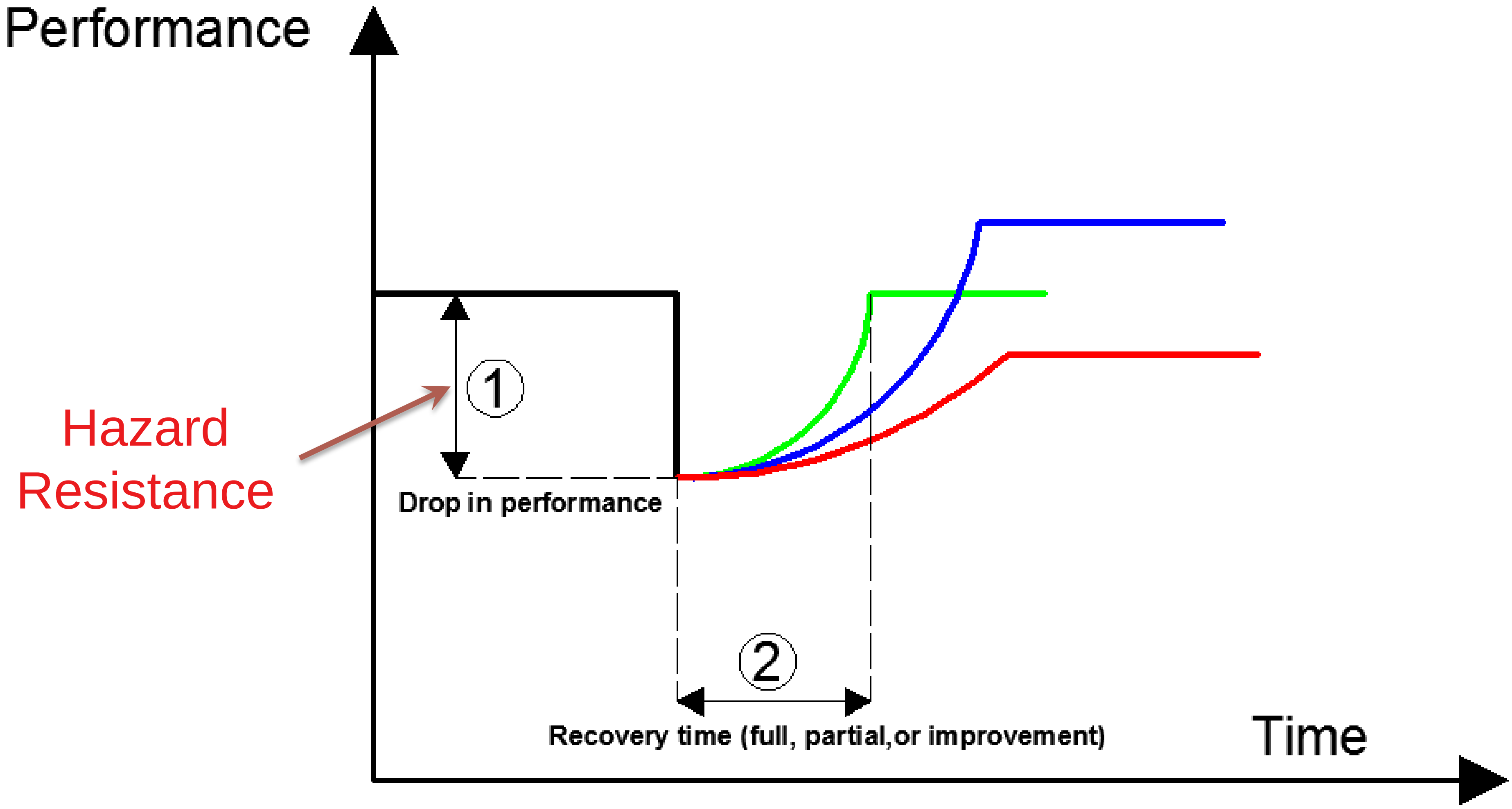
We can measure performance during conditions that are:

- Typical/intended
- Atypical/unintended

Resilience: a system's response to problems

Resilience: a system's response to problems

Hazard Resistance



Buildings are integral to sustainability

Quantifying sustainability performance is essential for progress

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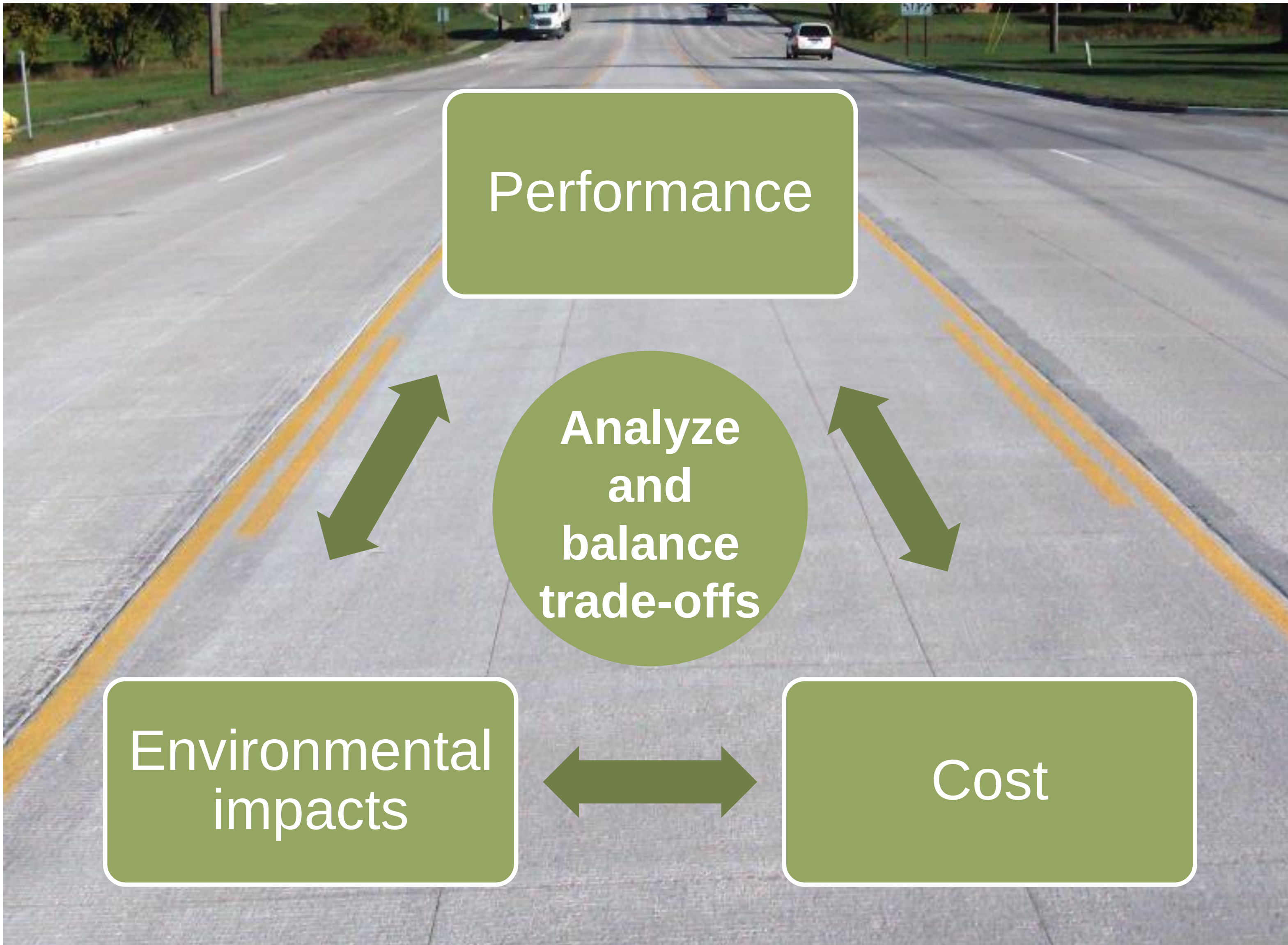
Infrastructure & buildings decisions involve trade-offs



A life cycle perspective is key for sustainability and resilience decisions

Multiple mechanisms for reducing environmental impact and cost

Materials Production

- Use recycled content
- Reduce energy
- Improve performance

Design & Construction

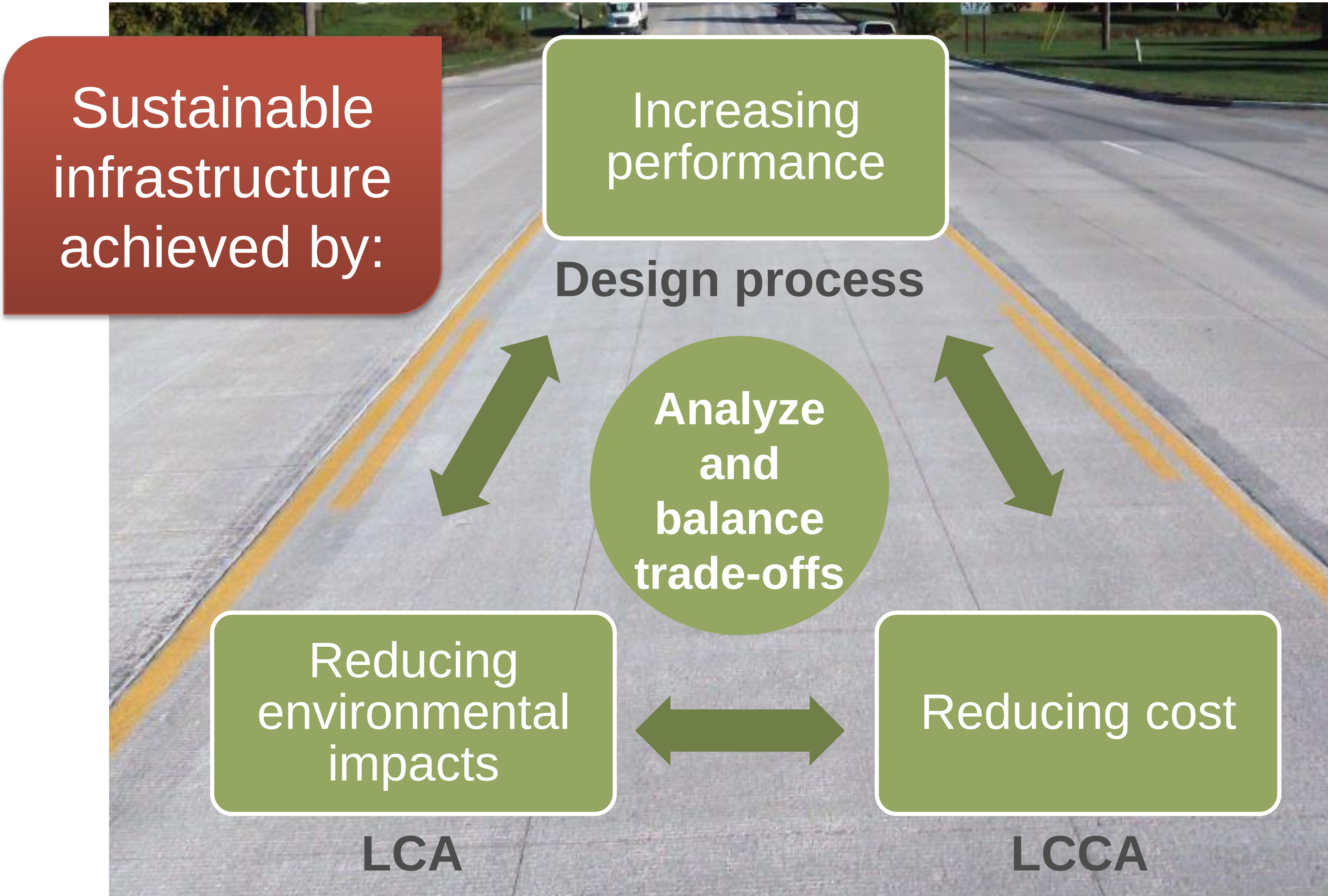
- Use less (i.e., stronger) material
- Create longer-lasting designs

Use

- Reduce energy consumption
- Reduce heat island effects

End-of-Life

- Enable material recovery
- Plan for component reuse

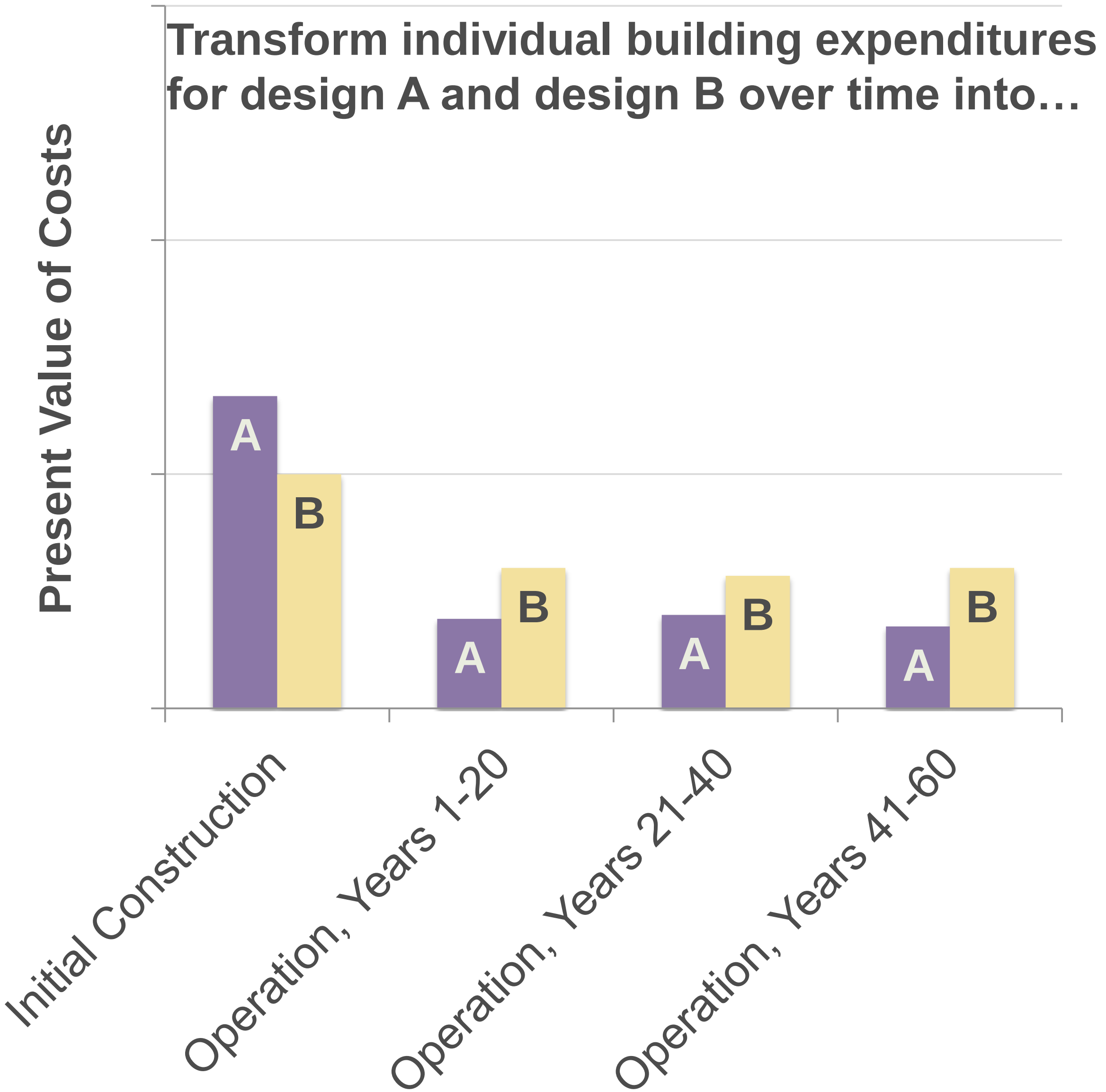

Sustainable infrastructure achieved by:
Increasing performance
Design process
Analyze and balance trade-offs
Reducing environmental impacts
LCA
Reducing cost
LCCA

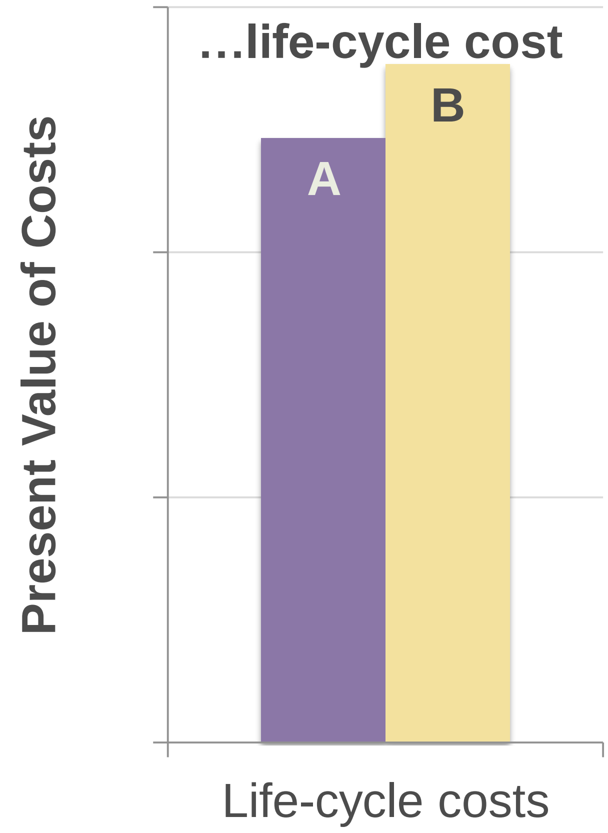
Which is preferred from a life cycle perspective?

Lower design standard	Higher design standard
Same location	Same location
Same appearance	Same appearance
Lower initial cost	Higher initial cost
Likely worse energy performance	Likely better energy performance
Worse hazard resistance	Better hazard resistance

Quantitative information is lacking on economic and environmental benefits of sustainable and resilient construction

LCCA – Life-cycle cost analysis: Method for evaluating total costs of ownership





Life cycle cost analysis with hazard resistance

Build + **Energy Use** + **Wear & Tear** + **Hazard Repair** + **End of Life**

Raw materials, labor, equipment, & energy

Electricity, gas, and oil consumption throughout life

Painting, windows, siding, etc.

Combines probability of hazard with damage from hazard

Waste and recycling, labor, equipment, & energy

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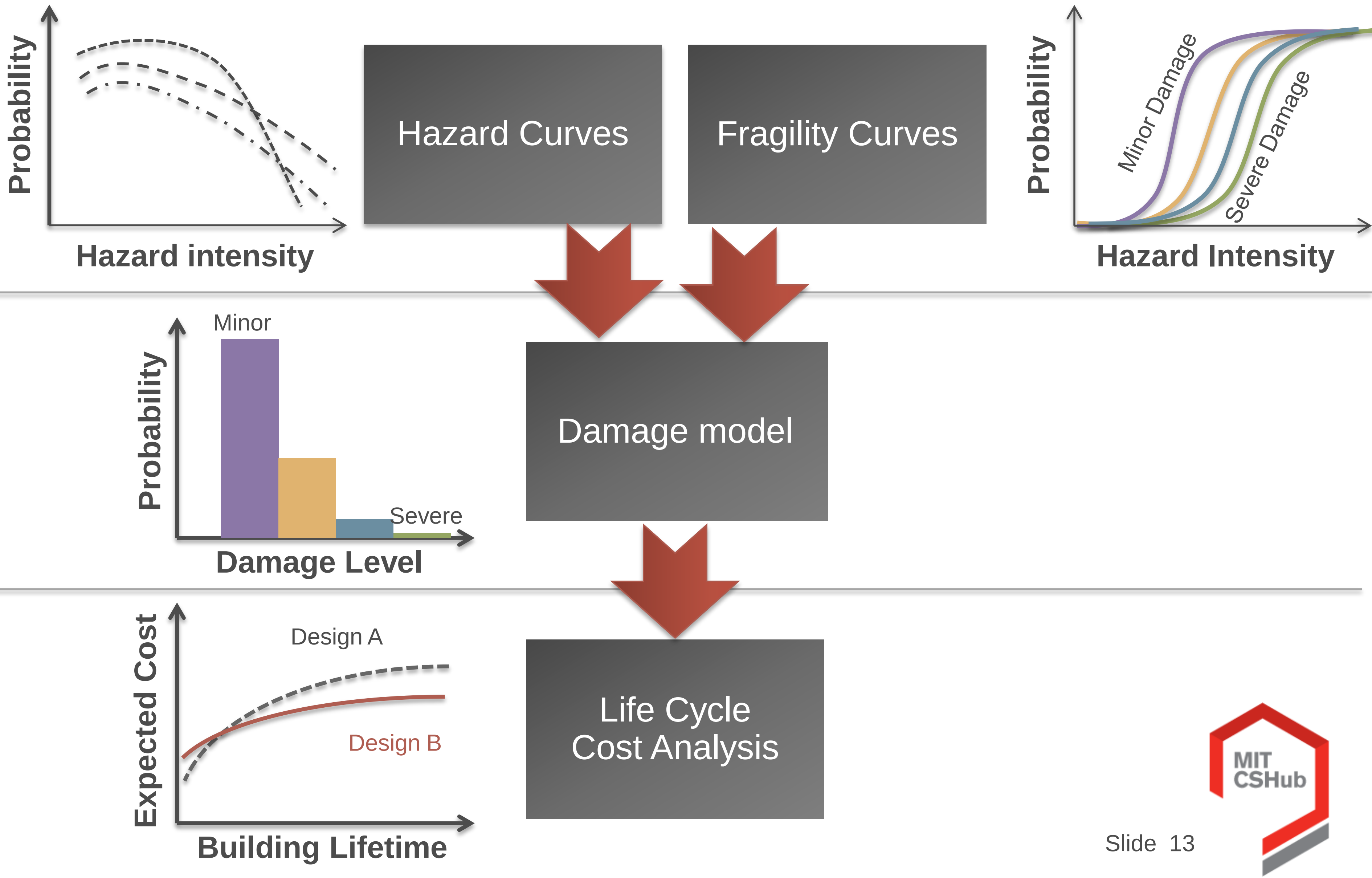
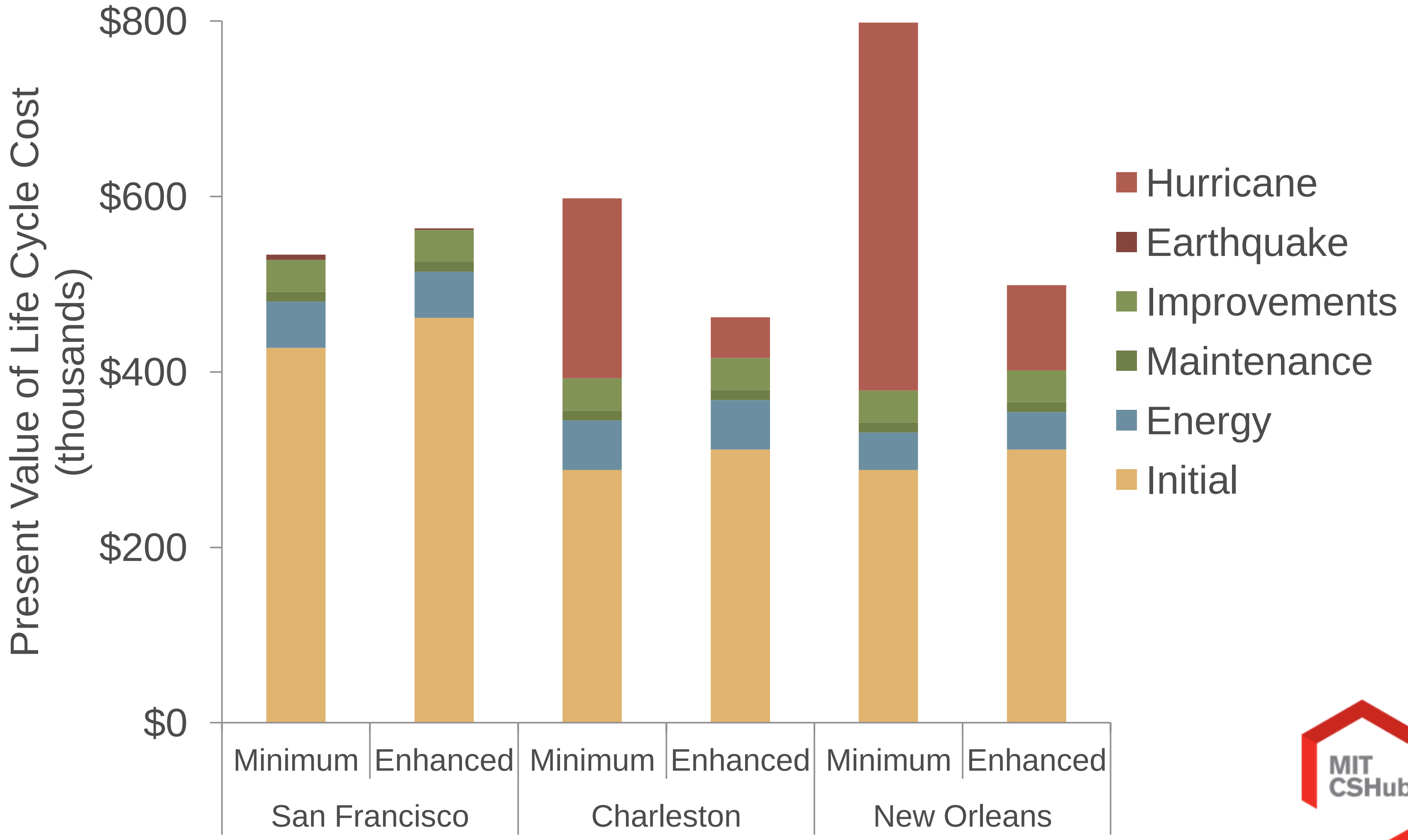
Probabilistic Hazard Repair Estimation



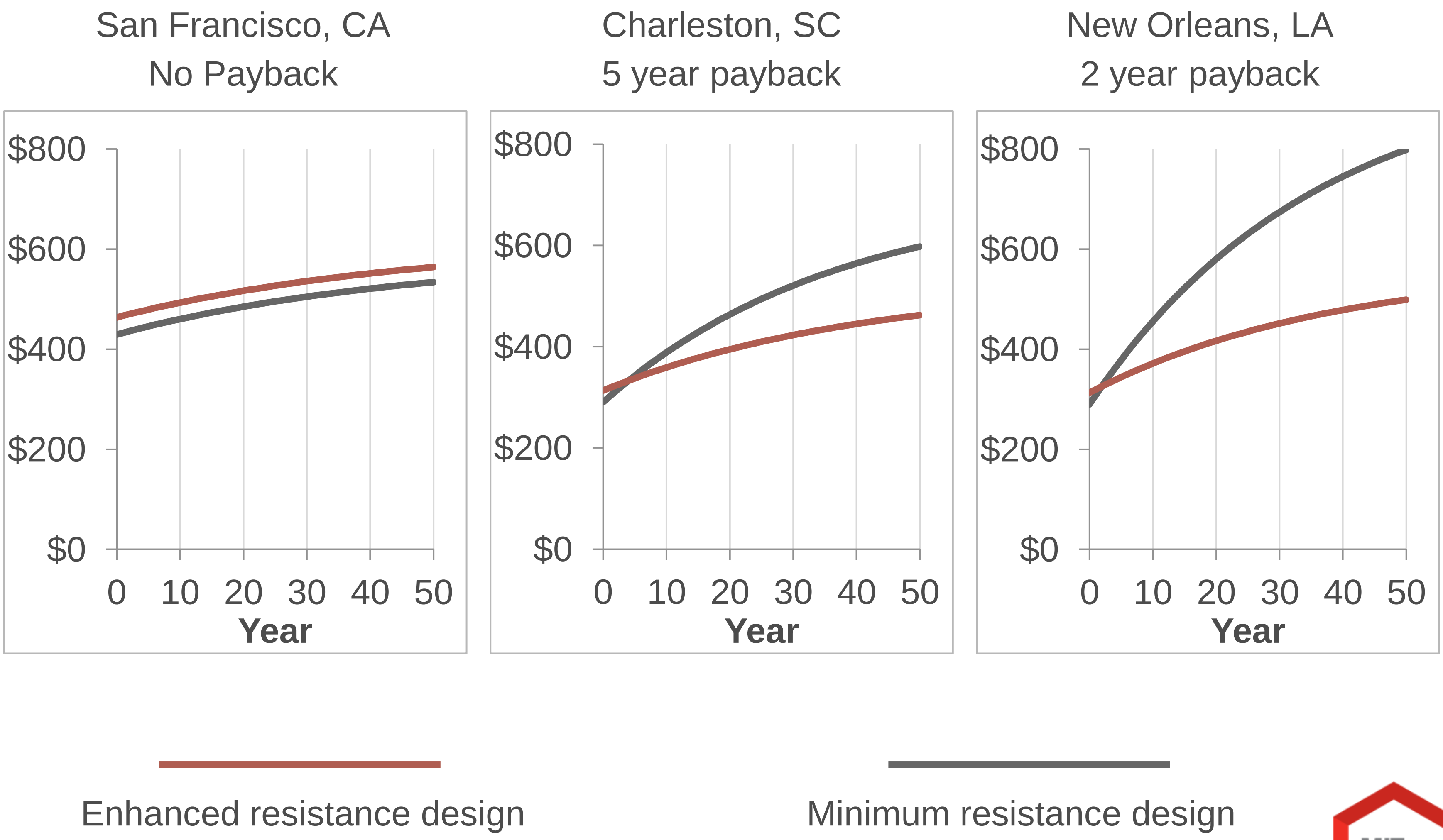
Key finding: life cycle perspective is important

LCC varies by location, discount rate, and hazard resistance

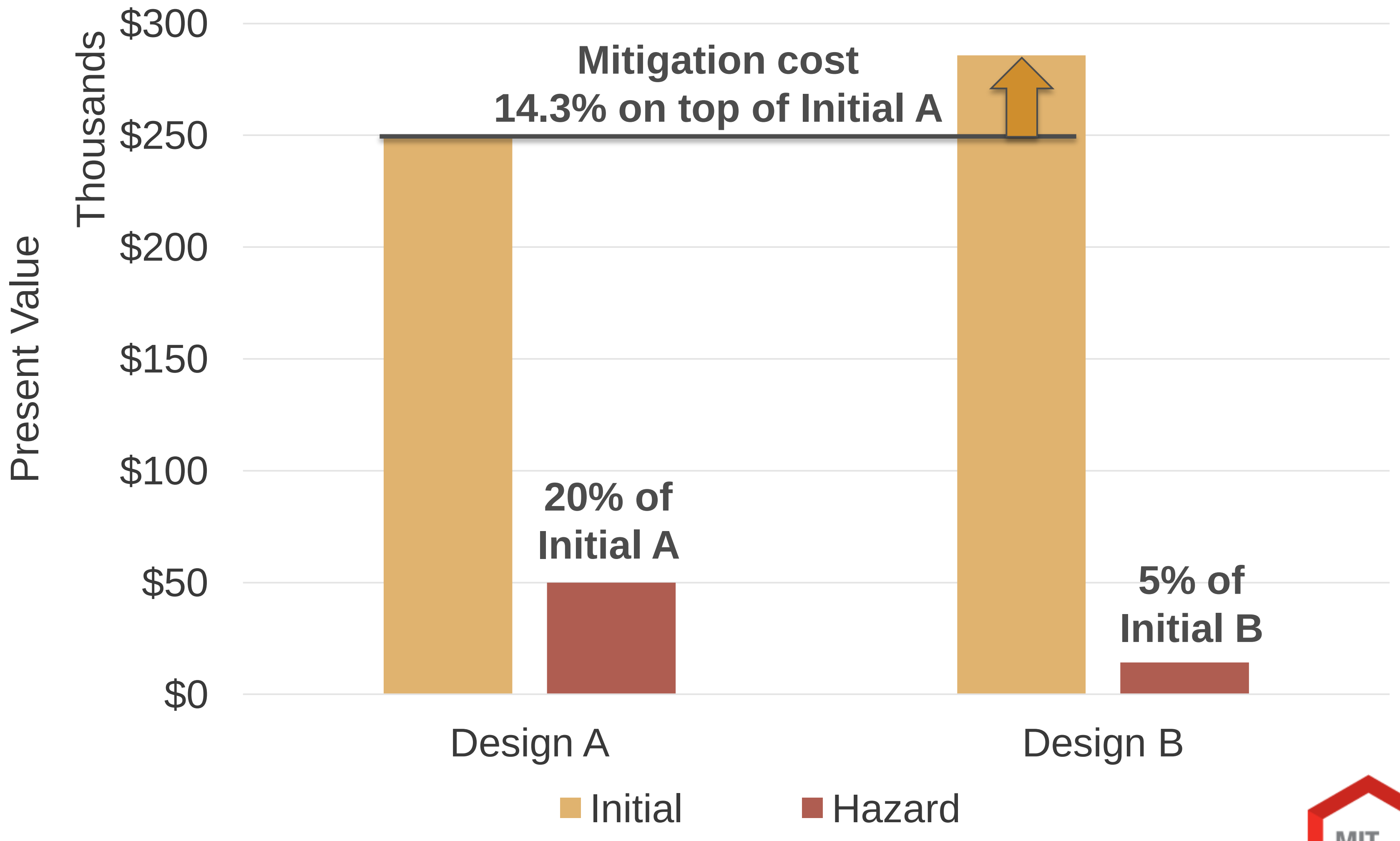


2 story, 1800sf, wood frame house

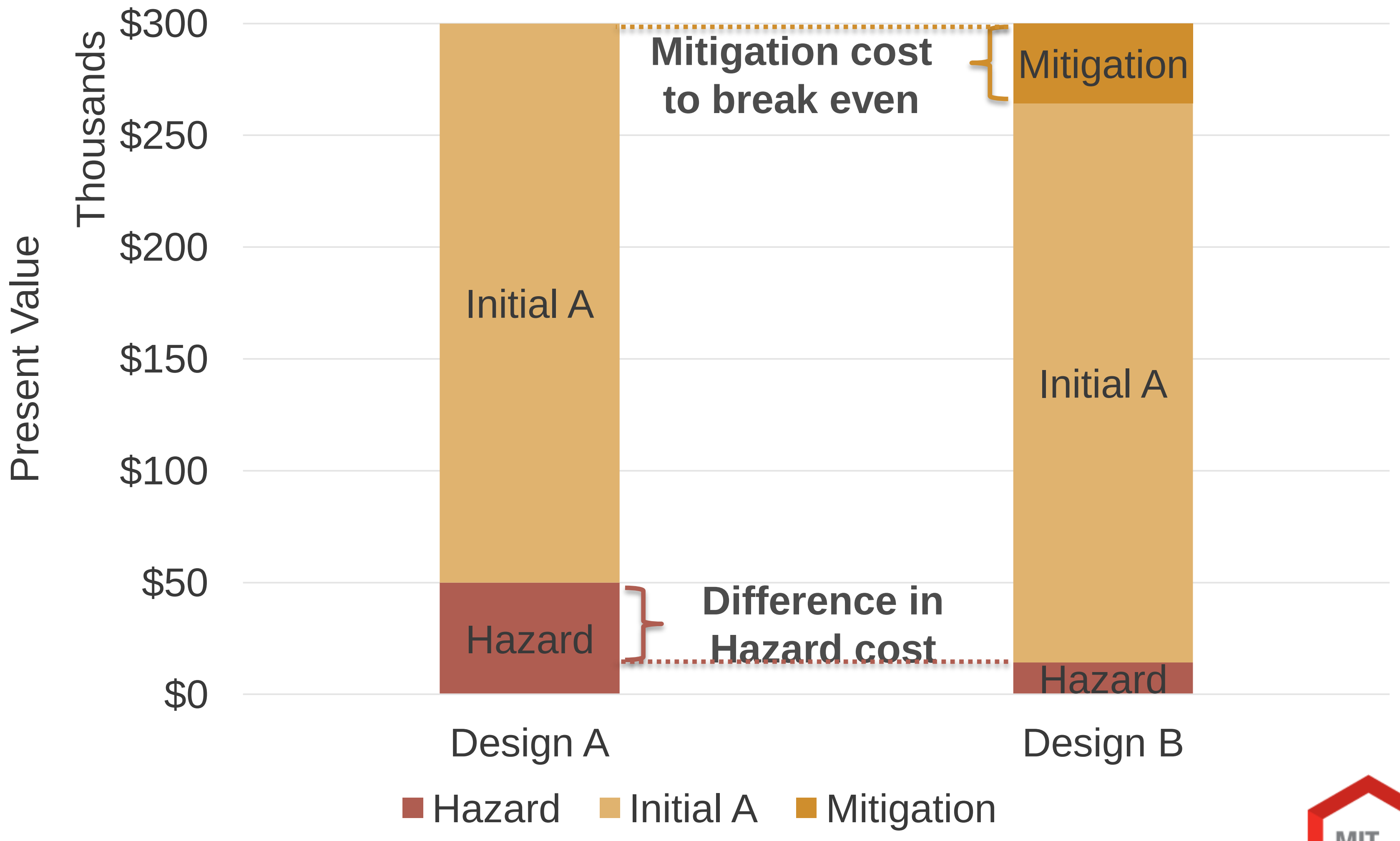
Probabilistic LCCA approach enables expected payback period



If $250k to build standard house, how much more would you pay for hazard resistance?



How much mitigation can you afford in order to break-even across life cycle?



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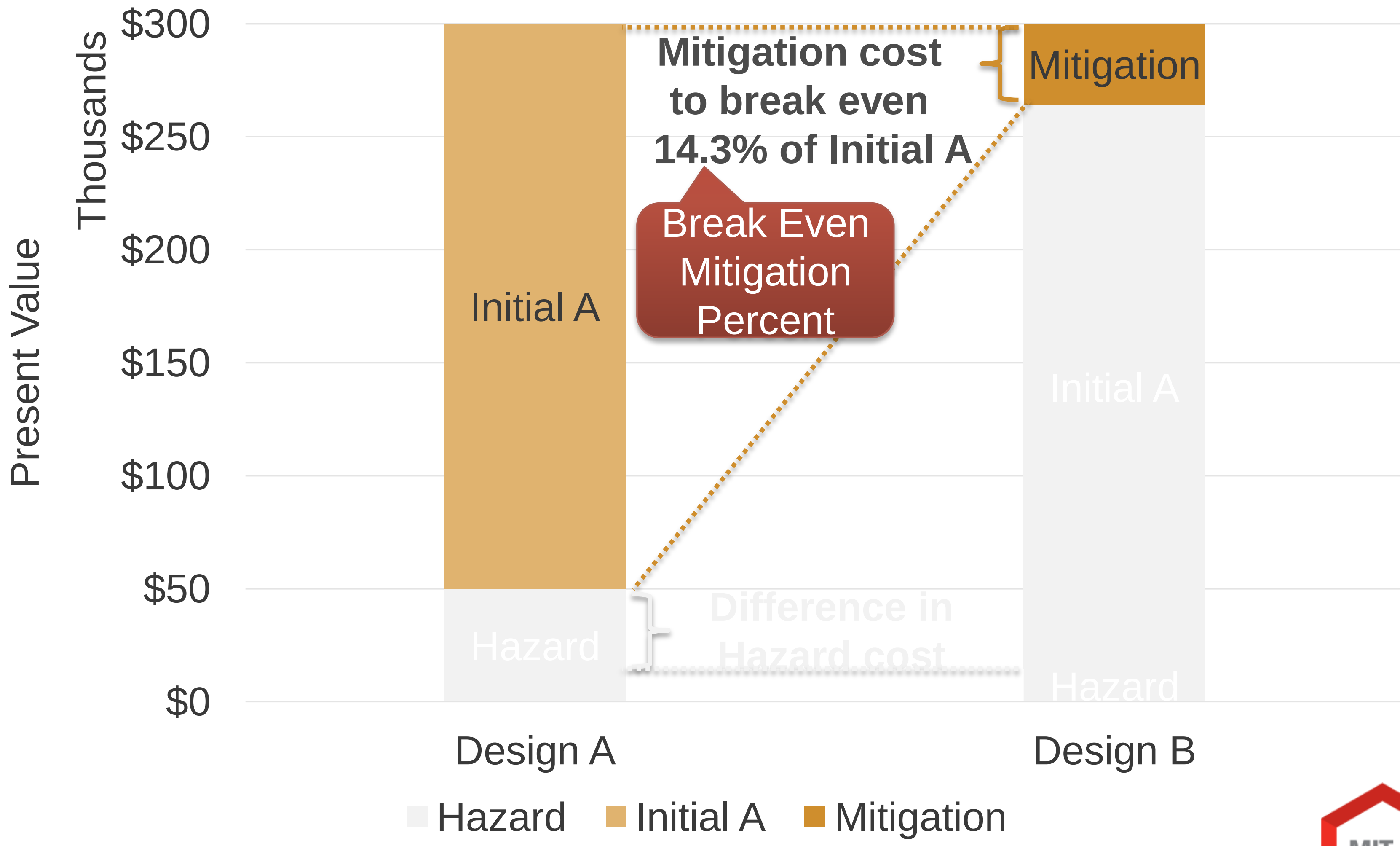
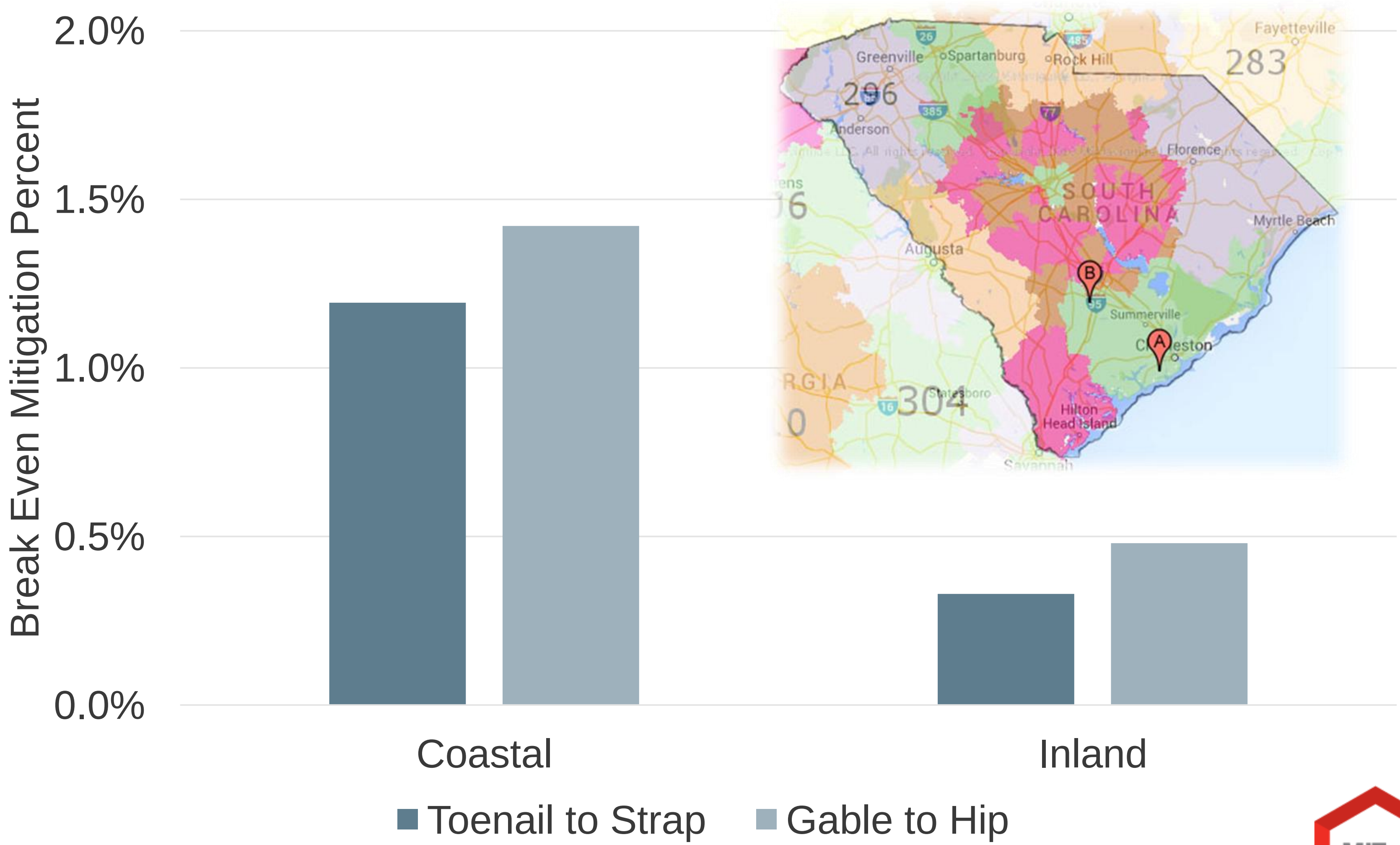
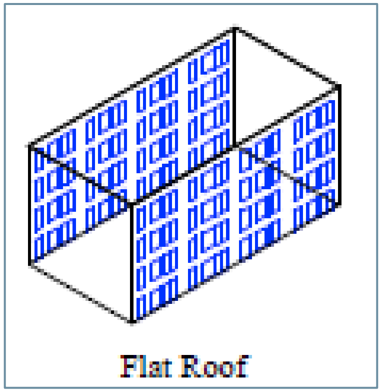


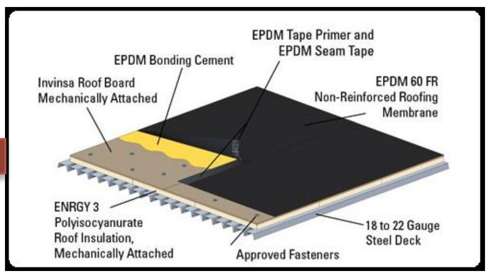
Example: South Carolina wood frame home
Comparing mitigation options

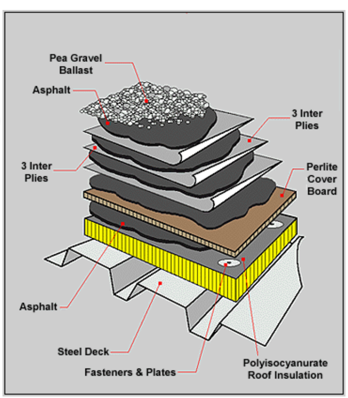


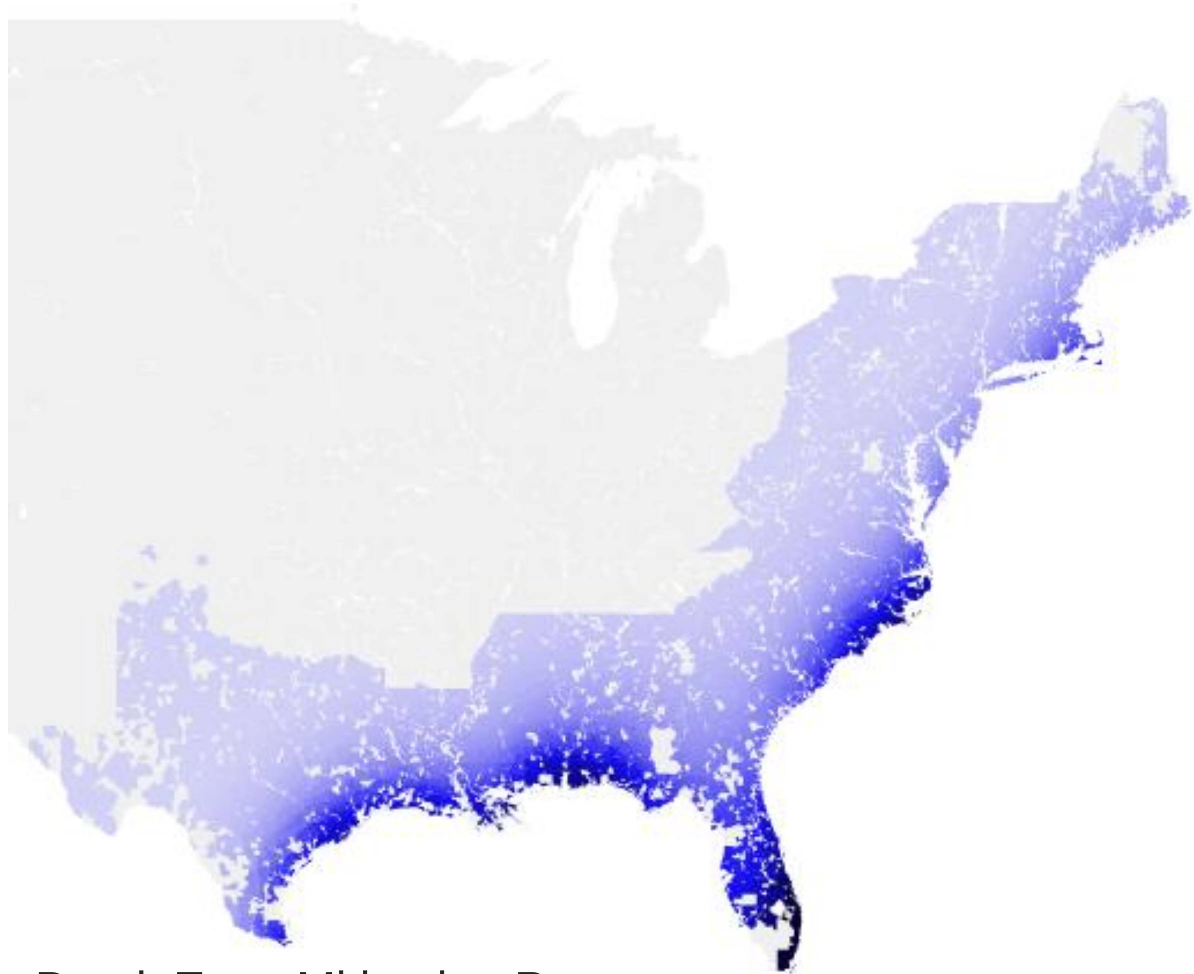
Example: Mid-rise non-engineered masonry

Break Even Mitigation Percent for enhanced roof









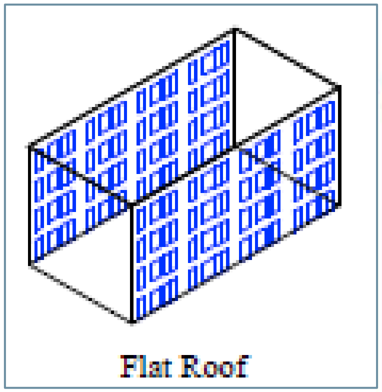
Break Even Mitigation Percent

0.00	1.50	3.00	%

Based on FEMA Benefit Cost Analysis tool

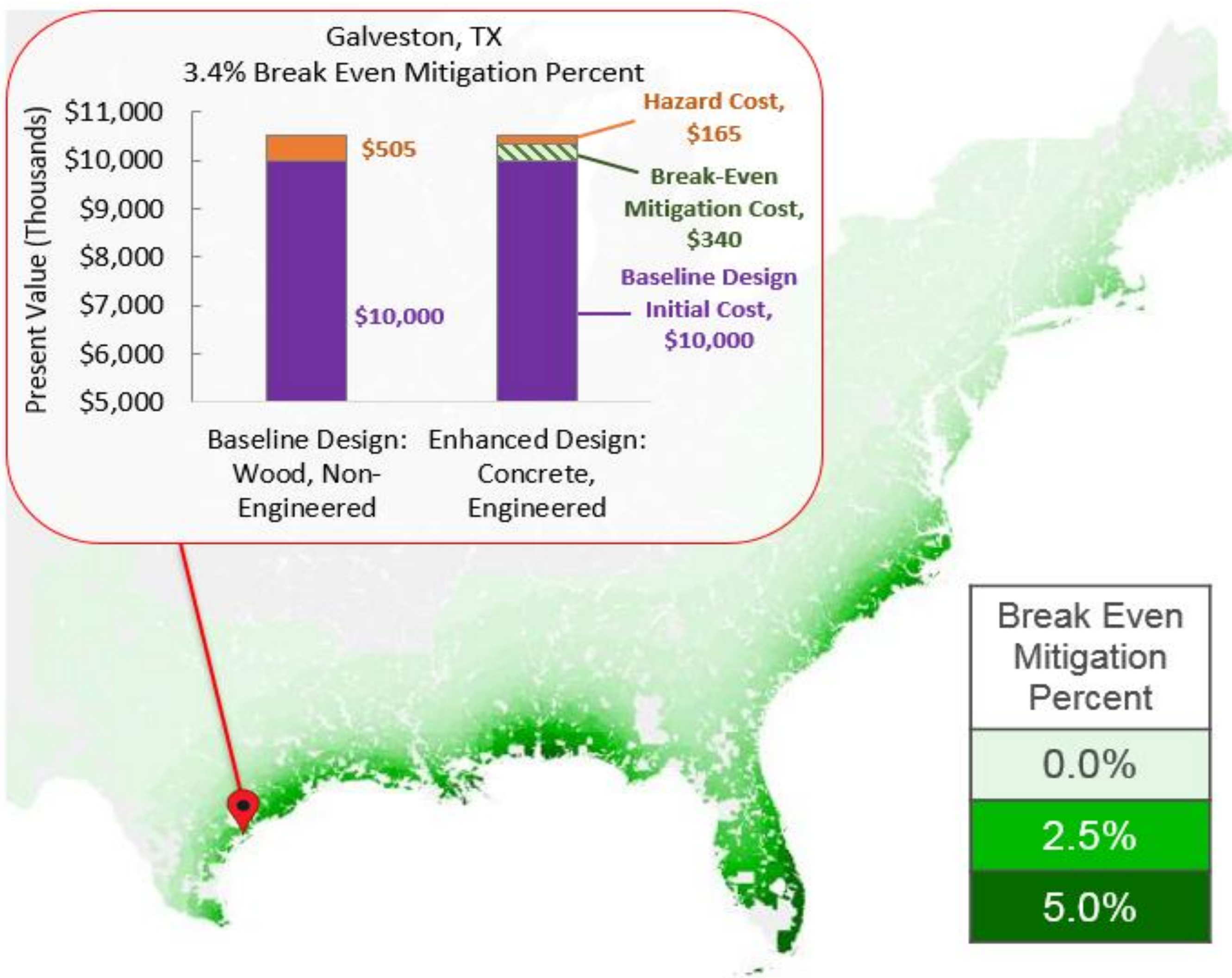
Example: Mid-rise change in structure

Non-engineered wood to Engineered concrete



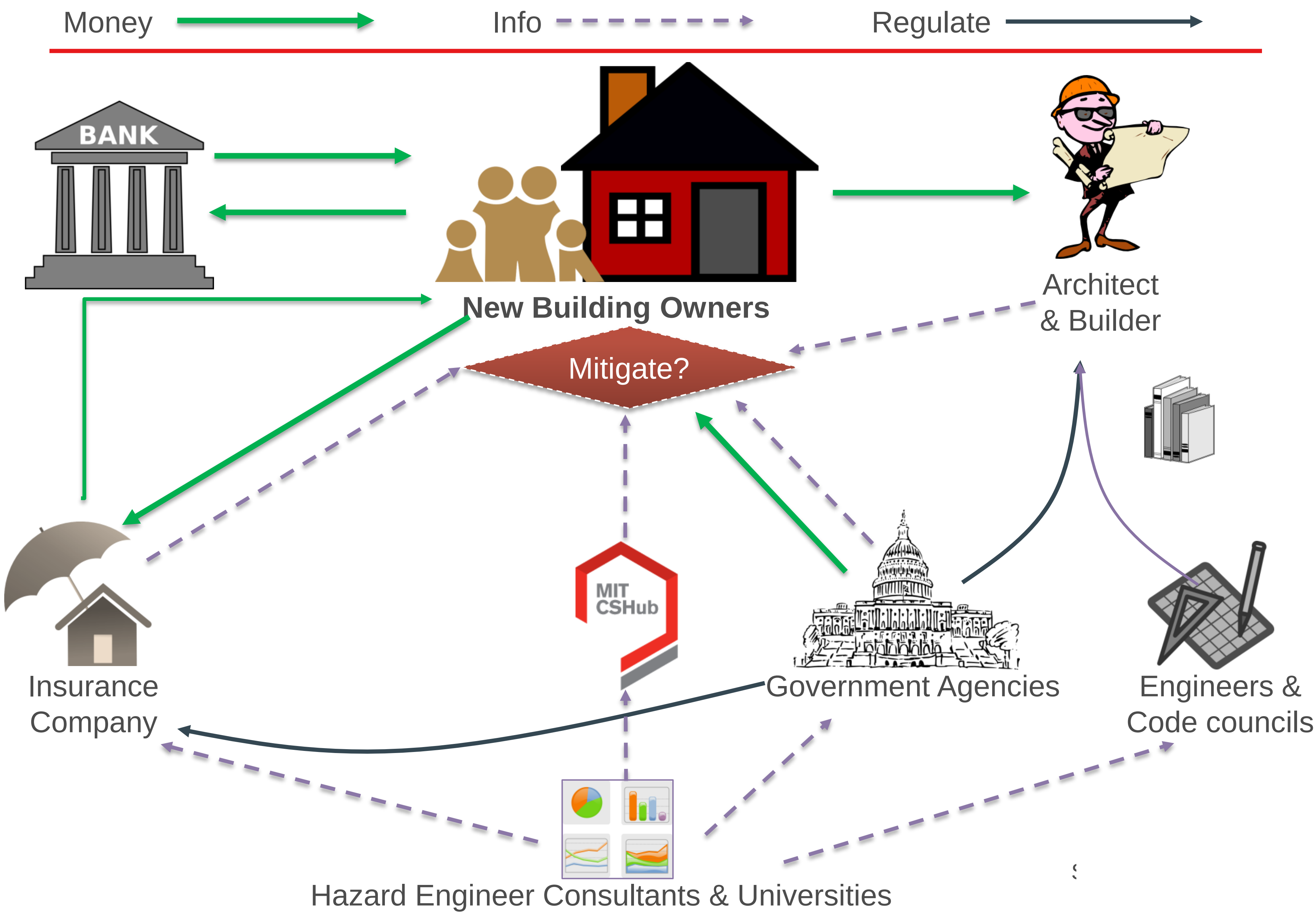
Non-engineered wood

Engineered concrete

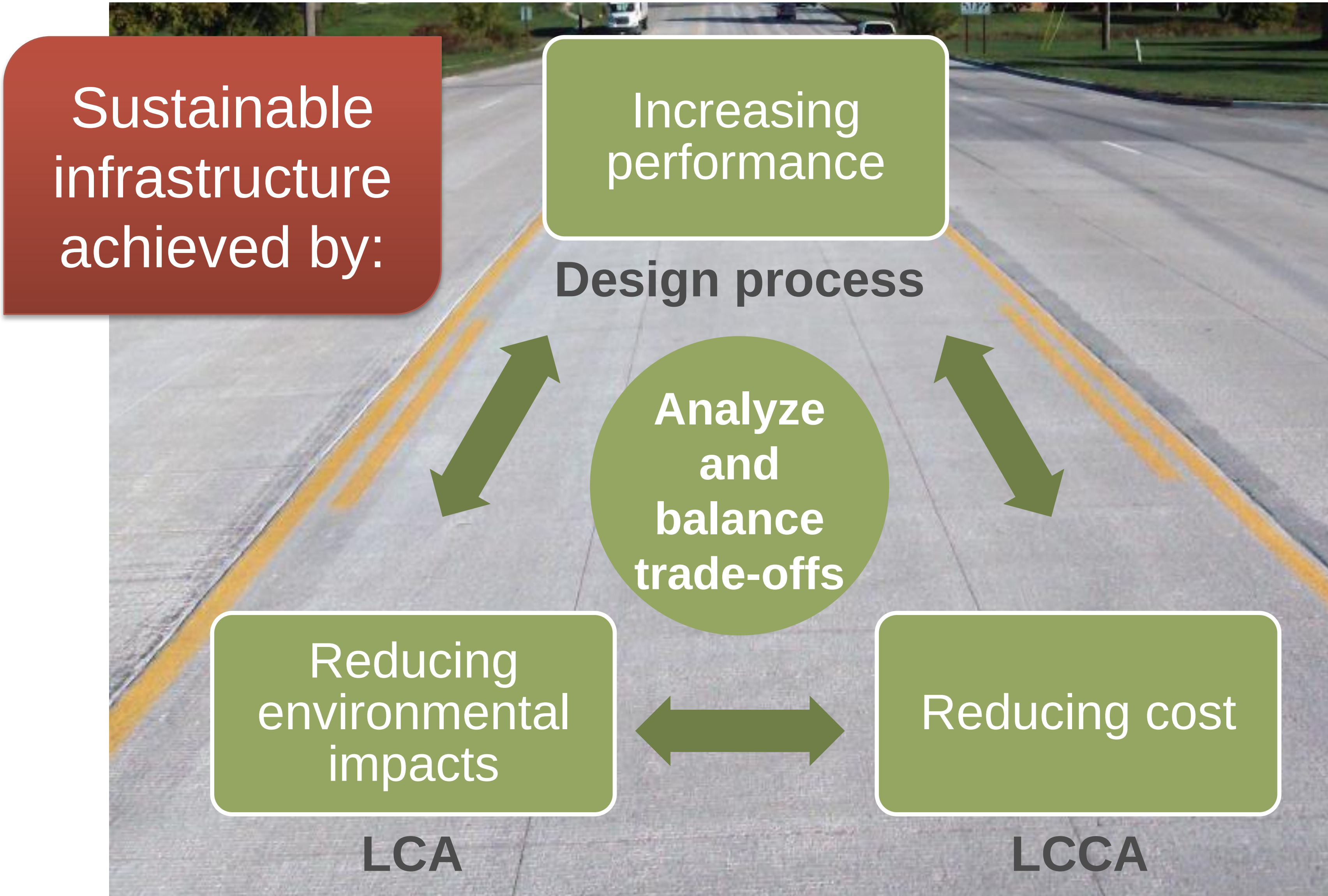


Based on FEMA Benefit Cost Analysis tool

Mitigation decisions involve many stakeholders



CSHub contribution: quantifying sustainability and resilience performance



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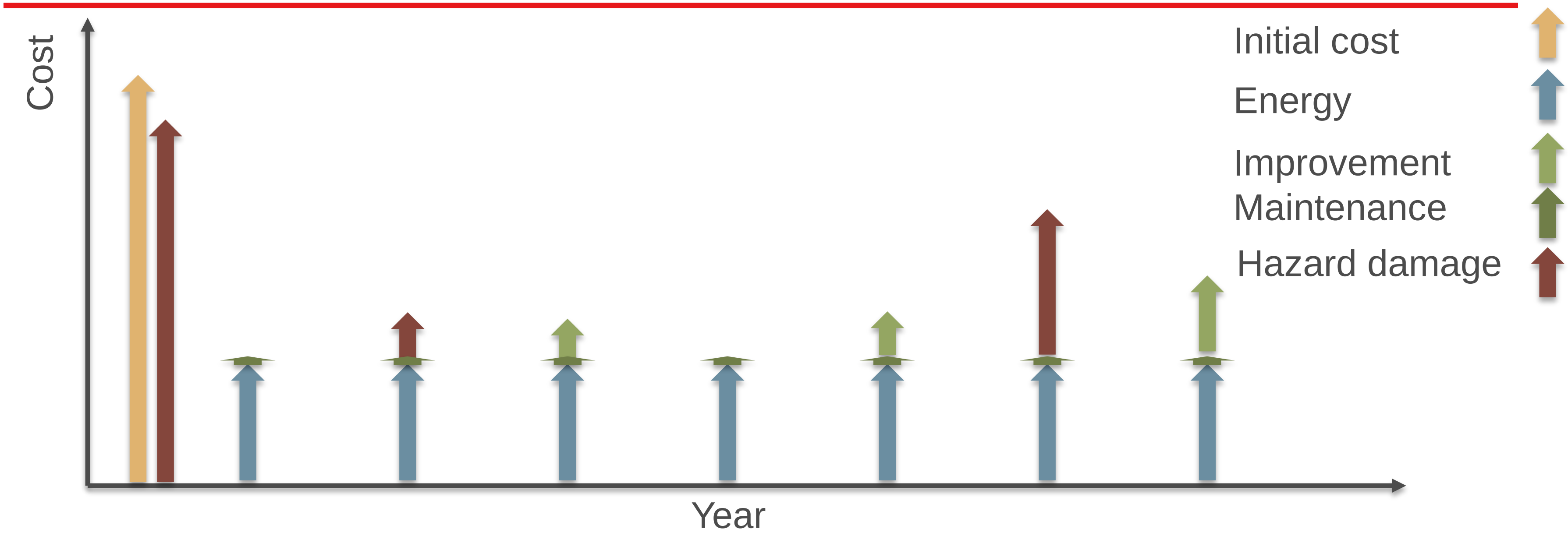
More information available at:

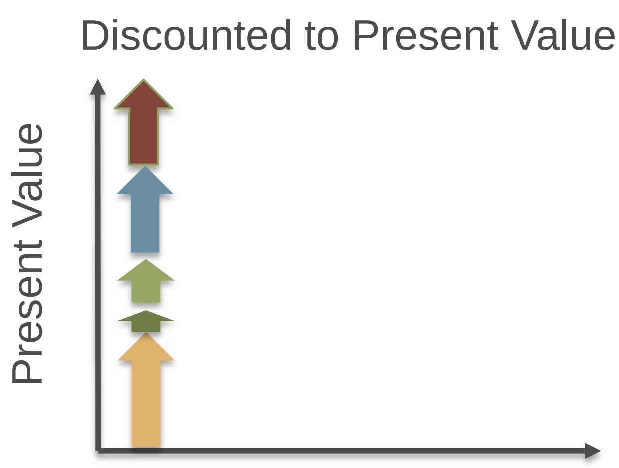
http://cshub.mit.edu/

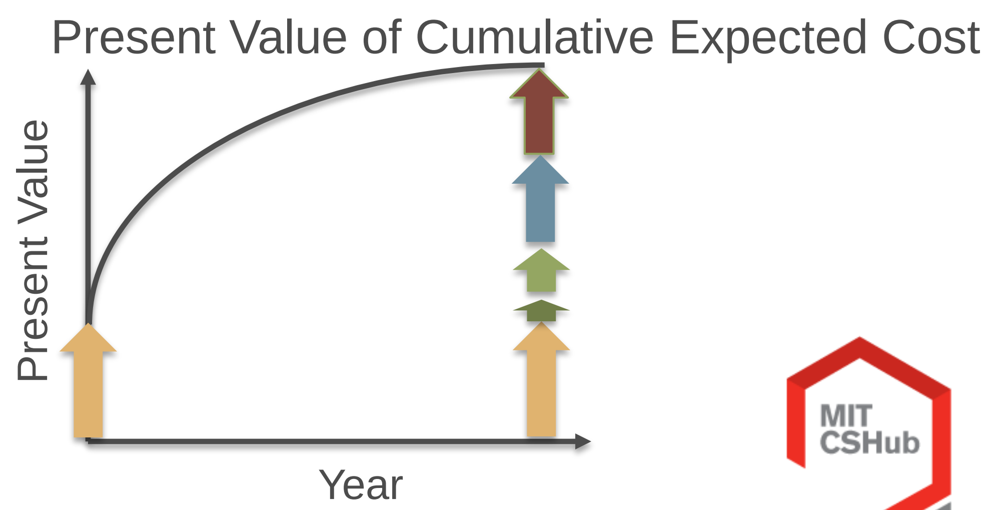
cshub@mit.edu

Back-up Slides

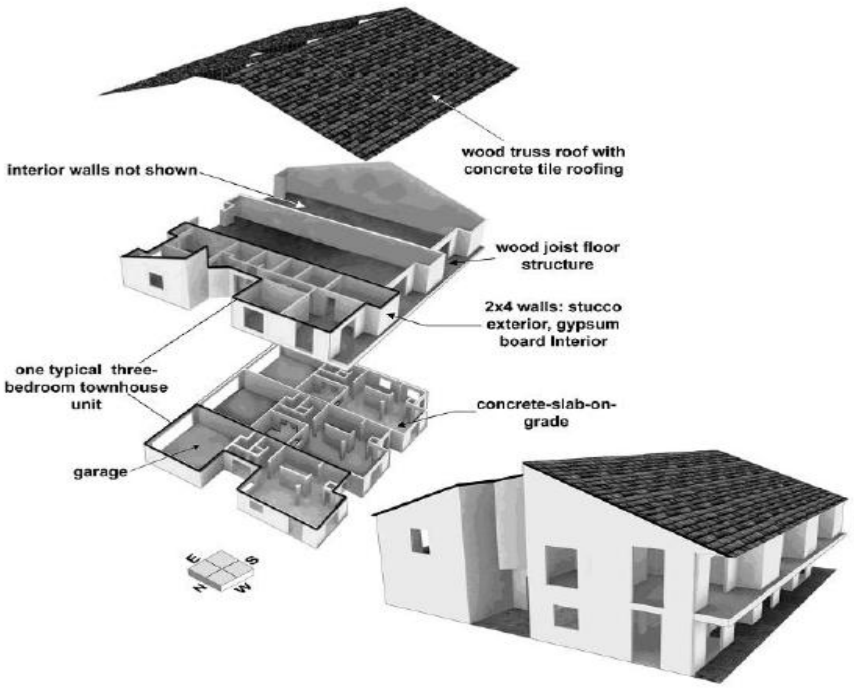
Cost representations across life cycle







Case study: Single family wood frame



CUREE-Caltech Woodframe Project

Two level of resistance:

- Minimum code compliant
- Enhanced

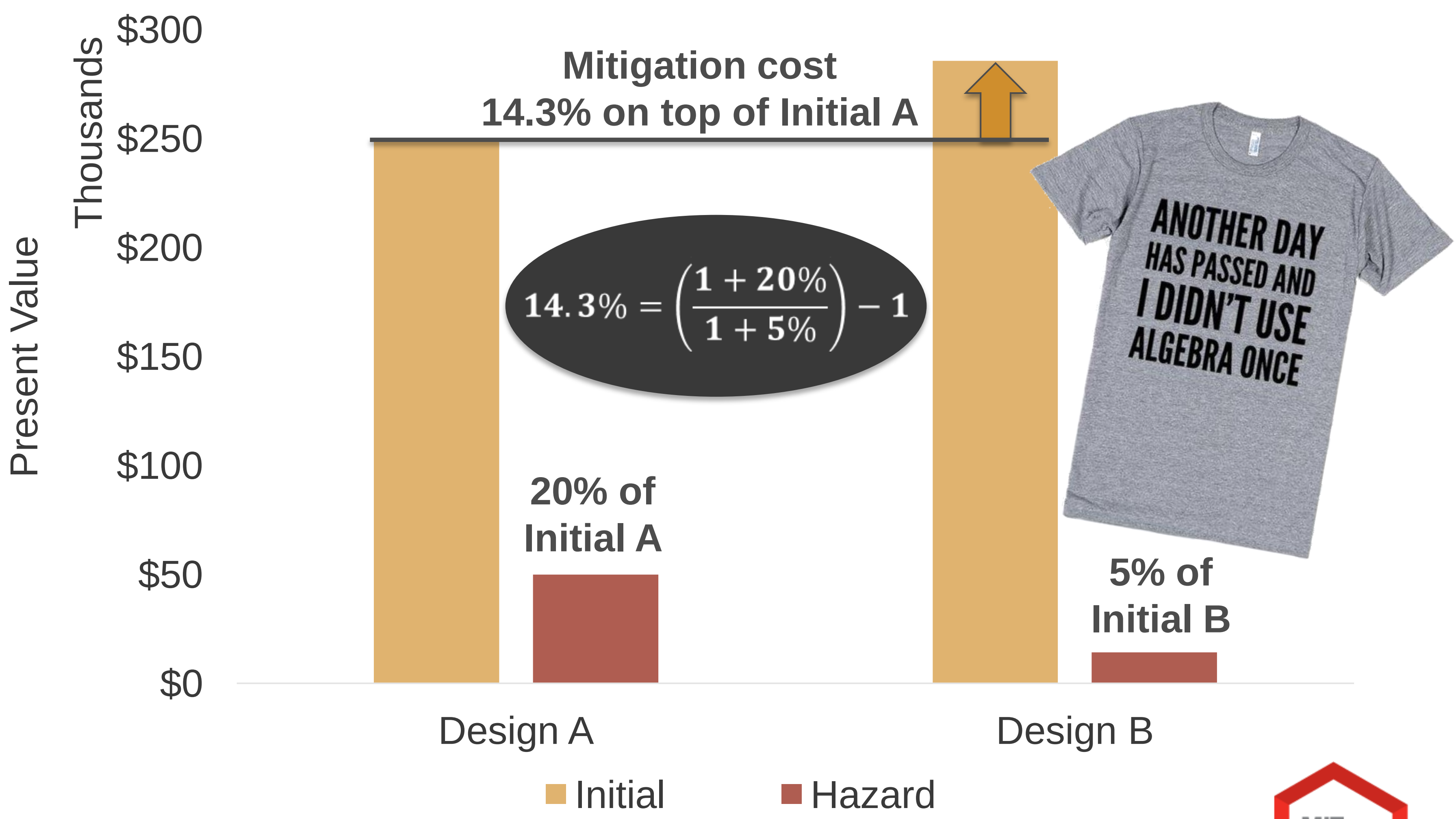
Seismic enhancements:

- reduce nailing spacing in the shear walls

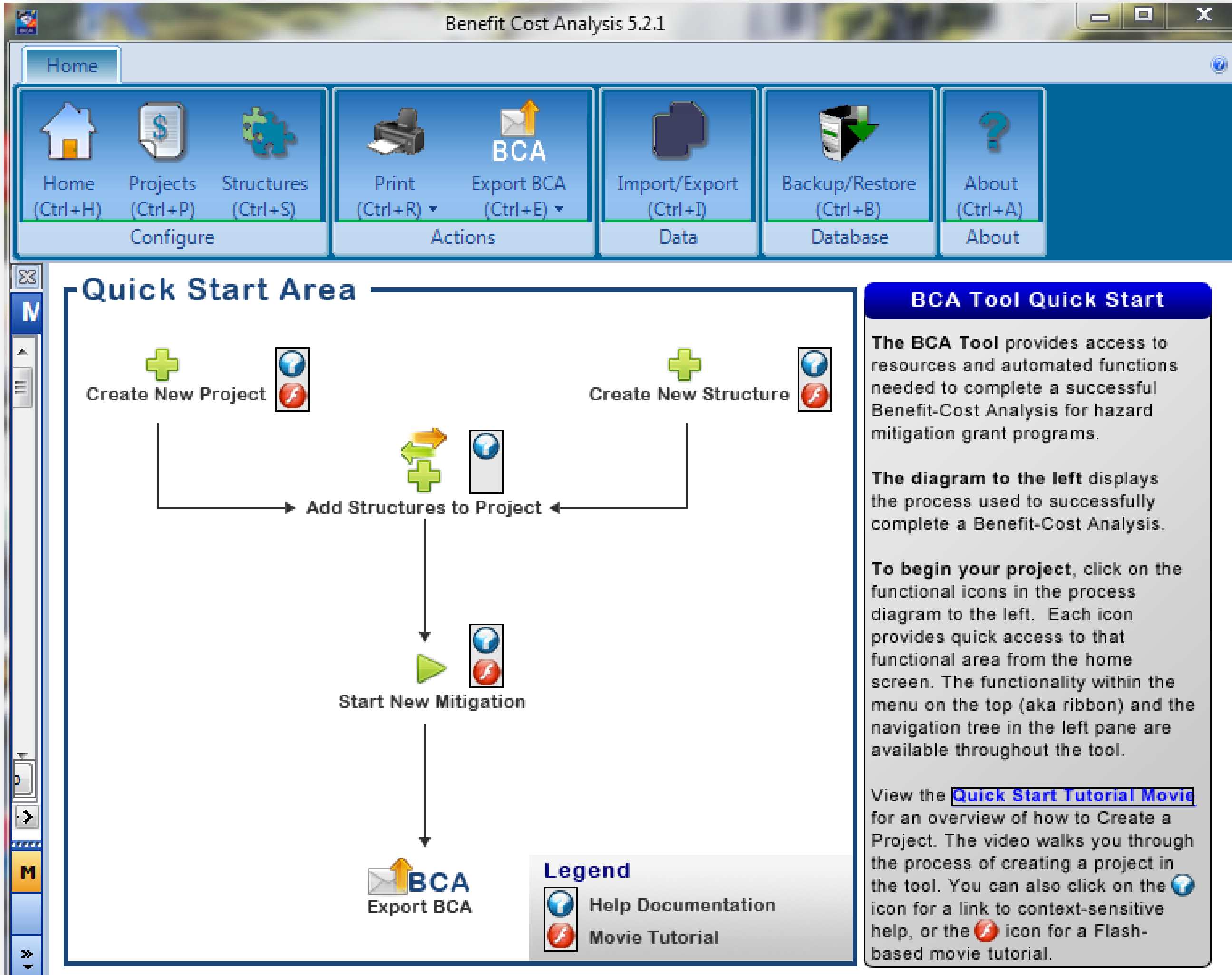
Hurricane enhancements:

- Increasing the resistance of roof shingle
- Stronger nails for roof panels
- Annealed glass thickens
- Stronger hurricane clip for roof to wall connection

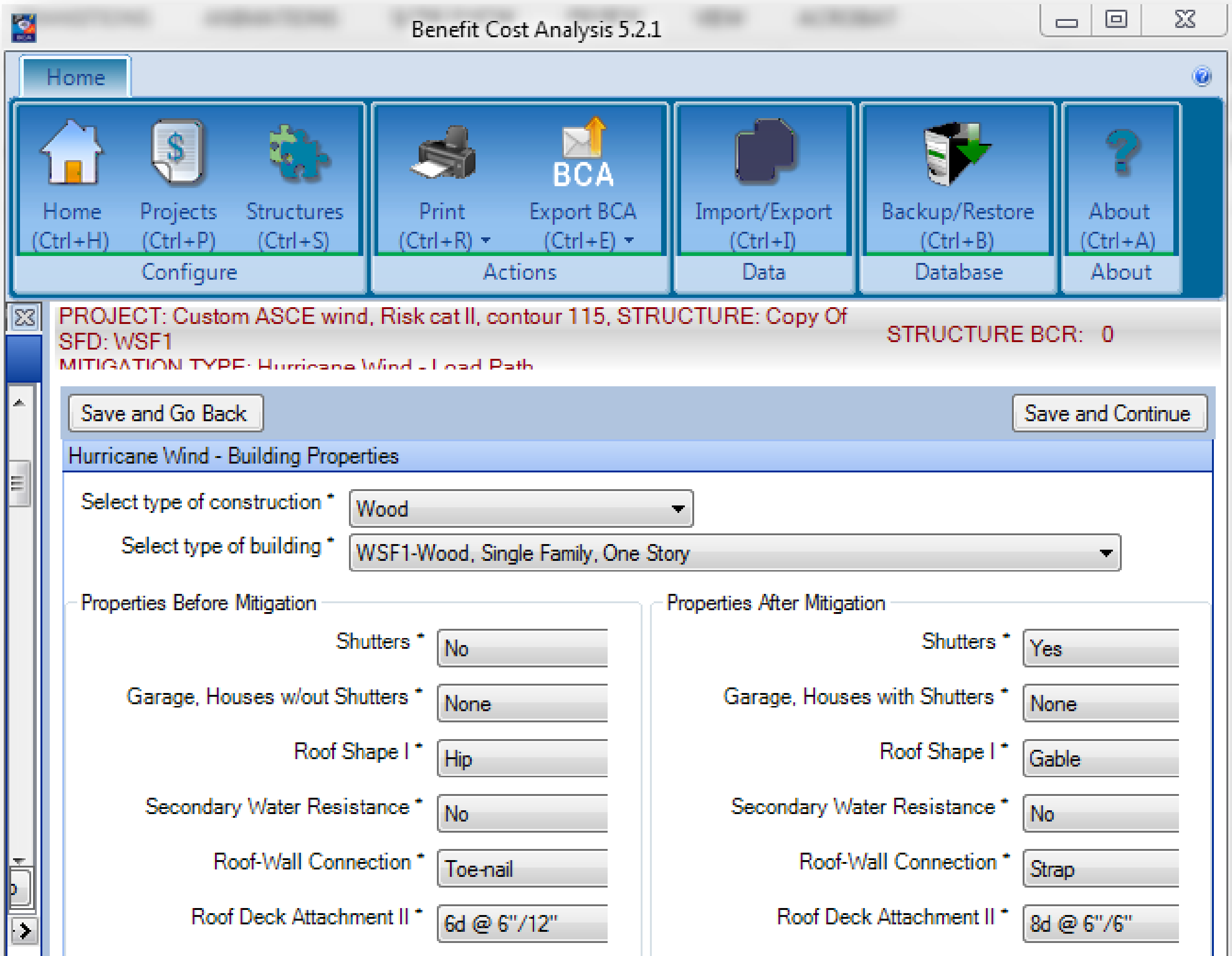
How to calculate Break Even Mitigation Percent



FEMA Benefit Cost Analysis tool

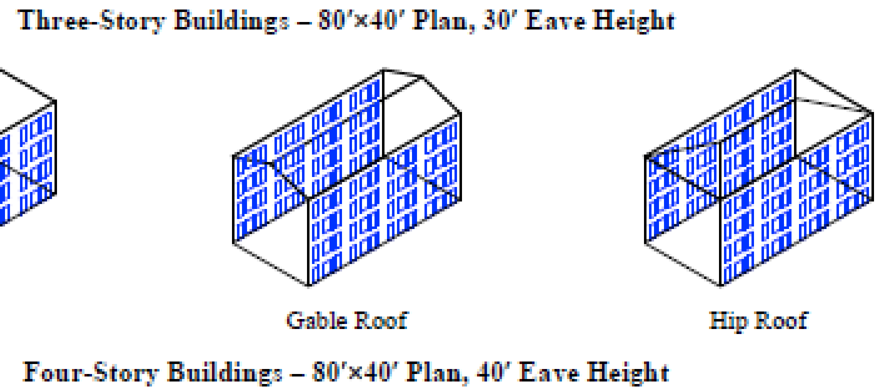


Compare life-cycle cost of hazards



Embedded FEMA buildings types

- Manufactured home
- Wood & masonry single family
- Wood, masonry, concrete multi-family
  - Engineered / non-engineered
- Strip mall
- Industrial/warehouse/factory
- “Commercial”



Hurricane mitigation examples

- Shutters
- Roof:
  - Type: Gable vs Hip vs Flat
  - Cover: Built-up vs EPDM
  - Roof-wall connection: Toe-nail vs strap
  - Spacing of nails in roof-deck attachment
- Masonry reinforced
- Window area (Low, Med, High)