

Resilient & Sustainable Design Implications of Urbanization on Low-Slope Roofing

Course Number EX301

Thursday, June 21, 2018, 10:30 to 11:30am

1 Learning Unit

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Speakers List

- Thomas J Taylor, PhD
 - Building & Roofing Science, GAF

Course / Learning Objectives

1. Discuss net-zero construction, wind uplift resistance, and low slope roofing trends, including rooftop energy generation, green and blue roofs, and water-harvesting capabilities.
2. Understand how urbanization has contributed to a complex, interconnected society that requires resilient design.
3. Identify the differences between sustainability and resiliency as they relate to low-slope roofing.
4. Chart material chemistry choices of low-slope roofing components, including building air barriers, and understand how roofing system components affect overall performance.

A'18



Resilient & Sustainable Design Implications of Urbanization on Low-Slope Roofing

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**The American
Institute
of Architects**

Collaboration Partner

Outline

- Resilience and Sustainability
- Roofing and Urbanization
- Low-Slope Roof Design
 - Resiliency and sustainability considerations
- Implications for Low-Slope Roof Specification



Let's Agree on Some Basic **Definitions, n....**

Forms: α. ME-15 **diffinicioun**, etc.
diffinition , etc., 15 Sc. **diffinitioun**;
definition.

The action of **defining**, or stating exactly what a thing is, or what a word means.

A precise statement of the essential nature of a thing; a statement or form of words by which anything is defined.

sustainable

adjective | sus·tain·able | \sə-'stā-nə-bəl\

Popularity: Top 10% of words | Updated on: 15 Mar 2018

Definition of SUSTAINABLE

- 1 : capable of being sustained
- 2 **a** : of, relating to, or being a method of harvesting or using a resource so that the resource is not depleted or permanently damaged • *sustainable* techniques • *sustainable* agriculture
b : of or relating to a lifestyle involving the use of sustainable methods • *sustainable* society

—sustainability  \sə-'stā-nə-'bi-lə-tē\ *noun*

—sustainably  \sə-'stā-nə-blē\ *adverb*

sustainable

adjective

Definition of SUSTAINABLE for English Language Learners

: able to be used without being completely used up or destroyed

: involving methods that do not completely use up or destroy natural resources

: able to last or continue for a long time

Sustainability is the capacity for:

- Human health and well being
- Economic vitality and prosperity
- Environmental resource abundance

impact **recycle**
zero waste
green
organic compost
diversion **Future state**

Key Questions for the Built Environment:

- Are materials safe for humans and the ecosystem?
- Is a design energy and resource efficient?
- Is a material available or will its use today cause a shortage in the future?

resilience

noun | re·sil·ience | \ri-'zil-yən(t)s\

Popularity: Top 1% of lookups | Updated on: 23 Mar 2018

Definition of RESILIENCE

- 1 : the capability of a strained body to recover its size and shape after deformation caused especially by compressive stress
- 2 : an ability to recover from or adjust easily to misfortune or change

resilience

noun

Definition of RESILIENCE for English Language Learners

: the ability to become strong, healthy, or successful again after something bad happens

Resilience is the capacity to:

- Overcome unexpected problems
- Continue or rapidly bounce back from extreme events
- Prepare for and survive catastrophes



A word cloud of terms related to resilience and disaster recovery. The words are arranged in a cluster on the right side of the slide. The largest words are 'coping' (dark red), 'defence' (gold), 'safe fail' (green), and 'social support' (brown). Other words include 'business impact' (gold), 'modularity' (green), 'redundancy' (blue), and 'flexible' (black).

coping **defence**
business impact
safe fail
redundancy modularity
flexible **social support**

Key Questions for the Built Environment:

- Can a structure be occupied and functional after flooding?
- Will occupants be able to function in the absence of utilities?
- What reduction in occupational capacity is acceptable?

A key question...

Are sustainability and resilience coupled, equivalent, or opposites?

Lets look at a few examples...

**More
Sustainable**



**Cradle to Cradle
Zero Waste to the Landfill
Green Roofs**

**Rainwater Harvesting
Day Lighting
Solar with Storage**

**Grid Only Power
Construction as Usual
Flood Zone Construction**

**Diesel Back-Up
Large Reserves of Bottled
Water**

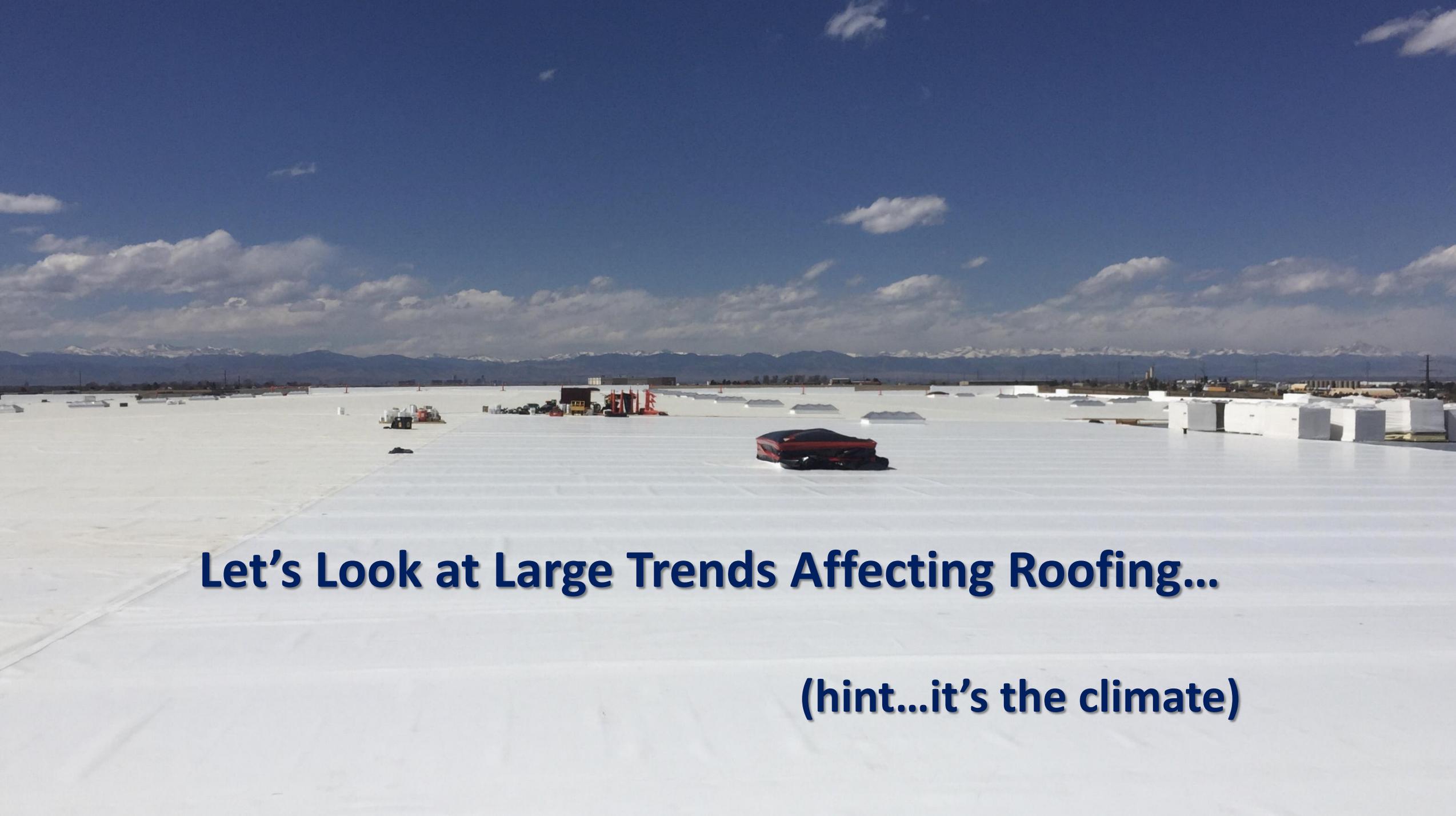
**Less
Sustainable**



**Less
Resilient**

**More
Resilient**

***Sustainability and Resilience are Different –
Choices Need to be Examined With Care***



Let's Look at Large Trends Affecting Roofing...

(hint...it's the climate)

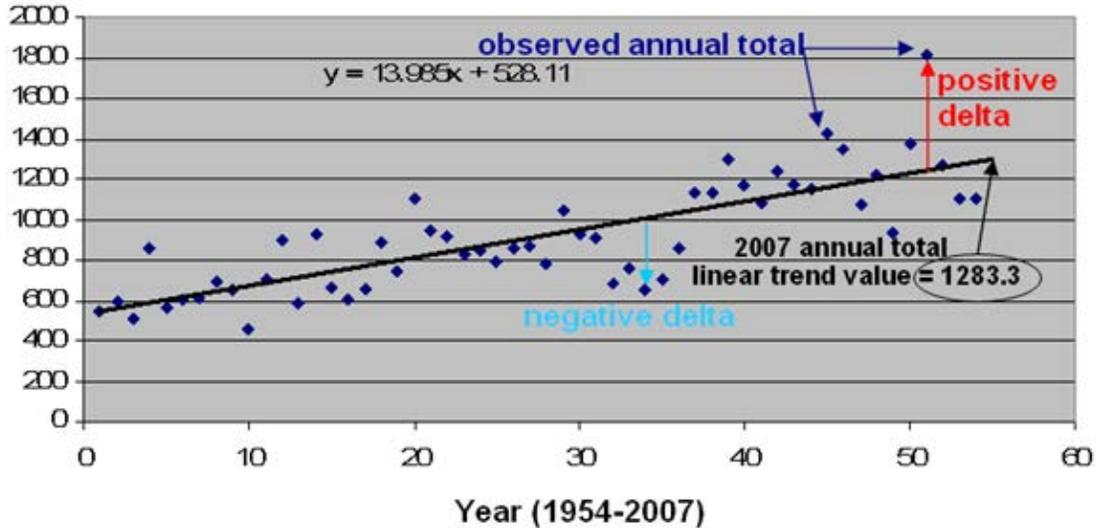
Wind Trends

Tornadoes appear to be increasing in frequency

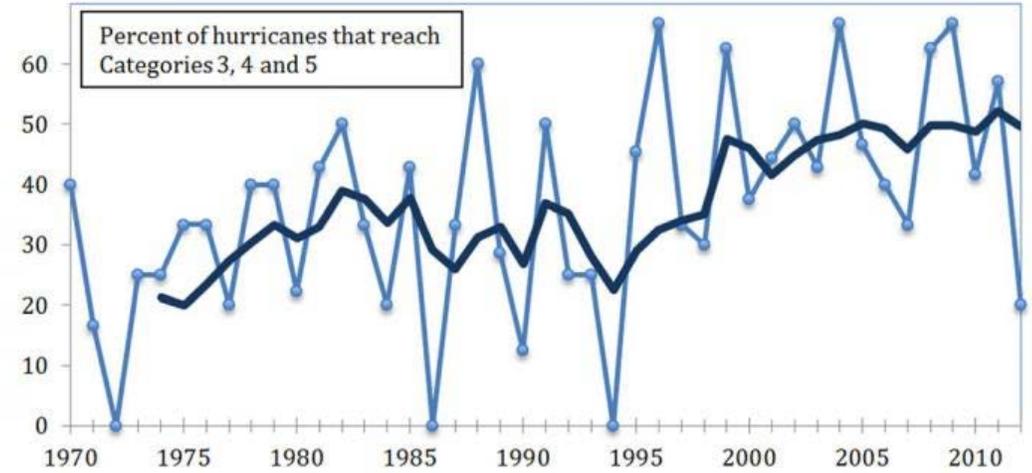
Hurricanes are growing stronger and more frequent

Maybe!

Tornadoes per year and linear trend



Atlantic Hurricanes Grow Stronger



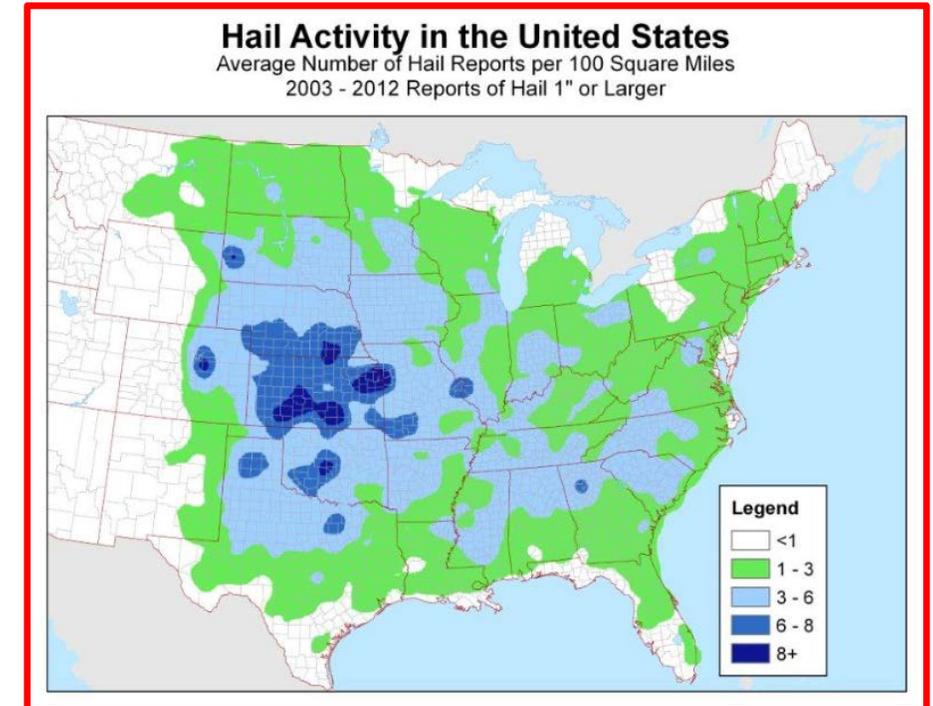
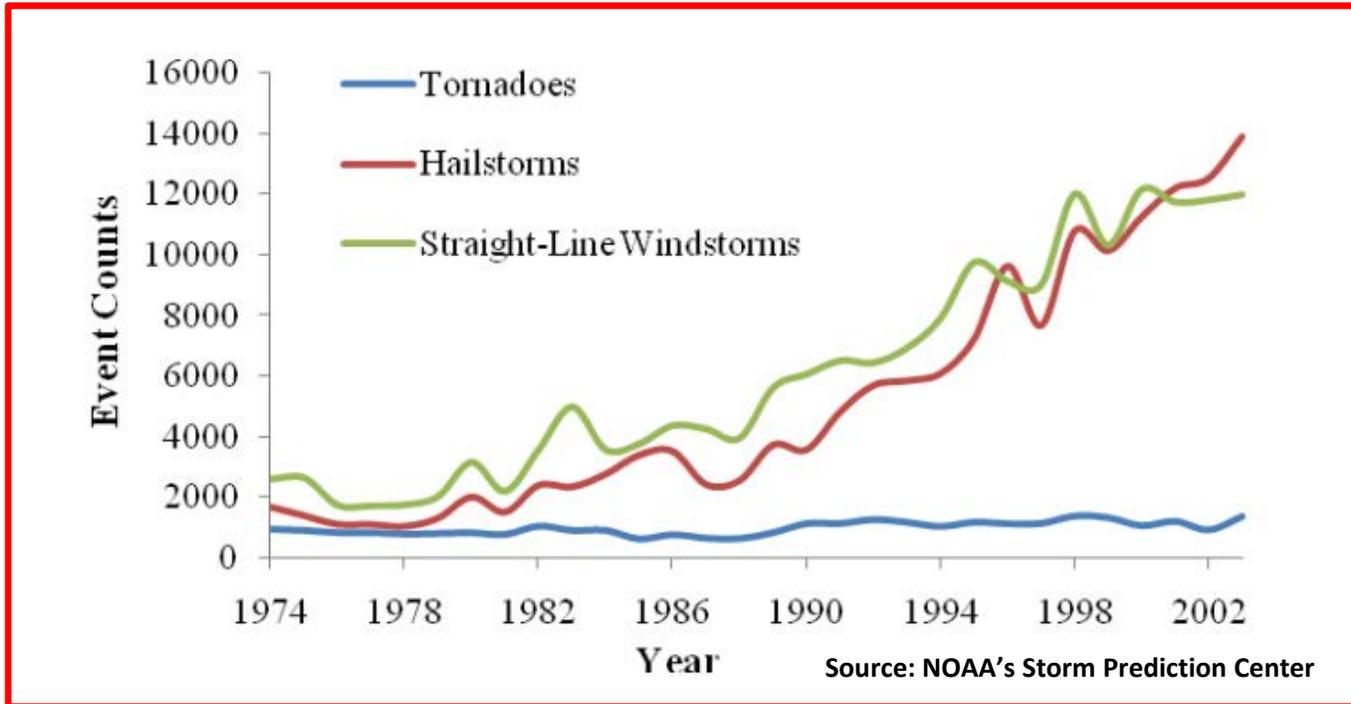
ATLANTIC NAMED STORMS
HIGHER ACTIVITY SINCE 1995



Data Source: NOAA's National Climatic Data Center

CLIMATE CENTRAL

Impact Resistance – Reported hailstorm events are rising



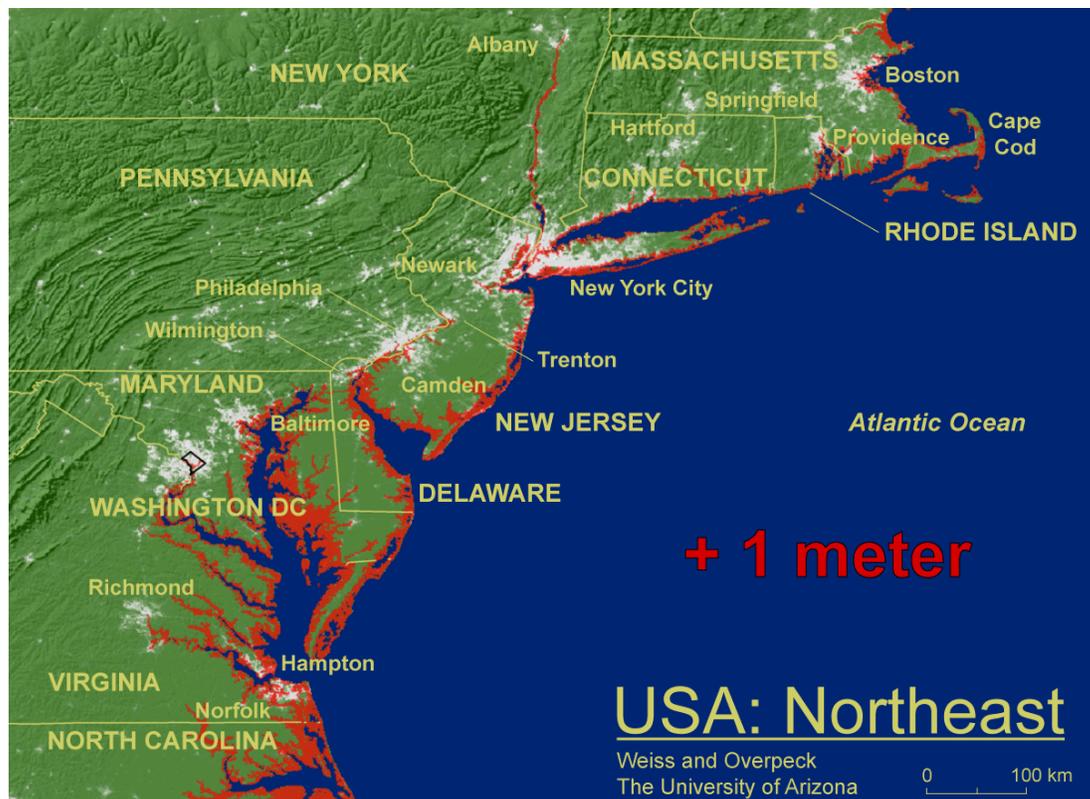
National hail claims estimates vary, but all are high:

- \$850 Million – 2009
- \$924 Million – 2010
- FM Global estimates total claims >\$1 Billion/yr (crops, property)

April 11th 2016 Wylie, TX Hail Storm

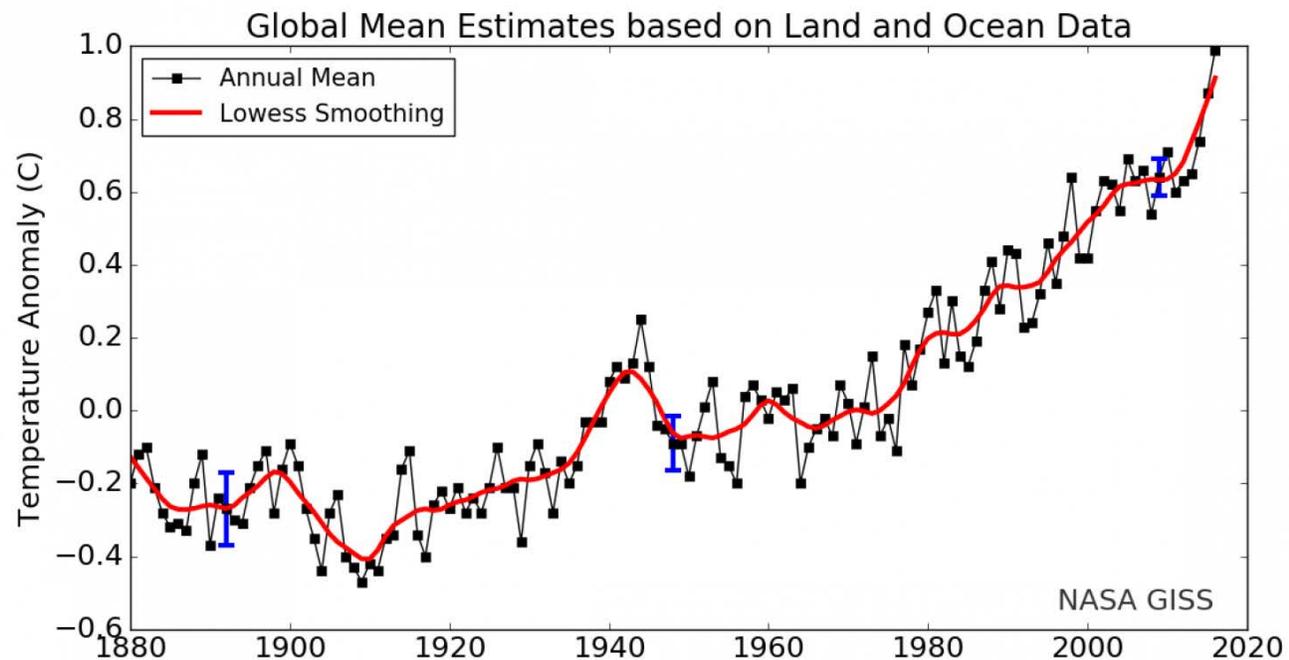


Coastal Urban Regions Could be Underwater



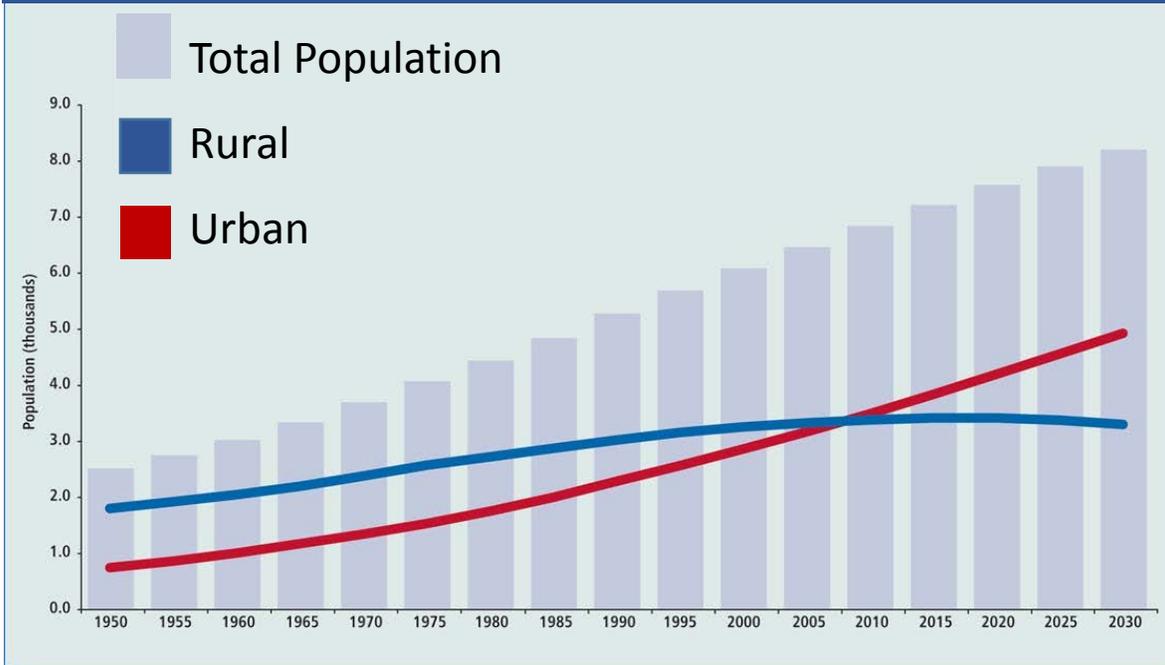
Affects buildings and infrastructure

Global Temperatures Continue to Rise



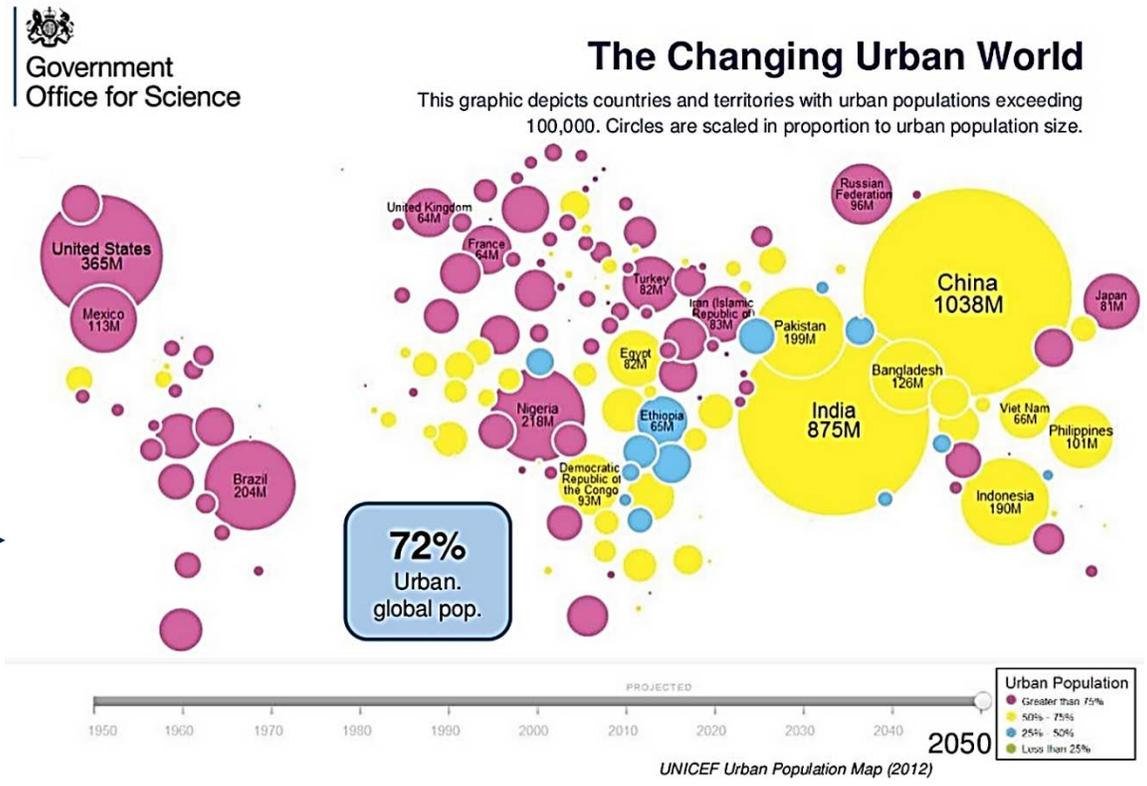
The Built Environment is Changing...

The Urban and Rural Population of the World, 1950-2030



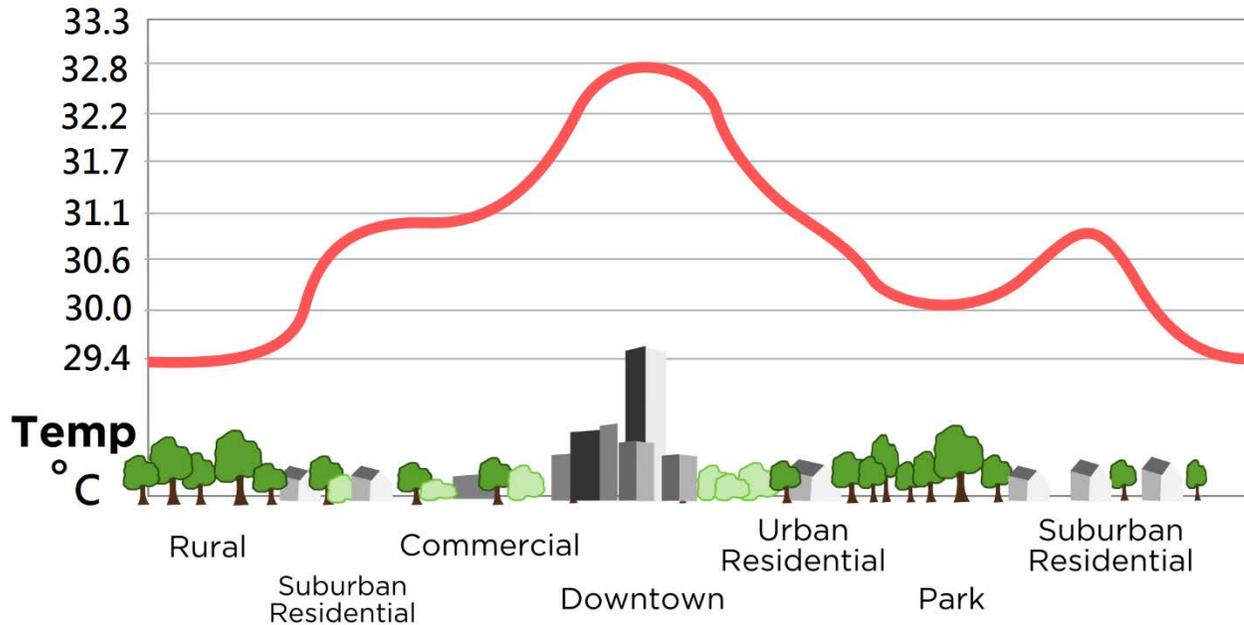
Urban areas are growing at the expense of rural

By 2050, 72% of the world's population could be urban



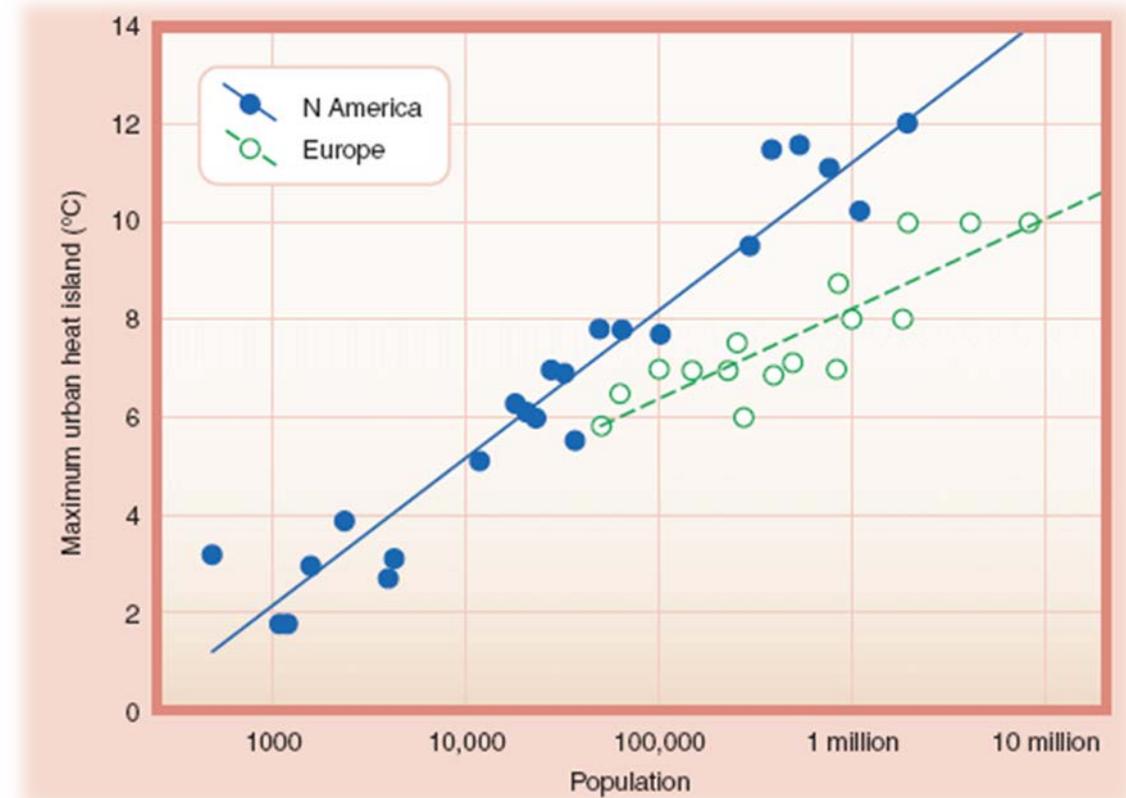
72% Urban. global pop.

Urban Heat Island – Microclimate Effect



As urban populations rise, UHI effect becomes more pronounced!

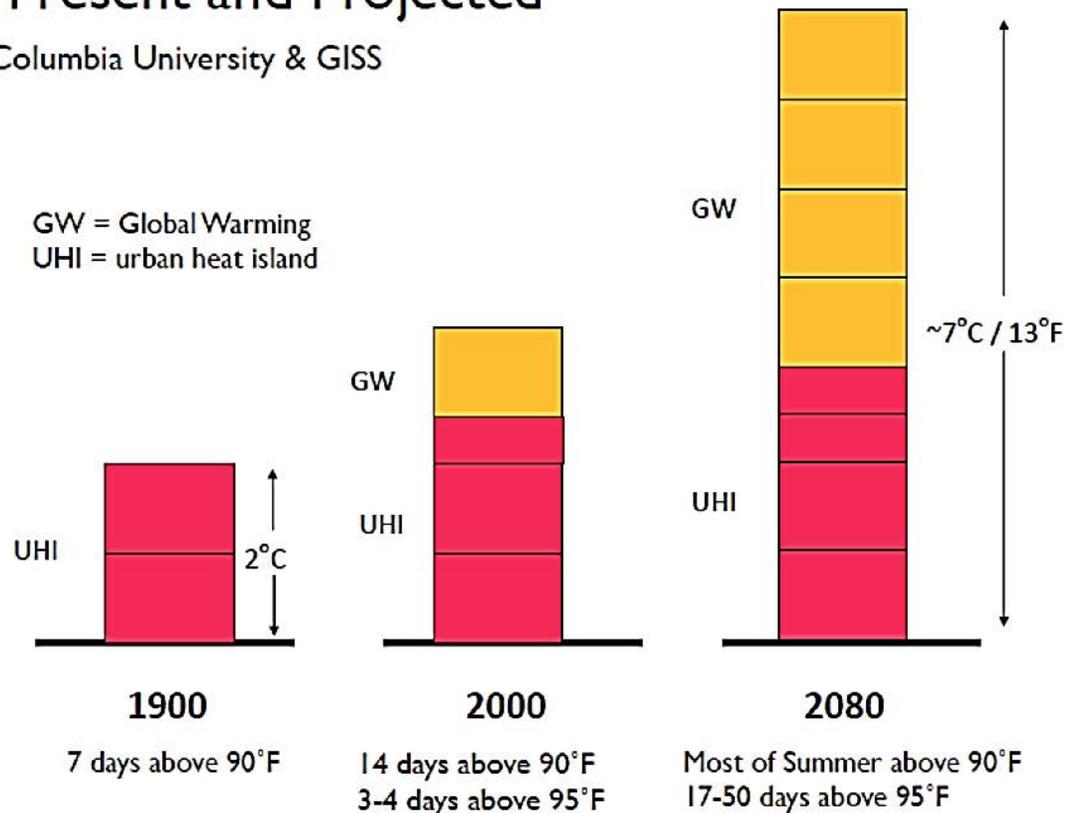
Reduced evaporation
Reduced plant transpiration
Absorptive surfaces
Heat canyons!



Global Warming Compounds Urban Temperature Rise

NYC's Heat Burden Past, Present and Projected

Credit: Columbia University & GISS

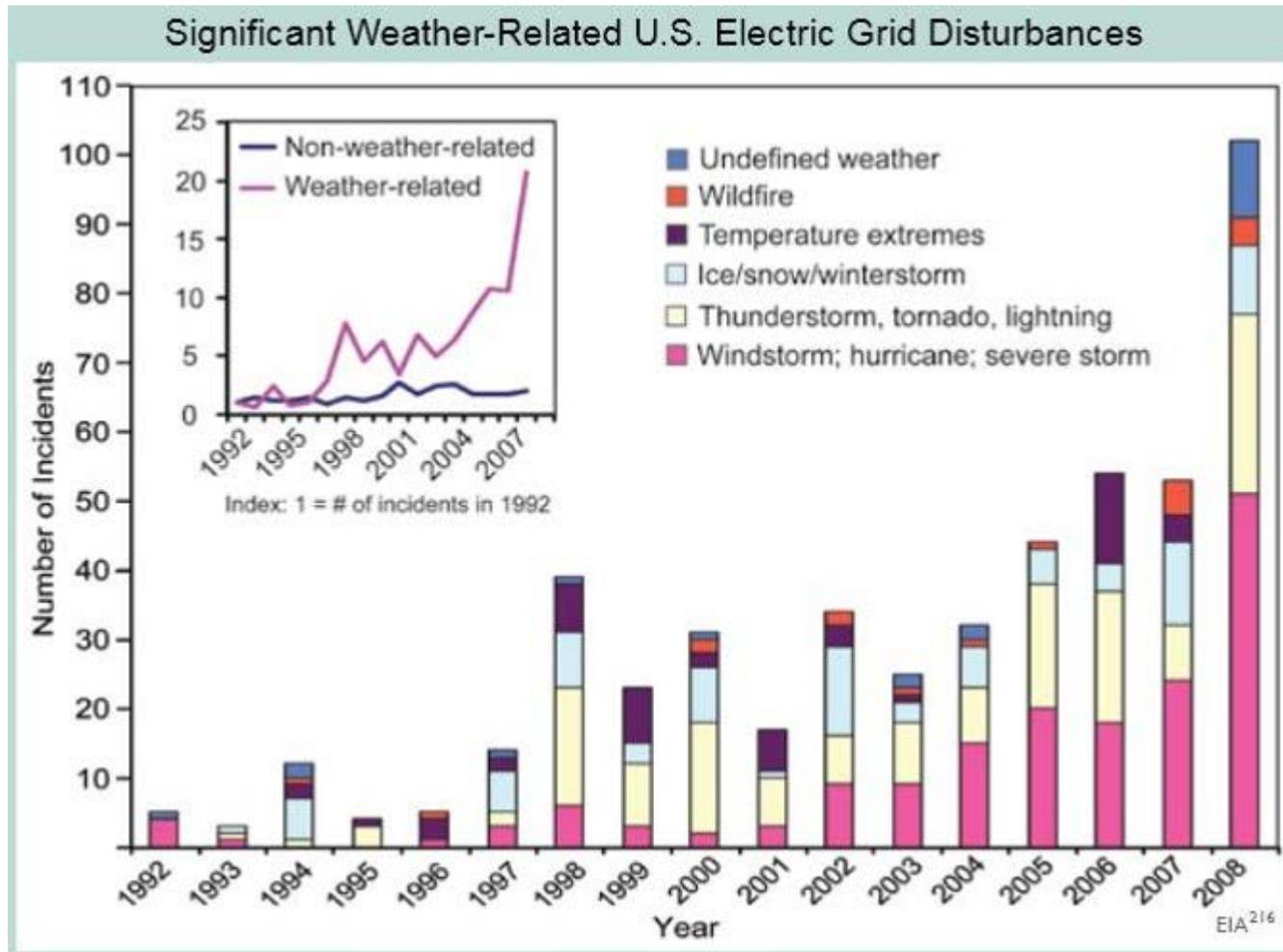


2080:

**Most of Summer above 90°F
17 – 50 days above 95°F**

Cool roofs help – but is it enough?

The Built Environment - Loss of Heat, Power, Electricity



Without electricity we lose:

- Heat
- Light
- Communications
- Transportation
- Financial Transactions
- Safety and Security Systems

Storms etc cause physical grid damage

Temperature extremes stress the grid (usage increases, causing brownouts)

And...

Cities

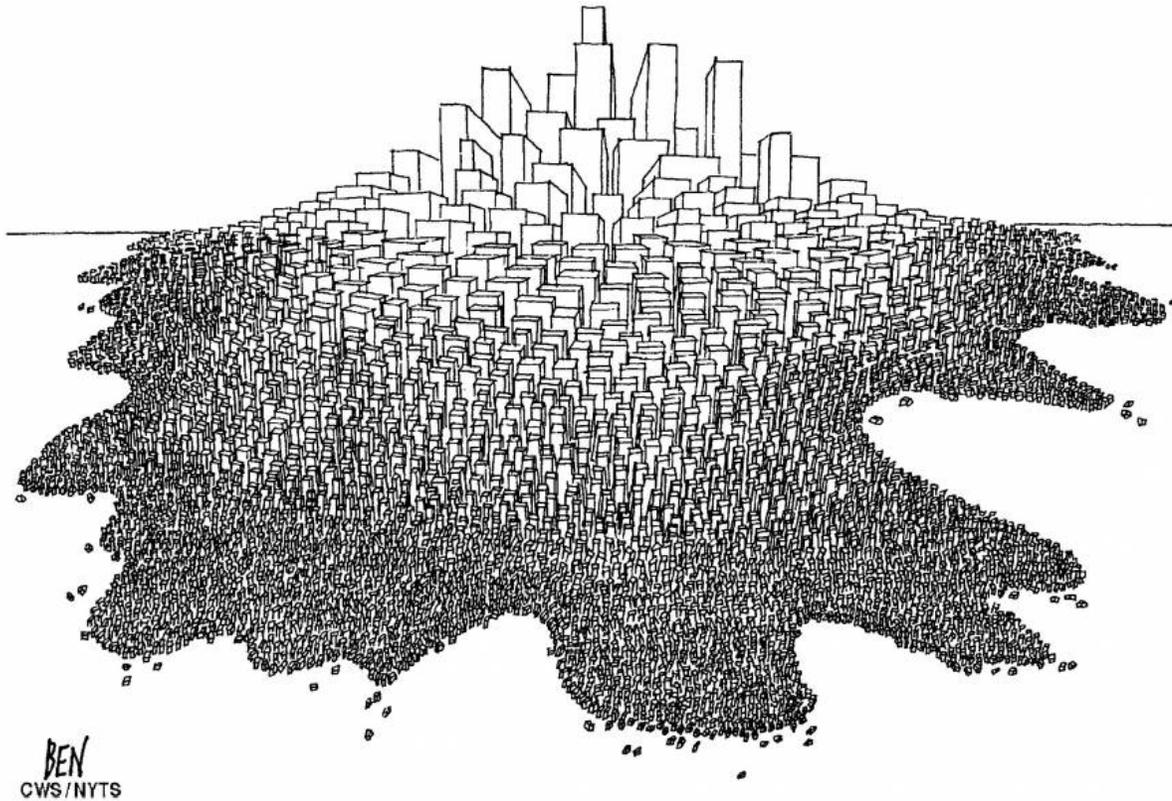
Produce 60% of all Carbon Dioxide



**Occupy <2% of the earth's surface.
Consume 78% of the world's energy and produce.
90% of urban centers are in coastal areas.**

“The effects of urbanization and climate change are converging in dangerous ways” ... UN Habitat

Urbanization Means...



More of the Built Environment Impacted by Urban Heat Island.

Greater Reliance on Distant Material and Energy Resources



Climate is Changing in Ways that are Difficult to Predict

Urbanization is Changing the Built Environment Fabric

Today's Solutions Might Not be Enough For Tomorrow

Sustainability and Resilience are Important But Are They Enough?

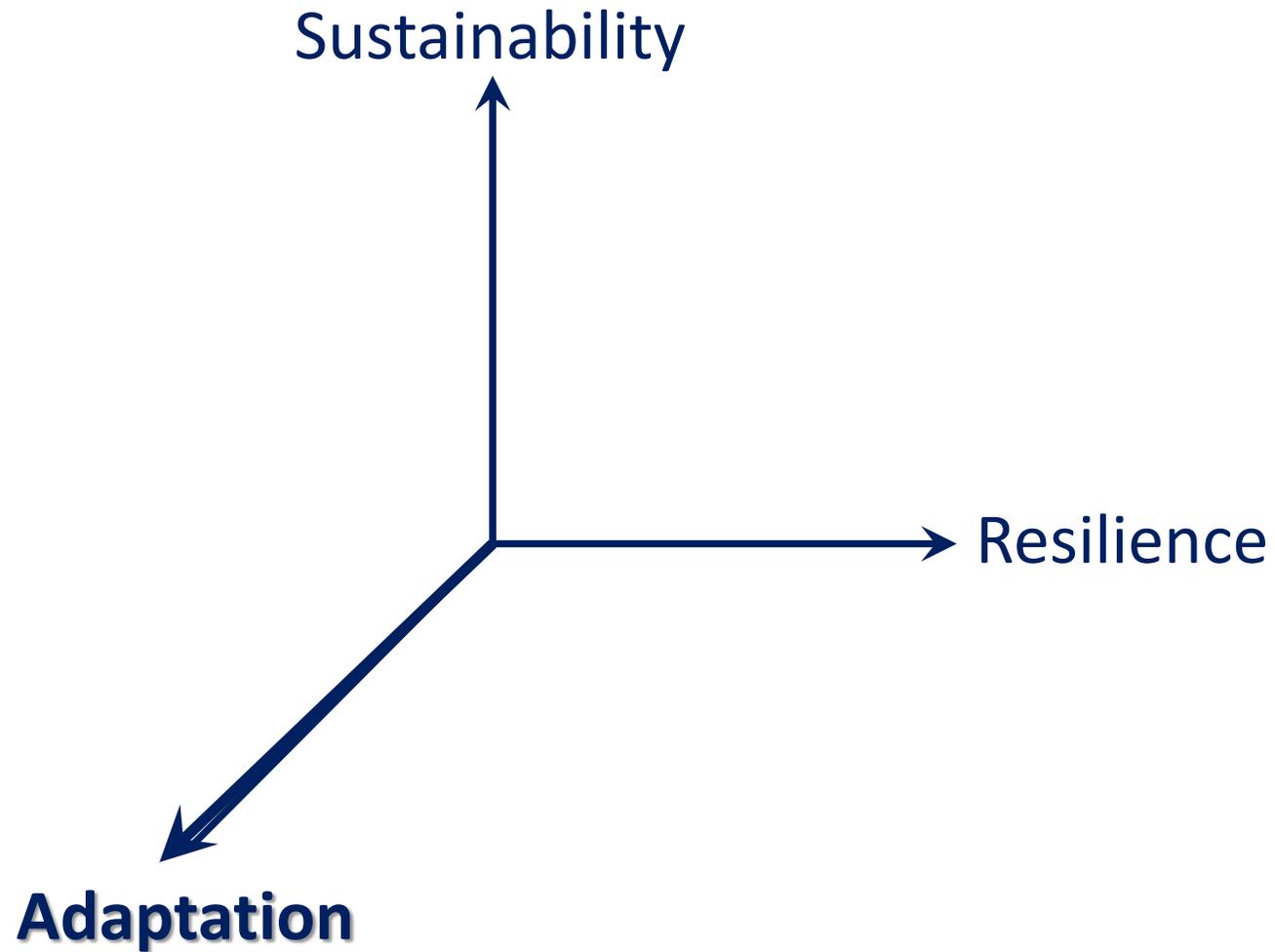


Sustainability is about doing no harm; protecting today's environment for future use.

Resiliency is really about being able to absorb the risks that are coming your way, and being able to bounce back quicker.

Sustainability and Resilience are necessary, but they are not enough!

The third axis...



The climate is no longer a constant

- Trends are no longer measured in millennia

The built environment is changing

- Urbanization is increasing

adaptation

noun | ad·ap·ta·tion | \,a-,dap-'tā-shən, -dəp-\

Popularity: Top 10% of words

Definition of ADAPTATION

- 1 : something that is adapted • a new *adaptation* of an old recipe; *specifically* : a composition rewritten into a new form • a screen *adaptation* of a novel
- 2 : the act or process of adapting • a process undergoing *adaptation* : the state of being adapted • *adaptation* to changing circumstances
- 3 : adjustment to environmental conditions: such as
 - a : adjustment of a sense organ to the intensity or quality of stimulation
 - b : modification of an organism or its | conditions of its environment : a herit. function and improves an organism's |

adaptation

noun | ad·ap·ta·tion | \,a-,dap-'tā-shən\

Definition of ADAPTATION for Students

- 1 : the act or process of changing to better suit a situation
- 2 : a body part or feature or a behavior that helps a living thing survive and function better in its environment

Adaptation is the ability to:

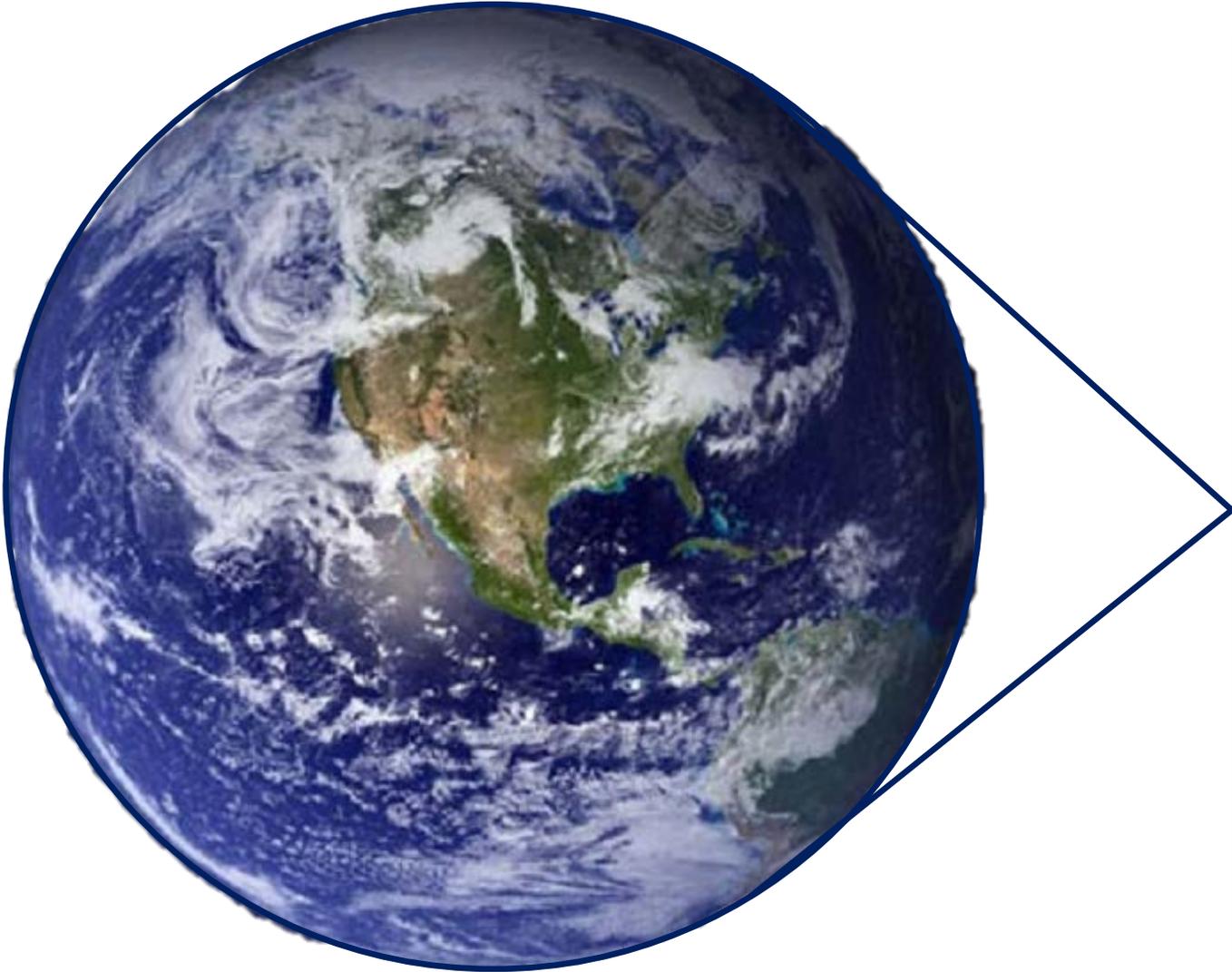
- Adjust to changing conditions
- Modify behavior in response to new circumstances
- Prepare for and survive long term change

adjust **modify**
improve
survival
transformation
acclimatization
shift **correction**

Key Questions for the Built Environment:

- Will today's structures be appropriate for long term climate change?
- Can building design adapt, maintain resilience, and sustainable practices? Adaptation should not accelerate change!

So, Let's Move From The Big Picture



To The Roof



Pre-Industrial Roofing...

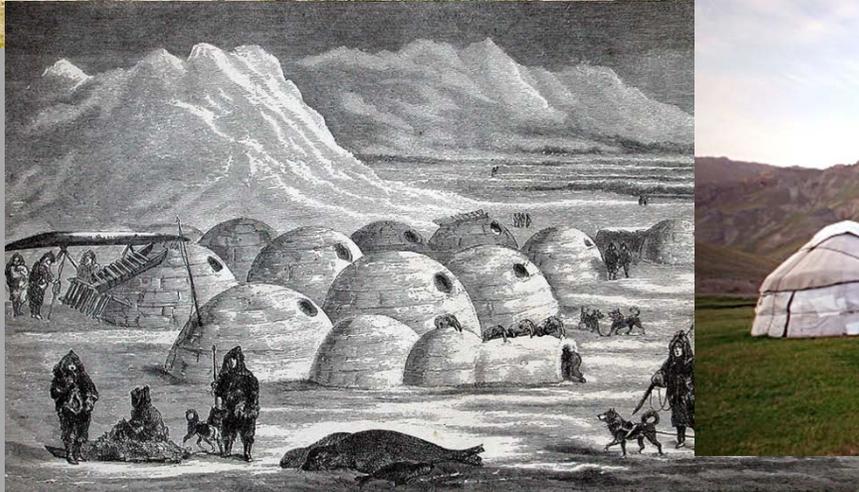
- Residential
- “Light Commercial”, aka, the blacksmith etc
- “Institutional”, aka the local church or meeting room
- “Warehouse”, aka grain storage, farm buildings

Local materials dominated

- **Sustainability** may or may not have been implicit, but **was not a consideration**
- **Resilience was a consideration of recognized local climate and weather patterns**
- Climate was assumed to be constant!



Pre-Industrial – Local Materials



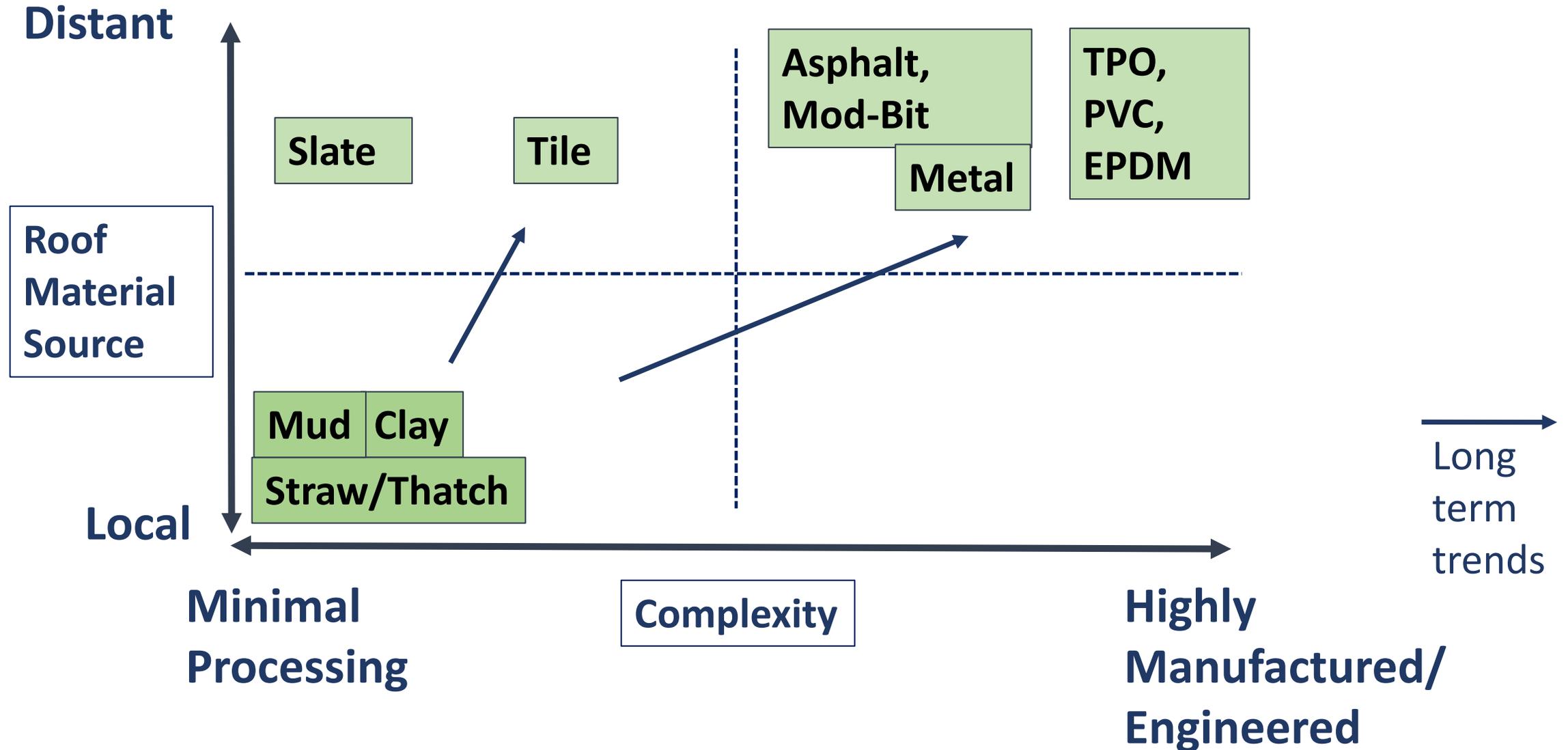
Post Industrial Roofing...

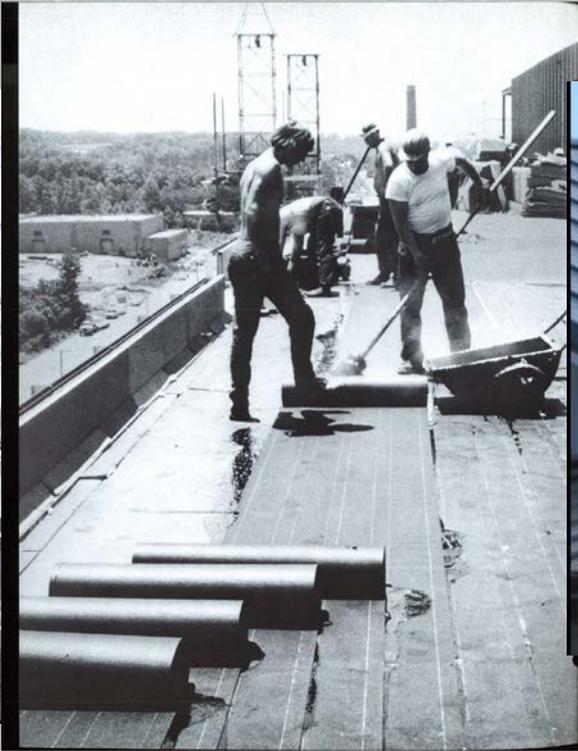
- Residential
- Light Commercial, eg. retail, offices
- Institutional, eg. hospitals, schools
- Warehouse, e.g distribution centers, large scale storage

Materials sourced from a distance

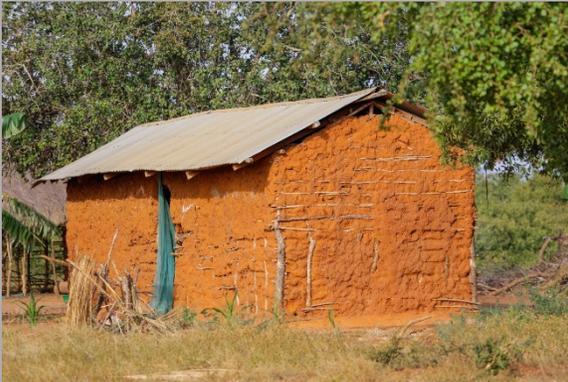
- **Sustainability** may or may not have been implicit, but **was not a consideration**
- **Resilience was a consideration of recognized natural events and weather patterns**
- Climate was assumed to be constant!

Pre-Ind. → Post-Ind. → Modern: Roof Material Trends

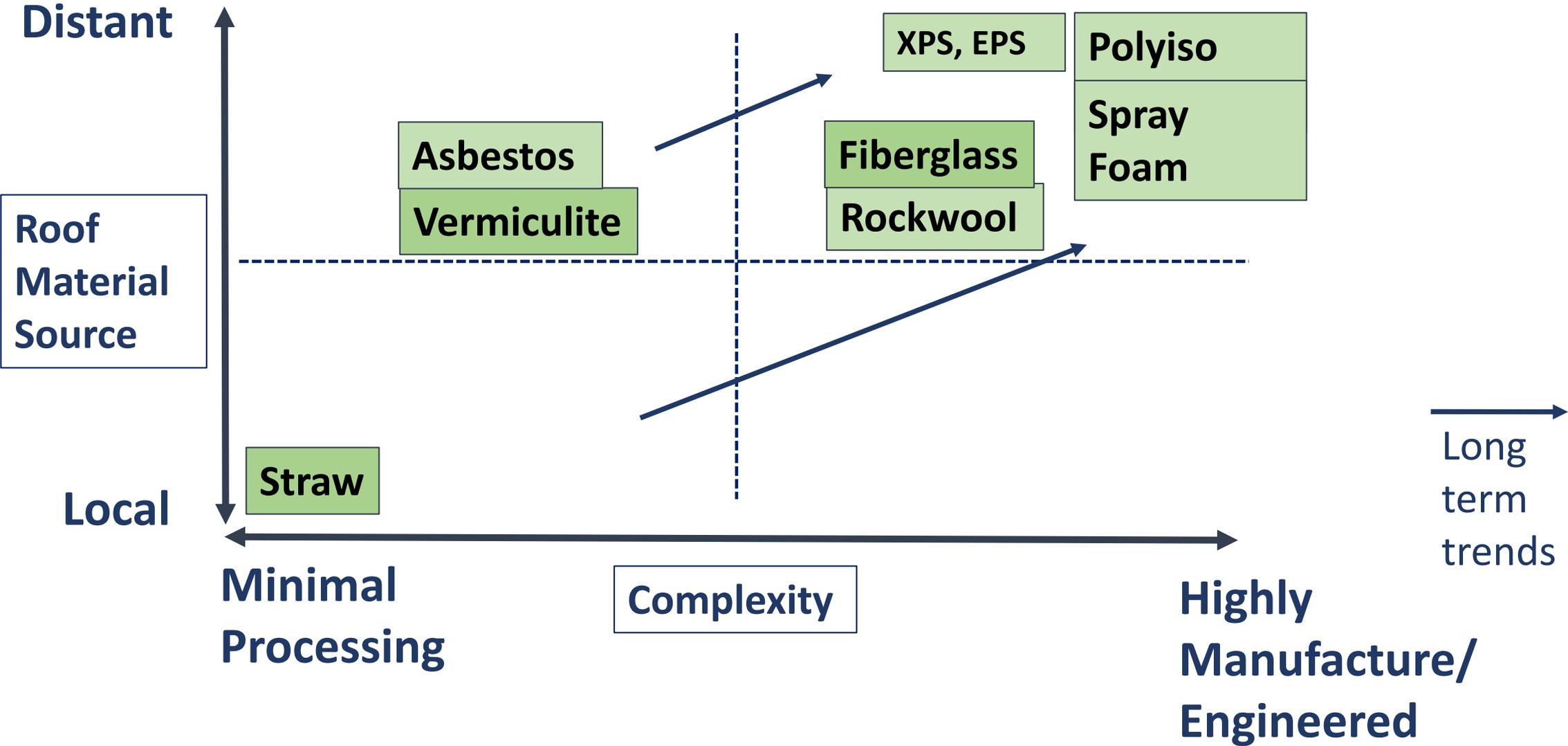


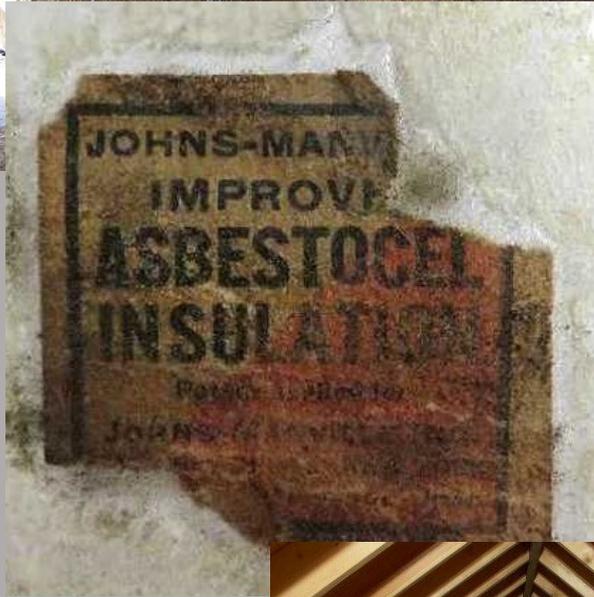
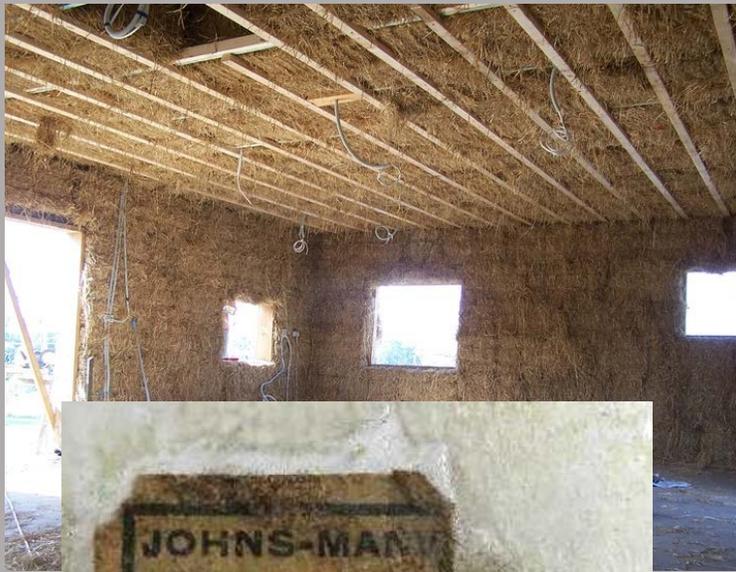


Post-Industrial – Highly Manufactured/Distant Sourcing

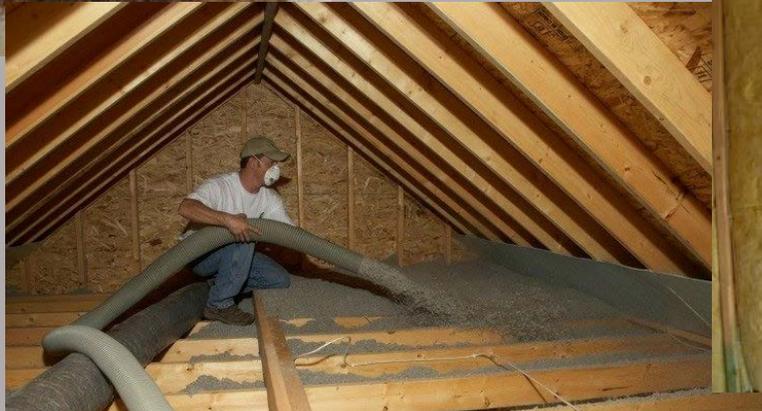


Pre-Ind. → Post-Ind. → Modern: Insulation Material Trends

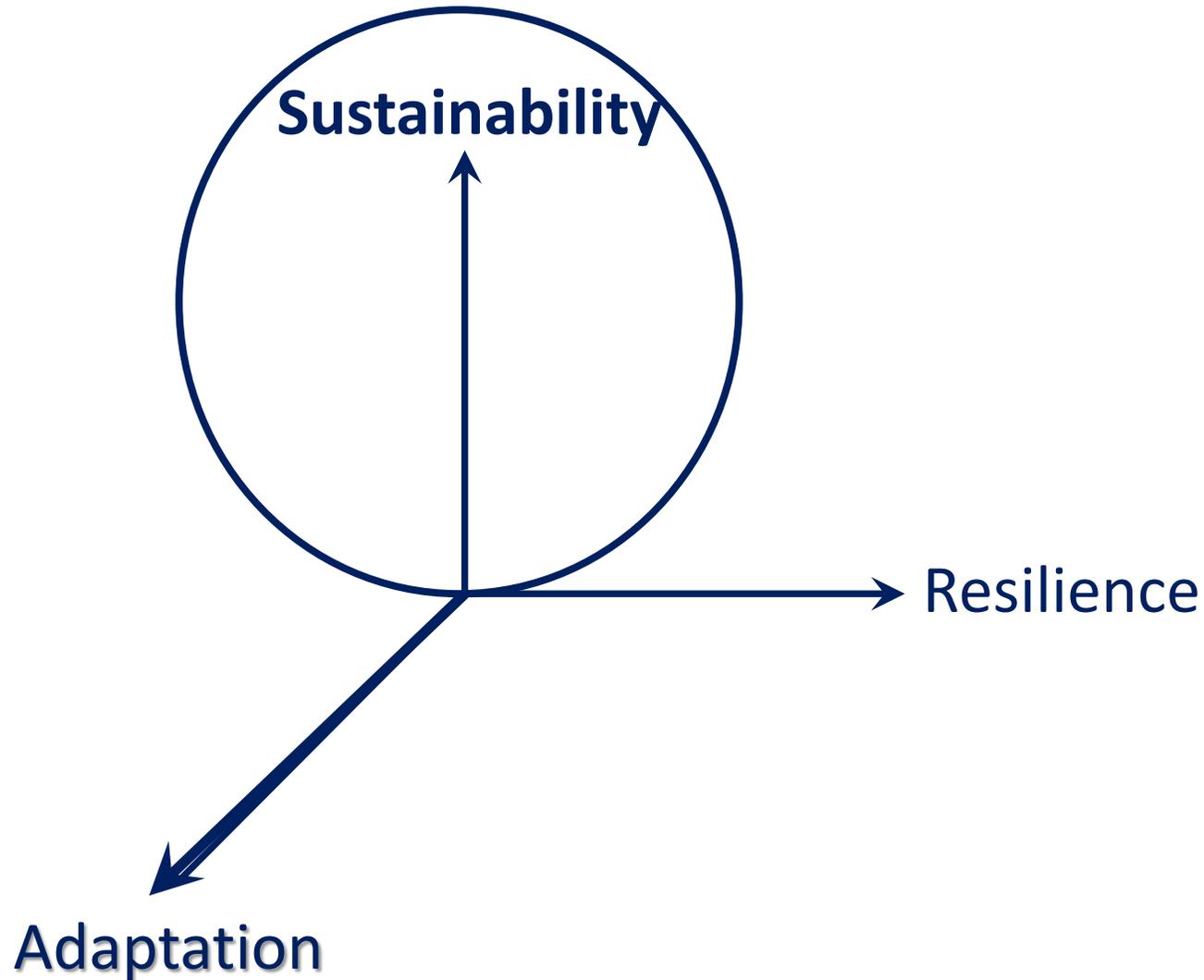




Insulation Materials



So, Lets Discuss Today's Roofs From the Perspective of...



Recap:

Sustainability is the capacity

for:

- Human health and well being
- Economic vitality and prosperity
- Environmental resource abundance

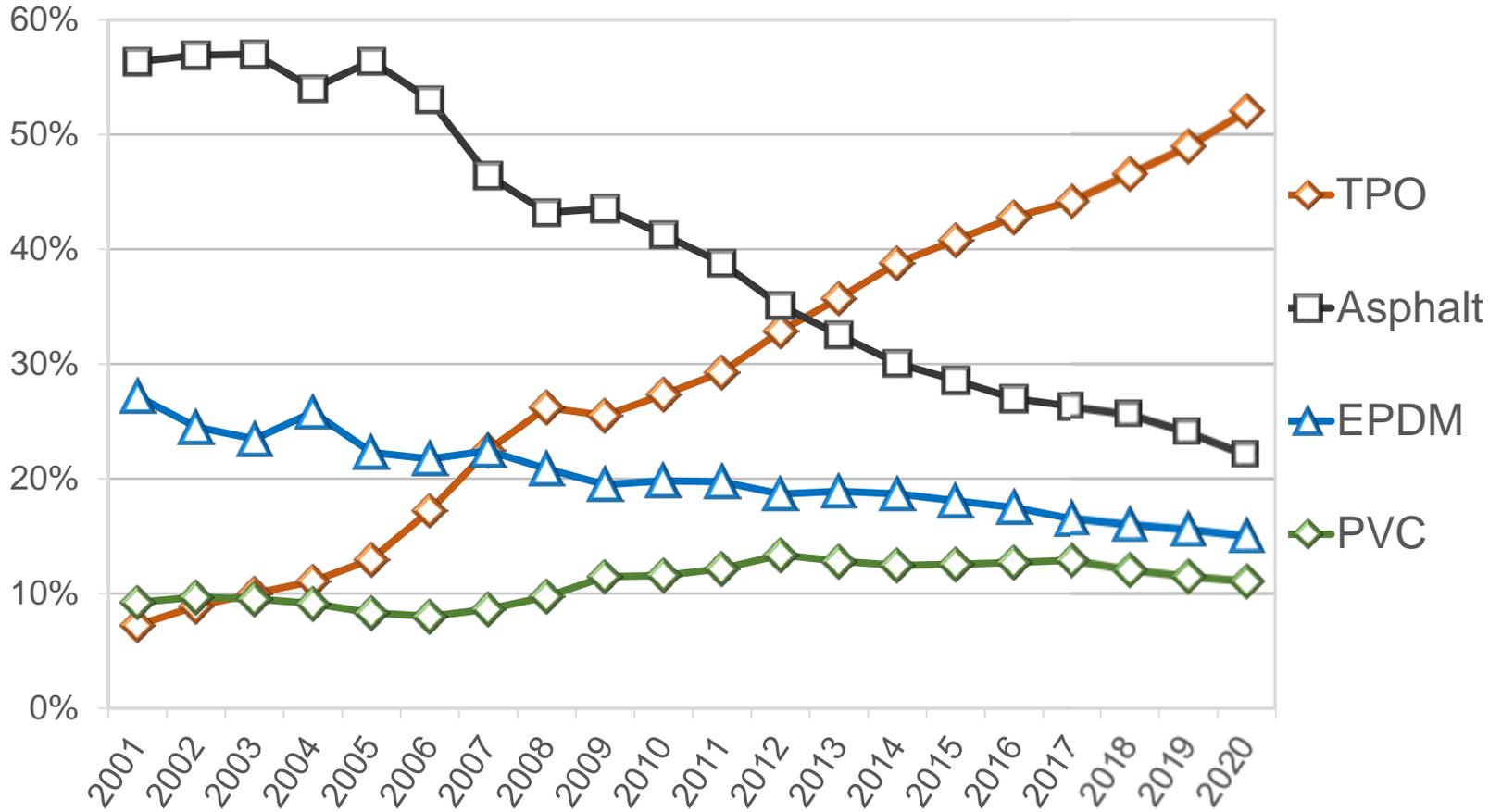
Sustainability of Roofing Materials

How to Judge?

- There are many opinions and options
- LEED v.4 provides a common baseline
 - Building Product Disclosure & Optimization
 - Environmental Product Declaration
 - Raw Material Extraction
 - Material Ingredients
 - Building Design & Construction – Sustainable Site
 - Heat Island Reduction



The Membrane Market...



As older TPO roofs get replaced, it will be in kind:

TPO Share Is Expected To Accelerate!

Sustainability Scorecard for Membranes

	BPD&O	Cool Roof	Notes
TPO	EPD, HPD, Cradle to Cradle	Yes	Depending on manufacturer
EPDM	EPD	White Version Only	
PVC	EPD, banned from Cradle to Cradle	Yes	Contains chlorine and phthalates
Asphaltic	EPD	Only When Coated	

TPO has sustainability credentials,

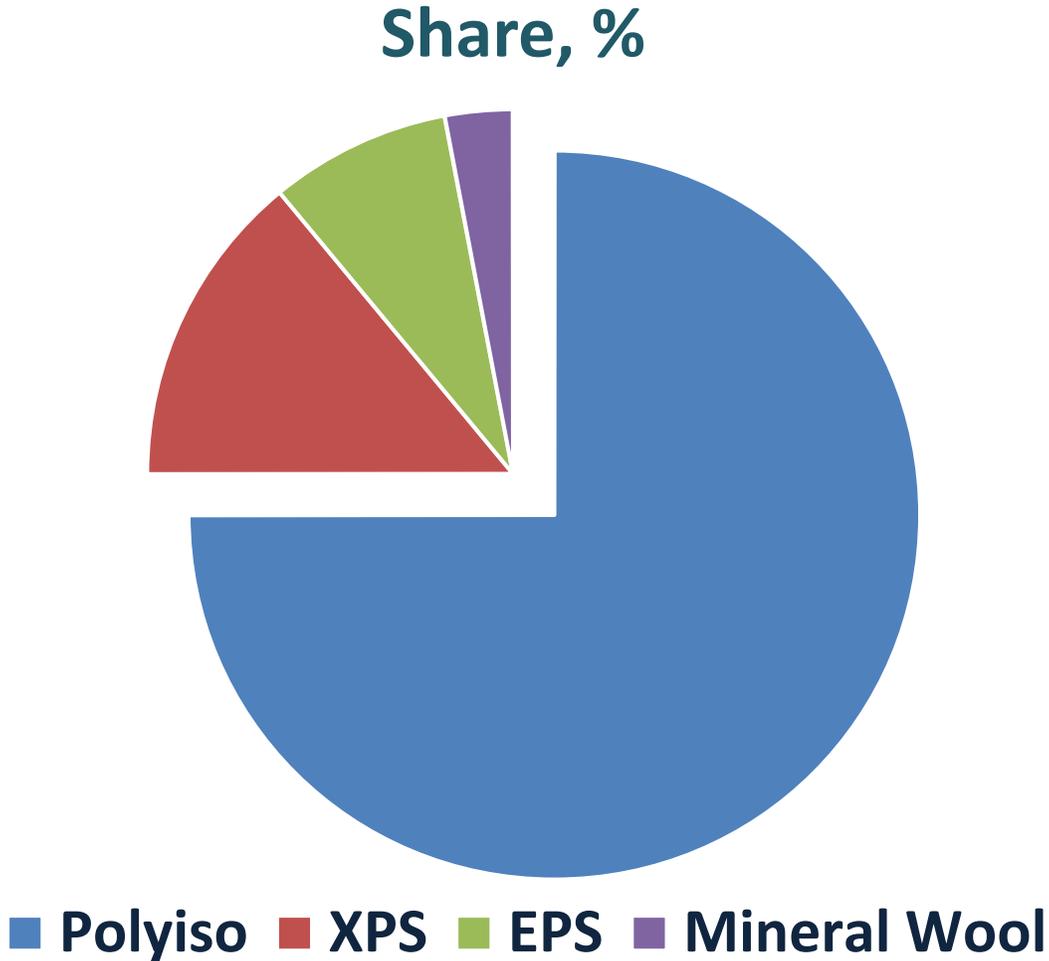
+++ > no red listed ingredients etc., potential long life (25 to 35 years), recyclable

--- > sourced from petrochemicals

Trend towards TPO appears justified, but recognize limitations/issues with petrochemicals

Note: **EPD & HPD process is one of “declaration”**; user must evaluate the data provided.

The Insulation Market...



Polyiso has largest share

XPS & EPS are not as fire resistant and cannot be used with solvent based adhesives

Mineral wool is vapor permeable – condensation risks have to be managed.

Sustainability Scorecard for Roof Insulation

	BPD&O	Notes
Polyiso	EPD, HPD	
Polyiso, Non-Halogen	EPD, HPD	Chlorine free
XPS / EPS	EPD, cradle to cradle	
Mineral Wool	EPD	Can contain formaldehyde

Insulation is essentially sustainable – it lowers building energy use!

Polyiso –

+++ > low density (material use is low), can be re-used, life cycle analysis is favorable, can be rated no halogen

--- > sourced from petrochemicals

Sustainability for Balance of System

	BPD&O	Pros	Cons
Gypsum Cover Boards	EPD, HPD	Plentiful raw material	Not readily recyclable
HD foam Cover Boards	EPD, HPD	Can be no halogen	Petrochemical sourced
Screws and plates	-	Steel	
Water based adhesives		Low volume, no VOC	Petrochemical sourced
Low VOC & foamed adhesives		Low volume, low to zero VOC	Petrochemical sourced
Solvent based adhesives		Low volume	VOC content, petrochemical sourced

Water based or low VOC/foamed adhesives should be favored

Most Balance of System attachment materials are low volume.

Important Side Notes...

Sustainable roofing is mainly **focused on material choices**

Content / how they are manufactured

Life cycle

Length of use / Durability

Long term trend towards highly manufactured materials made far away will not reverse!

Roof System Sustainability – Conclusions

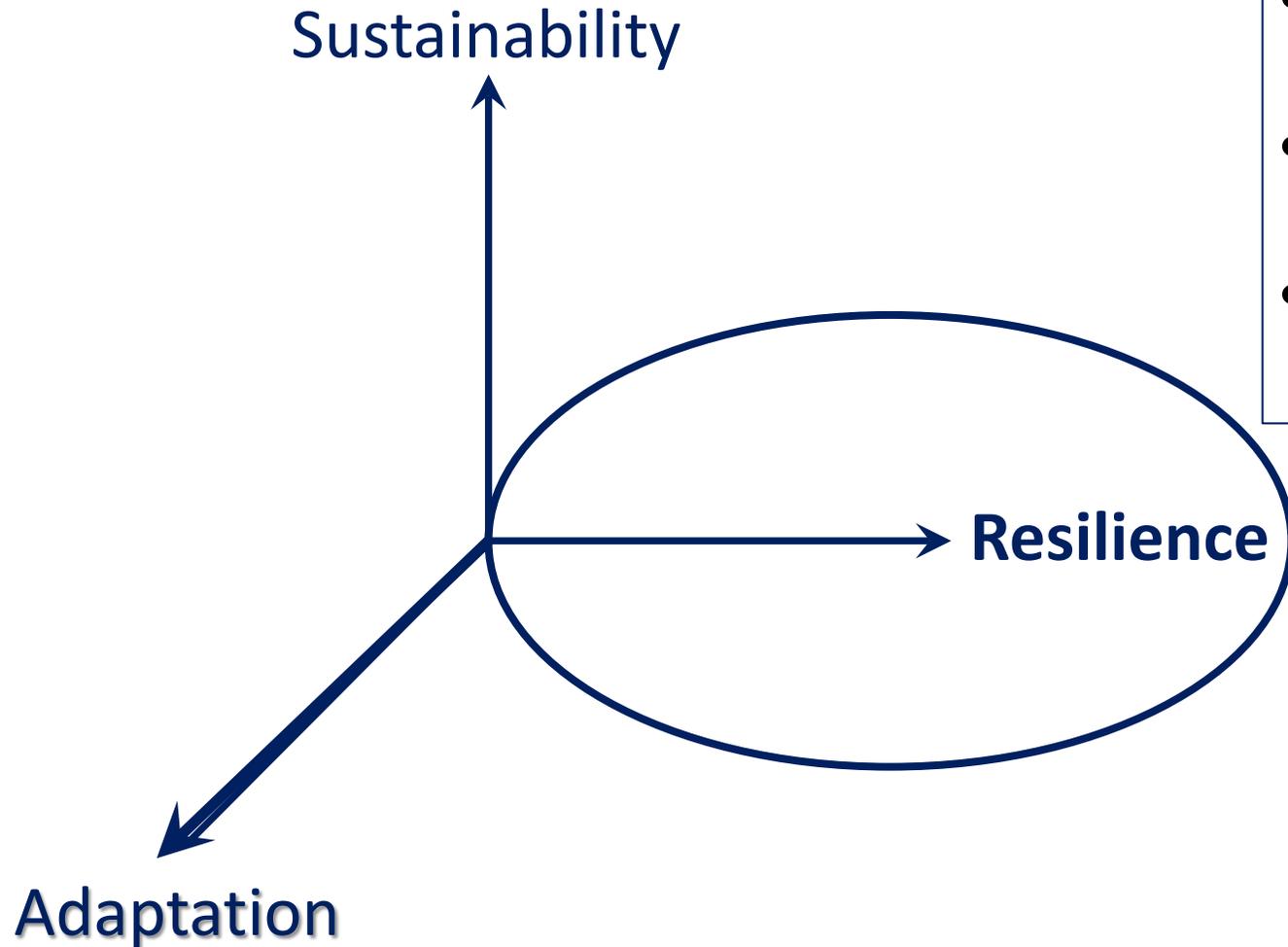
- EPD and HPD trend is increasing transparency
 - ✓ Architects & designers can make informed decisions
 - ✓ Responsible manufacturers are engaged in the discussion and taking more care with ingredients
 - ≈ More third party verification is needed
- LEED is incentivizing “sustainability”
- Popular roof components, TPO & polyiso, are reasonable choices (especially no halogen polyiso)

Recap:

Sustainability is the capacity for:

- Human health and well being
- Economic vitality and prosperity
- Environmental resource abundance

Let's Examine the Second Axis for Today's Roofs...



Recap:

Resilience is the ability to:

- Overcome unexpected problems
- Continue or rapidly bounce back from extreme events
- Prepare for and survive catastrophes

Resilience of Roofing Materials

How to Judge?

- There isn't a standard!
- It's not even the right question
- Resilience is about the built environment / the building

It's a roof assembly question

How does the roof assembly enhance a building's resilience?



Roof System “Challenges” – Today’s Solutions

High Wind / Storms

- Wind Resistance

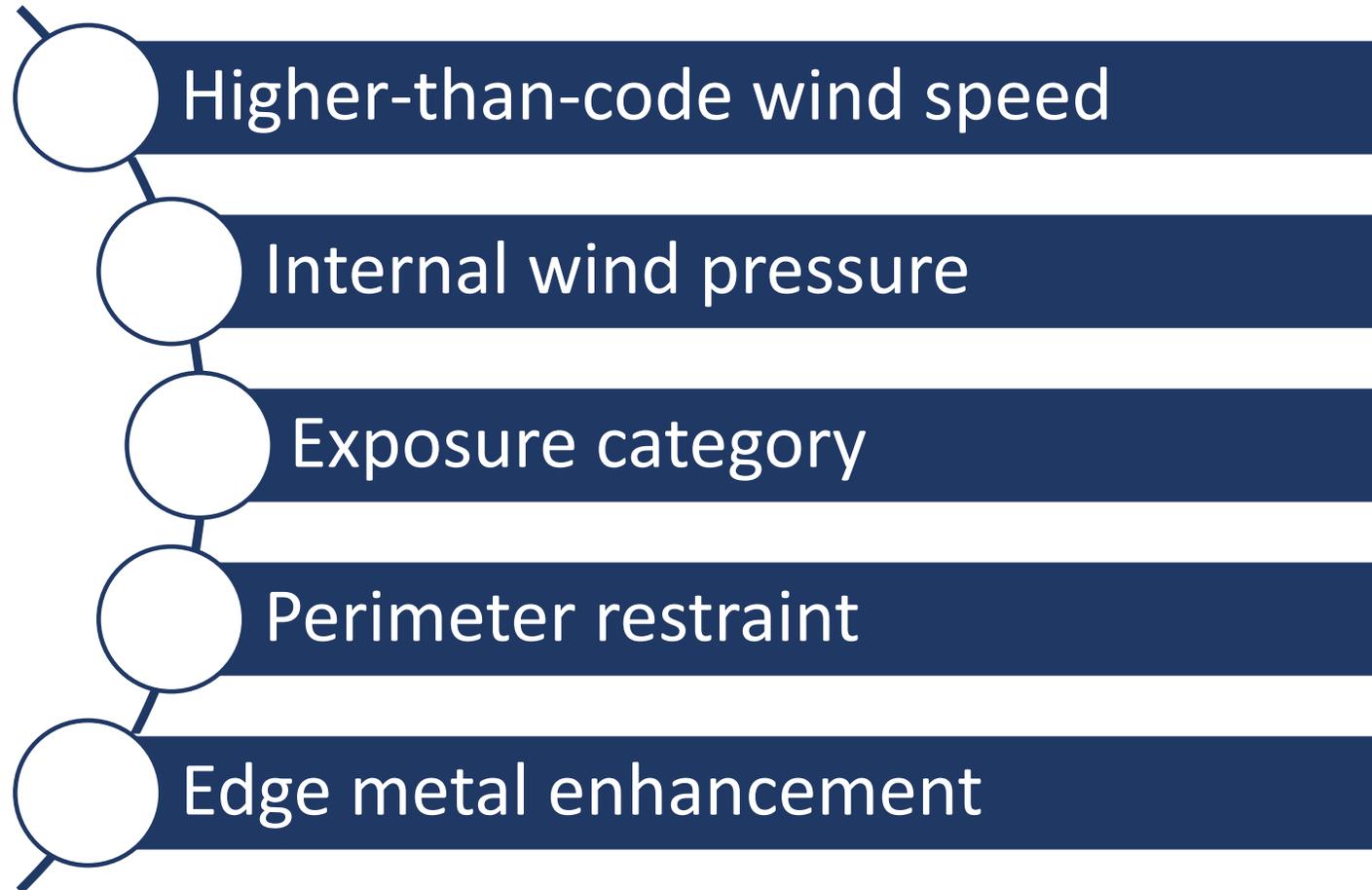
Hail

- Impact Resistance

Loss of Heat

- Insulation
- Air Barriers

Resilient Wind Uplift Design



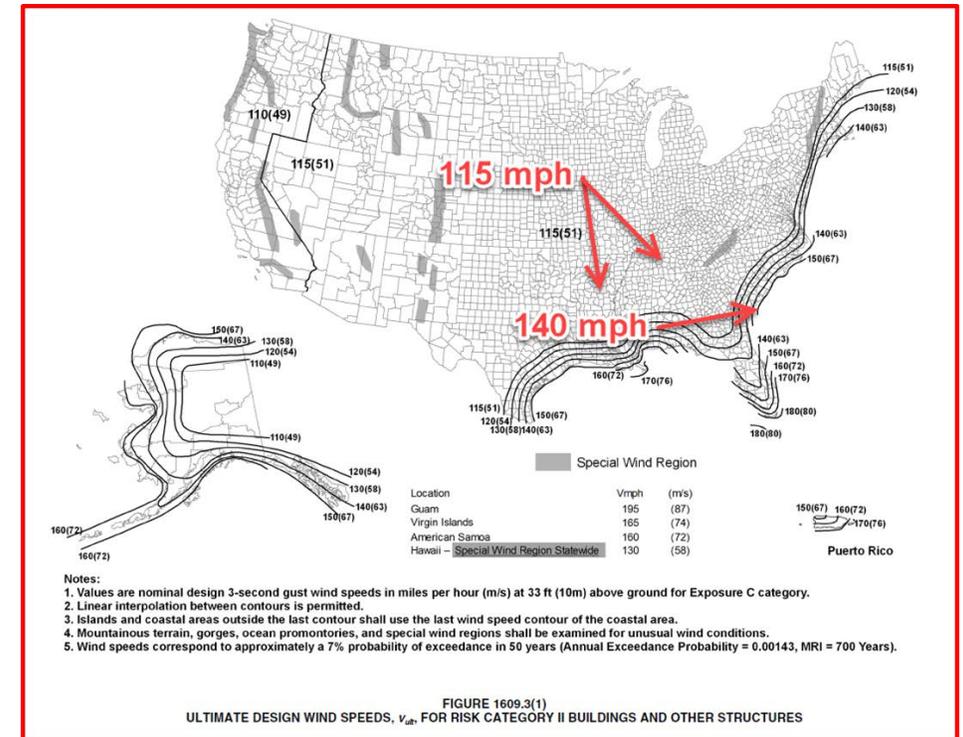
Wind Uplift, Example 1

- A two story office in Little Rock, AR needs a new roof.
- Size: 28' tall, 75' wide, and 200' long.

Design Uplift Pressures are:

FM 1-28:	101psf
RoofWindDesigner.com:	67psf *
SPRI WD-1:	47psf *
GAF:	114psf

* Enclosed, Allowable Stress Design



Wind Uplift, Example 2

- A two story office in Charleston, SC, needs a new roof.
- Size: 28' tall, 75' wide, and 200' long.
- Design Uplift Pressures are:
 - FM 1-28: 160psf
 - RoofWindDesigner.com: 114psf*
 - SPRI WD-1: 80psf*
 - GAF: 164psf

*Enclosed, Allowable Stress Design



Use assumptions that are conservative and forward thinking!

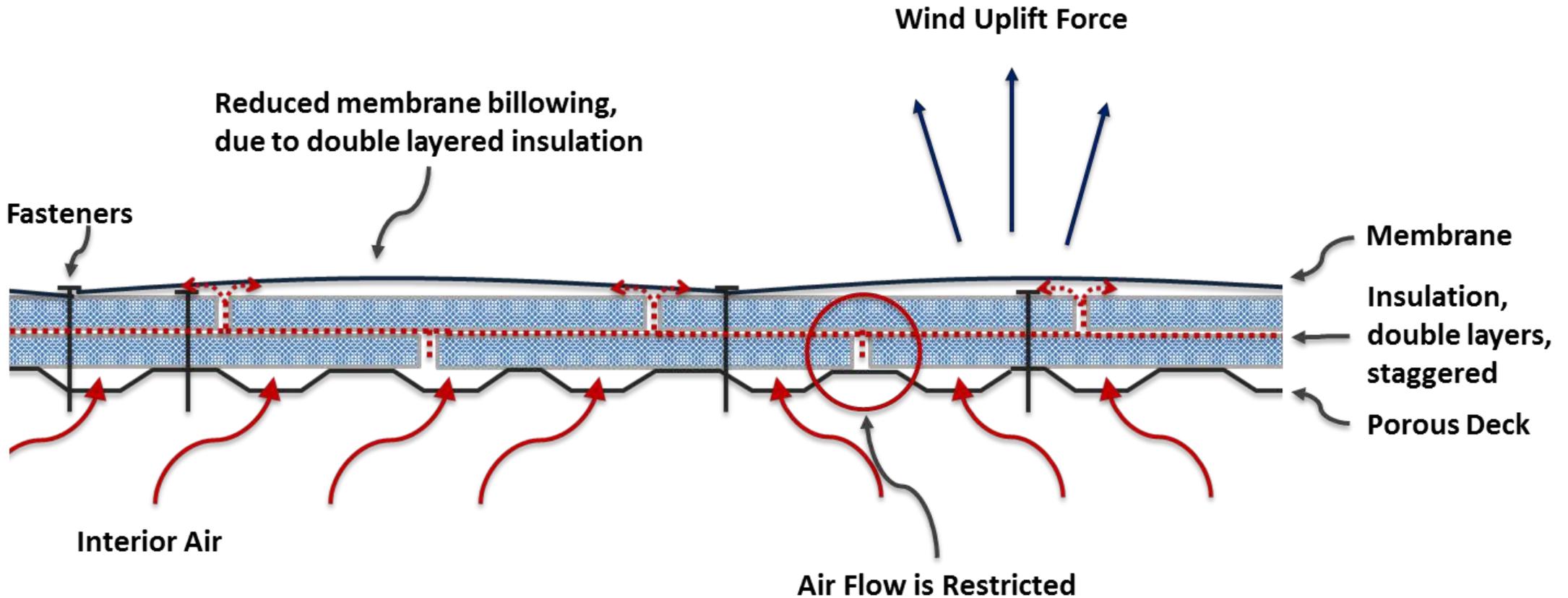
Wind Uplift – Consider More Conservative Approaches

- Use a higher risk factor – eg. more than Risk Factor 1 !
- FM 1-28 uses look-up charts – inherently rounding up
- RoofWindDesigner assumes windows/doors stay intact
- Fully adhered systems are inherently conservative
- Look closely at edge design

Many wind failures start at the edges

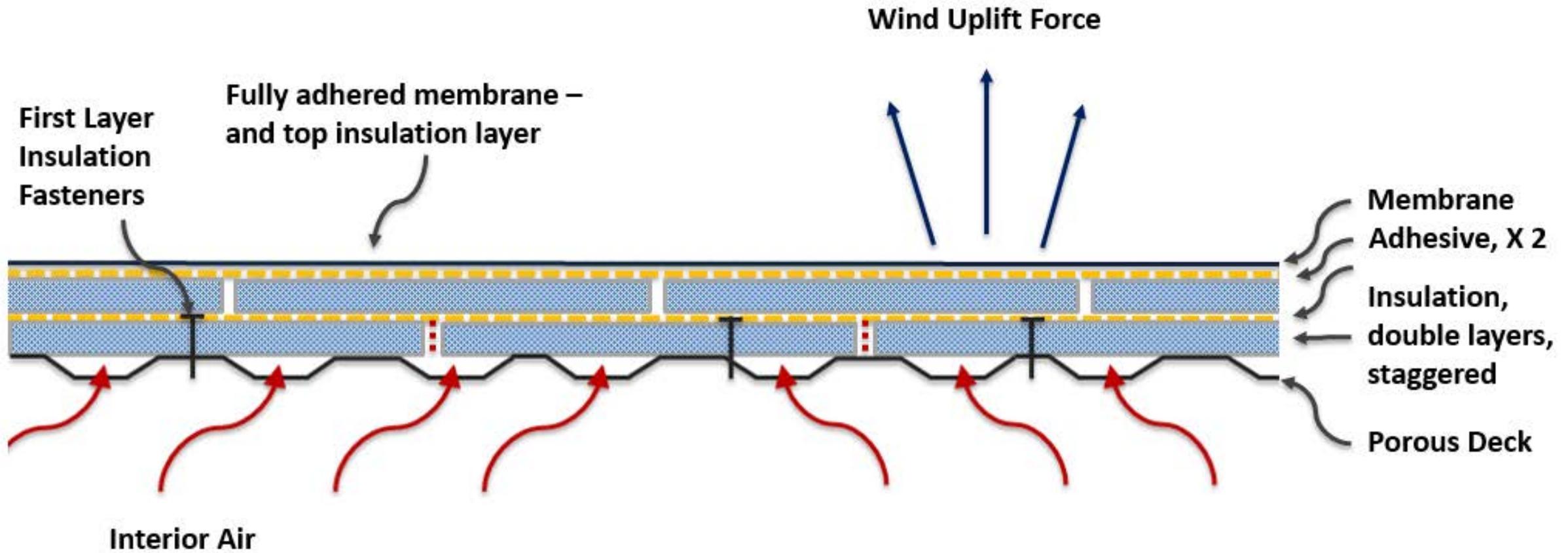


Wind Performance - Today's Standard...



Air can be drawn up into this assembly;
could be problematic with increased wind loads

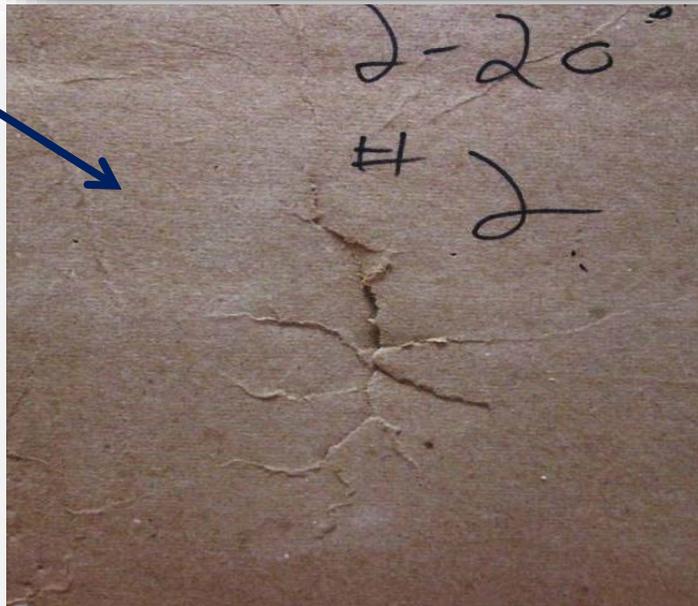
Today's Best System for Lowered Risk...



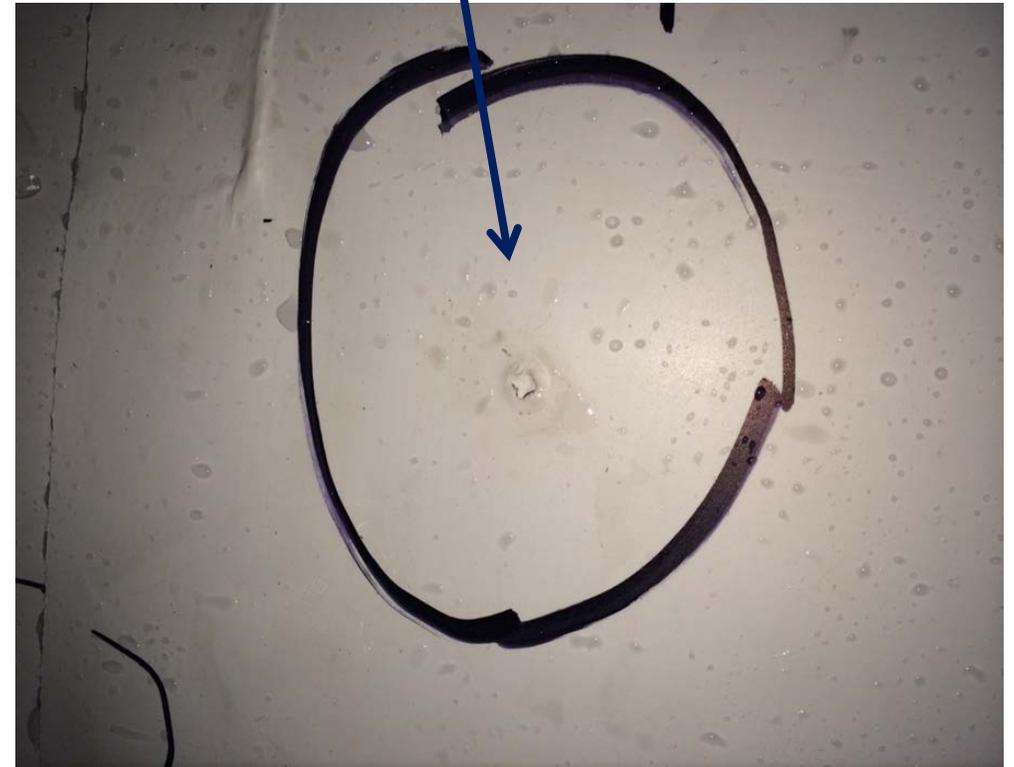
The **best** roof system – system is more monolithic, but, **load is still through the fasteners**

Impact Resistance - Damage

Polyiso is easily damaged in large hail events



Fastener head telegraph's through after 2 inch ice-ball impact.



High hail areas should consider fully adhered attachment!

Impact Resistance – Recommended Approach

- Specify a cover board – HD polyiso offers some resiliency
- Fully adhere the membrane and the cover board
 - No exposed fasteners
- Consider thicker grades of membrane
- Consider using fleeceback membrane
- Specify a membrane that won't degrade for several decades



Figure 1 – Launcher used to direct freezer ice balls downwards to impact a simulated roof system.

INTRODUCTION

Single-ply membranes now represent over 50% of the U.S. commercial roofing market, with thermoplastic polyolefin (TPO) being the most often used. A recent study of TPO suggests that today's membrane could perform well past 20 years, and some manufacturers offer warranties out to 35 years for specific high-performance versions.^{1,2} The weathering of TPO has been examined in many laboratory studies and field evaluations. Performance has generally been assessed in terms of membrane cracking, surface erosion, and other characteristics that could lead to water intrusion.

Recently, the authors evaluated the puncture resistance³ and ice ball impact resistance of TPO membranes.^{4,5} Using 2-inch-diameter ice balls and following a procedure similar to that of FM 4473, *Specification, Test Method for Impact Resistance of Rigid Roofing Materials by Impacting with Freezer Ice Balls*,⁶ they found that as long as impact was not above a fastener, the membrane was not punctured. They recommended the use of fully adhered systems and adhered high-density (HD) polyisocyanurate (polyiso) coverboard to minimize damage to either the membrane or the underlying insulation. It was noted that HD polyiso suffers less damage after ice ball impact compared with gypsum cover board.

The previous work used unaged material, with all testing being done indoors at room temperature. Cullen noted, "The results of testing new materials may not be valid since the hail impact resistance of many roofing materials changes upon exposure to weather."⁷ Later, Crenshaw and Koozts also questioned the focus on testing only new materials.⁸ More recently, Graham has also cautioned, "Impact resistance testing is done on new, unweathered products at standard room temperatures." However, he noted that hail rarely impacted new roofs and, additionally, often occurred during decreasing temperatures.⁹

This work builds on our previous focus on the ice ball impact resistance of TPO systems and examines the effects of accelerated aging. As noted by Graham, it is important to recognize that the relationship between hail and ice ball impact resistance hasn't been established. Ice ball impact testing attempts to rank the performance of materials, but their correlation to hail resistance is not known.

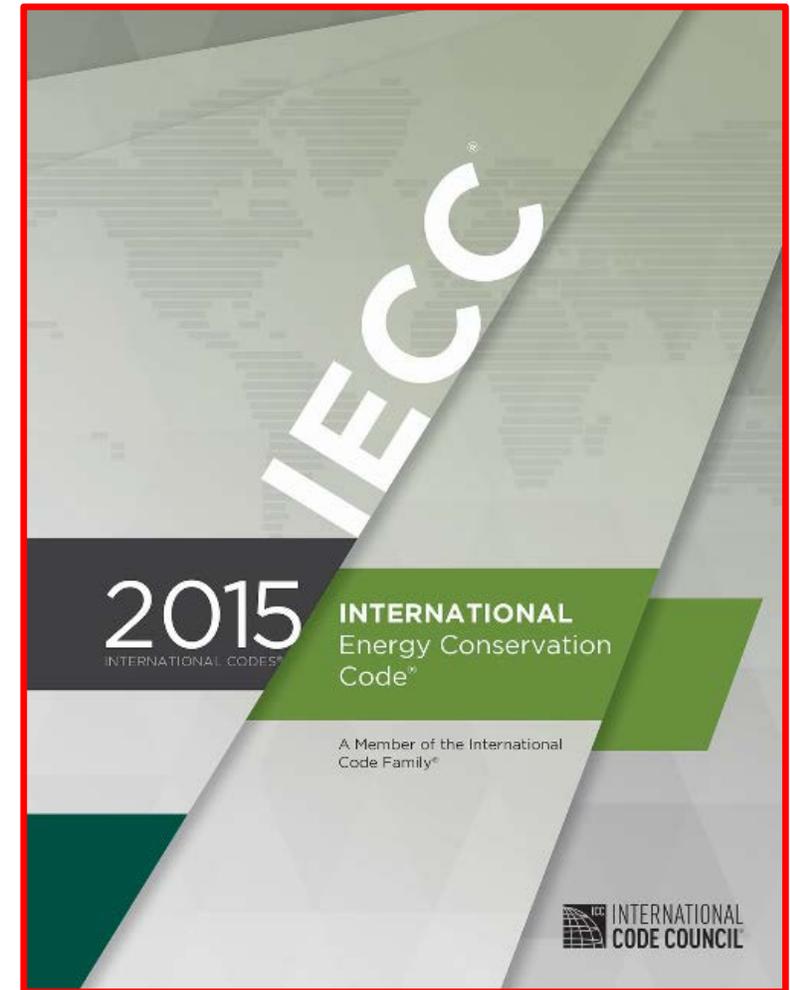


**Underside of
gypsum cover
board, after 2"
impact**

Insulation

International Energy Conservation Code

- IECC contains two separate sets of provisions
 - Commercial/Residential
- IECC—Commercial Provisions
 - “...apply to all buildings except for residential buildings 3 stories or less in height.”
- IECC—Residential Provisions
 - “...apply to detached one- and two-family dwellings and multiple single family dwellings as well as Group R-2, R-3 and R-4 buildings three stories or less in height.”



Insulation for Commercial Projects

3 Options

STANDARD

ANSI/ASHRAE/IES Standard 90.1-2016
Supersedes ANSI/ASHRAE/IES Standard 90.1-2013
Includes ANSI/ASHRAE/IES addenda listed in Appendix H

Energy Standard for Buildings Except Low-Rise Residential Buildings (I-P Edition)

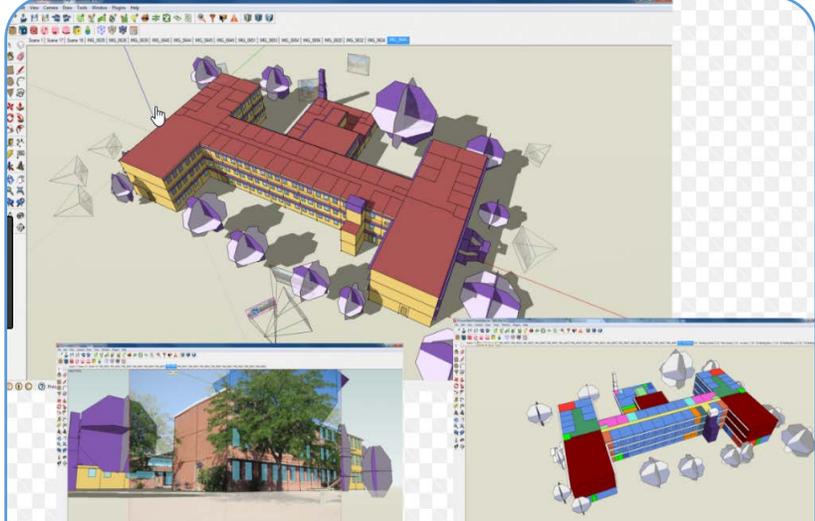
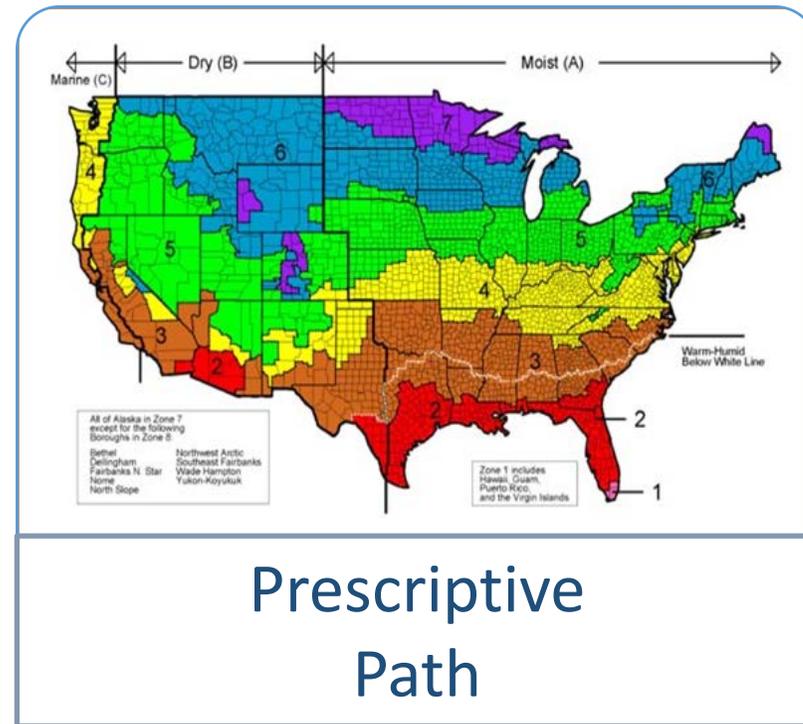
See Appendix H for approval data by the ASHRAE Standards Committee, the ASHRAE Board of Directors, the IES Board of Directors, and the American National Standards Institute.

The Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action or requests for change to any part of the Standard. The change substantial form, instructions, and deadline may be obtained in electronic form from the ASHRAE website (www.ashrae.org) or in paper form from the Senior Manager of Standards, the latest edition of an ASHRAE Standard may be purchased from the ASHRAE website (www.ashrae.org) or from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org, Fax: 404/528-2215, Telephone: 404/528-8600 (toll-free), or toll-free 1-800-521-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

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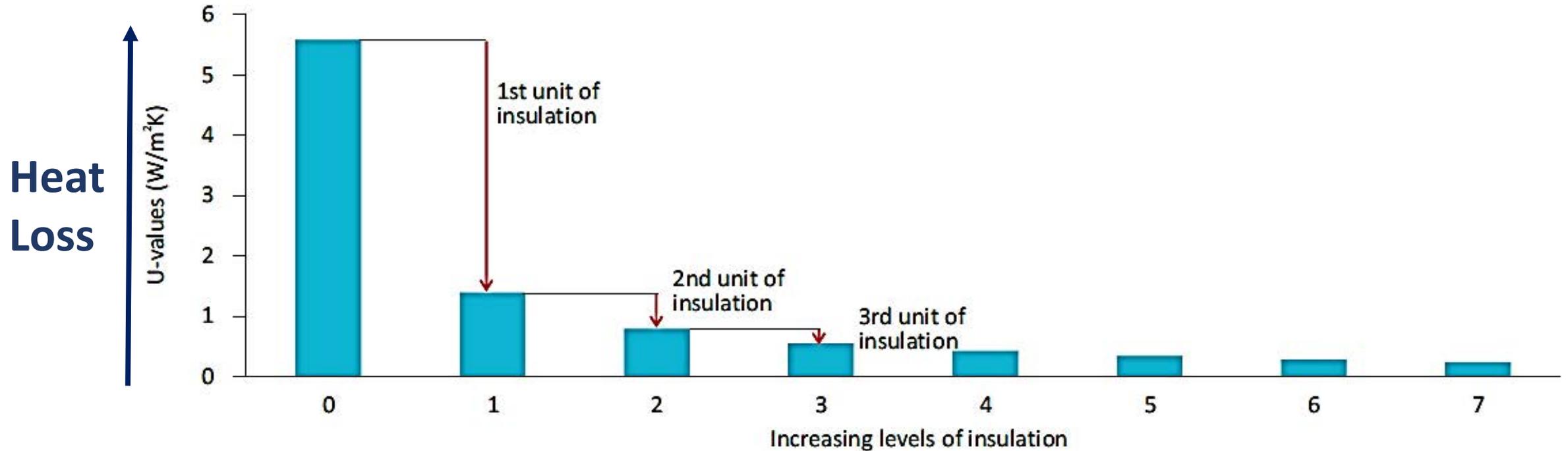


**ASHRAE
90.1**



**Performance
Path**

Diminishing Returns of Additional Insulation



Source: IEA (2013a), *Transition to Sustainable Buildings: Strategies and Opportunities to 2050*, OECD/IEA, Paris.

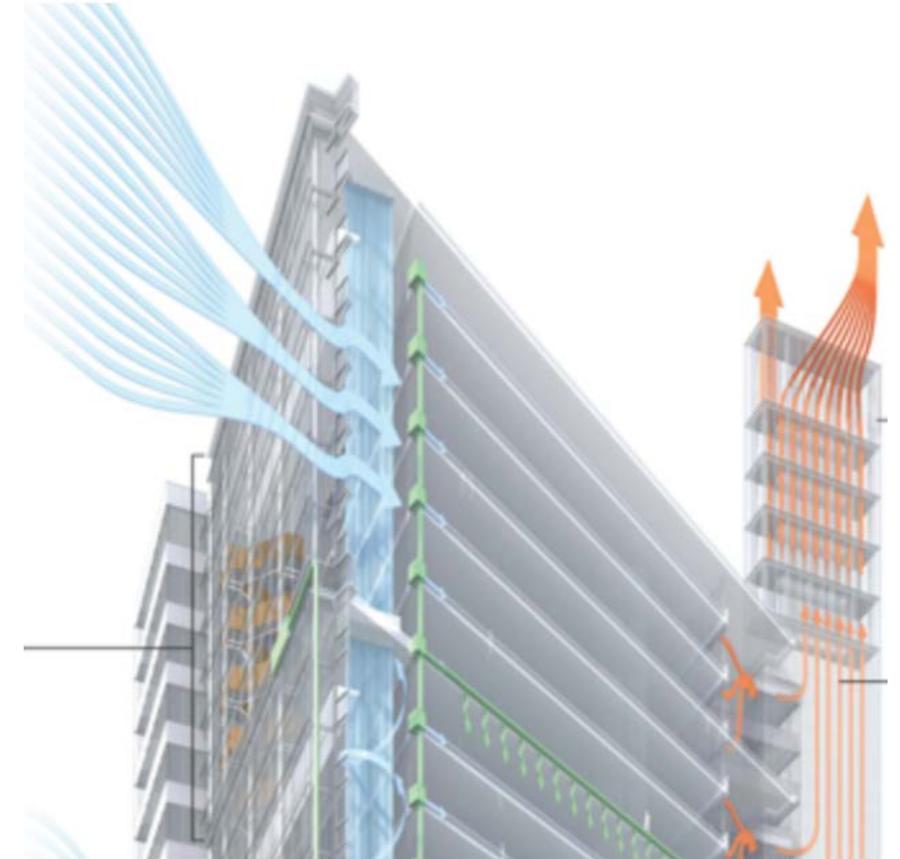
**Always be conservative and meet the latest Codes,
but we can't continue to pile on insulation**

Across all building types and climates, **reducing air leakage could save 5 to 40%** of heating and cooling energy

With reasonably tight structures in cold climates, **energy savings could be 20 to 30%**

Technology Roadmap

Energy efficient building envelopes



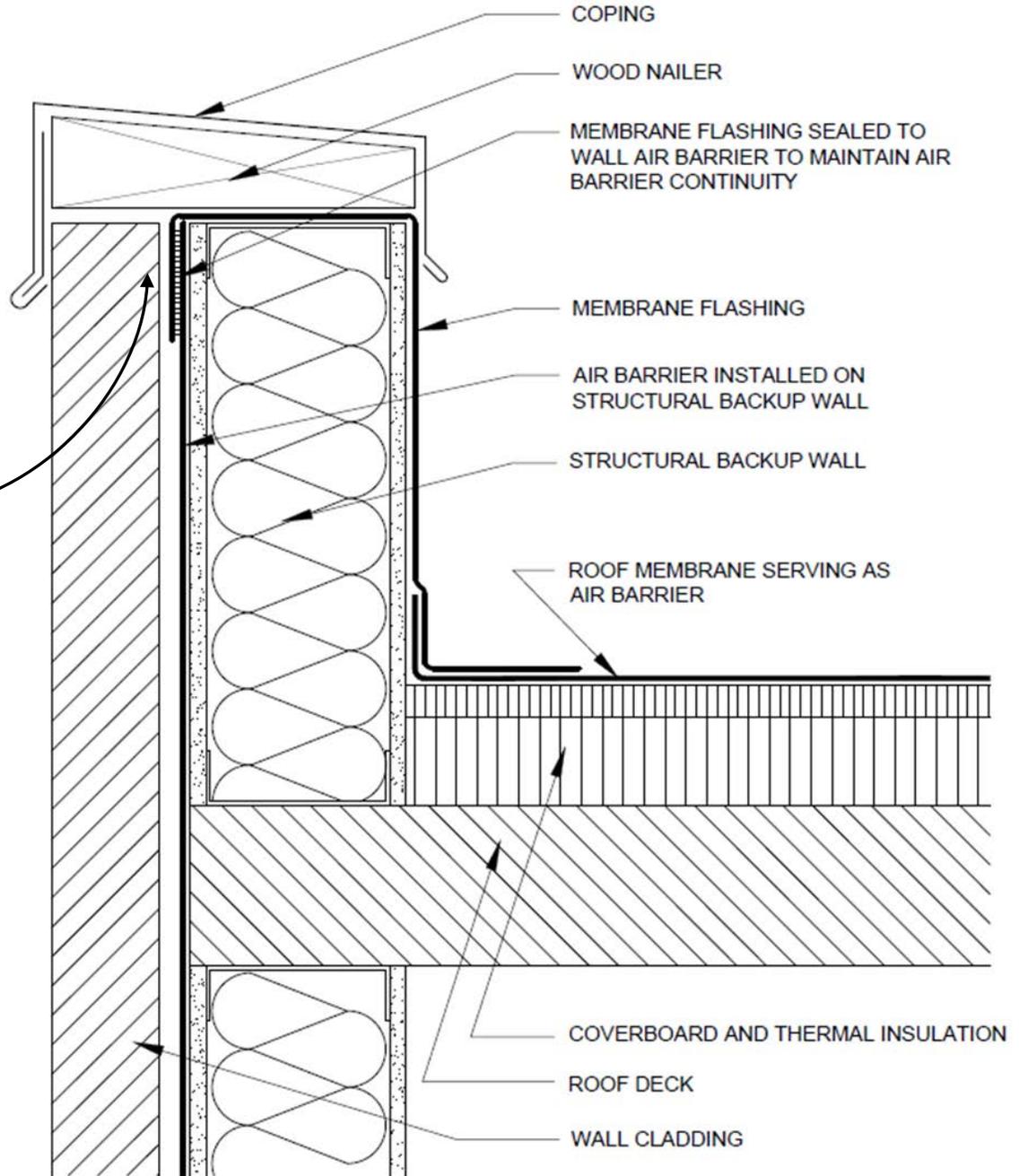
Air Barriers are Essential for Retaining Conditioned Air

Roof membranes are air impermeable

To be an Air Barrier they must –

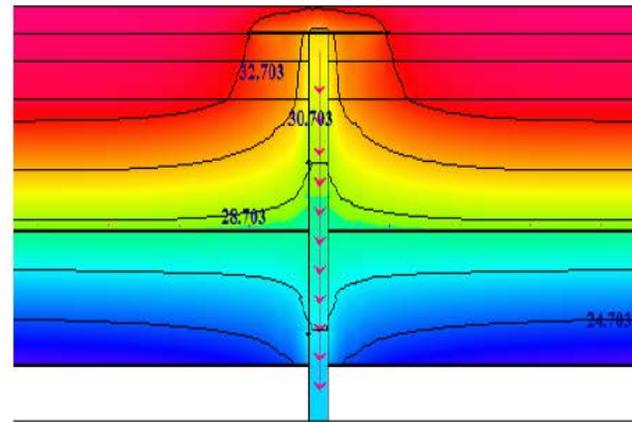
Be tied into the wall system

Hint – if the wall air barrier stops below the parapet wall, the roof membrane must extend down to it.

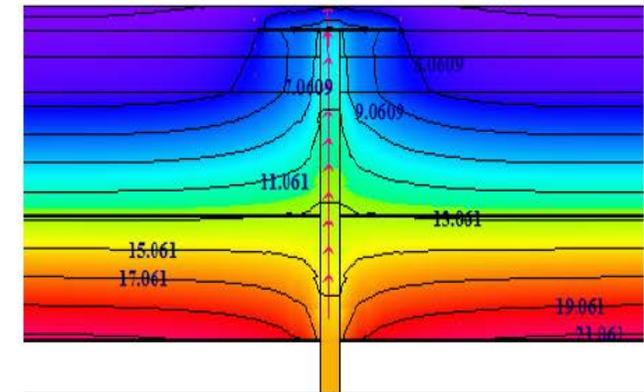
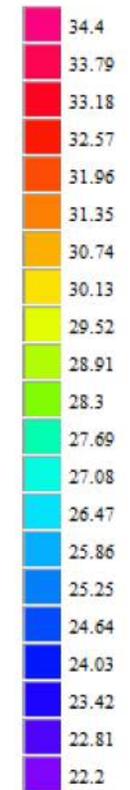


Fasteners and Thermal Bridging

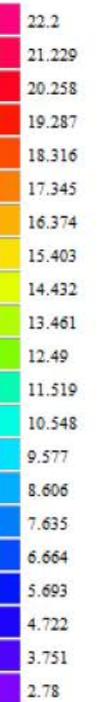
With Fasteners



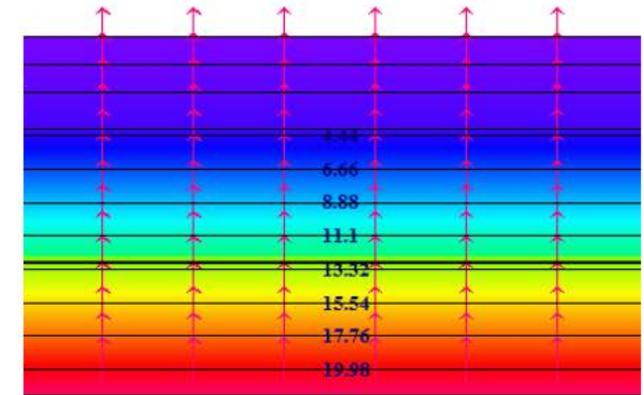
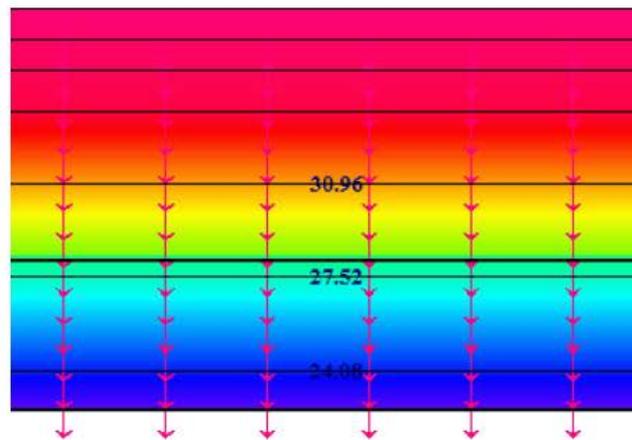
Temp [°C]



Temp [°C]



Without Fasteners



Summer Condition

Winter Condition

Thermal Bridges

Each “dot” is a fastener.



Adhesive or Fastener Attachment

The ideal installation includes adhesive or fastener attachment of bottommost layer.

- 2+ layers
- Staggered joints
- Fasten only bottom layer

This is the most energy efficient way to design, specify and install insulation.



Article

Optimizing Single-Ply Low-Slope Roofing Assemblies for Insulation Value

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Received: 22 March 2018; Accepted: 26 April 2018; Published: 28 April 2018



Abstract: Low-slope roofing assemblies can be designed with a range of insulation and membrane-attachment methods. Various building and energy codes appear to assume fastening methods to have an insignificant effect on insulation value, meaning that design and effective values are essentially the same. Recent studies showing that mechanically fastened systems could have very significant loss of insulation value are reviewed. This study uses thermal losses shown in those recent studies and examines the practical effect on various roof assemblies. Fully mechanically attached systems are compared with those that use adhesive attachment for the membrane and part of the insulation assembly. The thermal losses are shown to be significant and are presented in terms of the economic loss of the insulation. The cost of lost R-value is contrasted with the cost of attachment. A system based on a first layer of mechanically attached insulation with a second layer of insulation and membrane being adhered is shown to be very similar in cost, once the lost R-value is included. Finally, the loss in energy efficiency is calculated over a 15-year time frame. When total system costs include fastening as well as energy efficiency, then mechanically attached systems are essentially equivalent to some fully adhered approaches. Overall, the work challenges the code assumption that fastening methods do not significantly impact insulation efficiency. Furthermore, the results have implications for any analysis that considers such factors as carbon footprint, since building-energy efficiencies might be lower than currently assumed.

Keywords: roofing assemblies; steel fasteners; heat transfer; energy impact; insulation value

Roof System Resilience – Conclusions

- Roof systems and designs are available that are more resilient than before
 - ✓ In the good, better, best approach to roof design – BEST needs to be implemented more often
 - ≈ As weather events get more “extreme” designers and manufacturers need to continue to strengthen systems

Recap:

Resilience is the ability to:

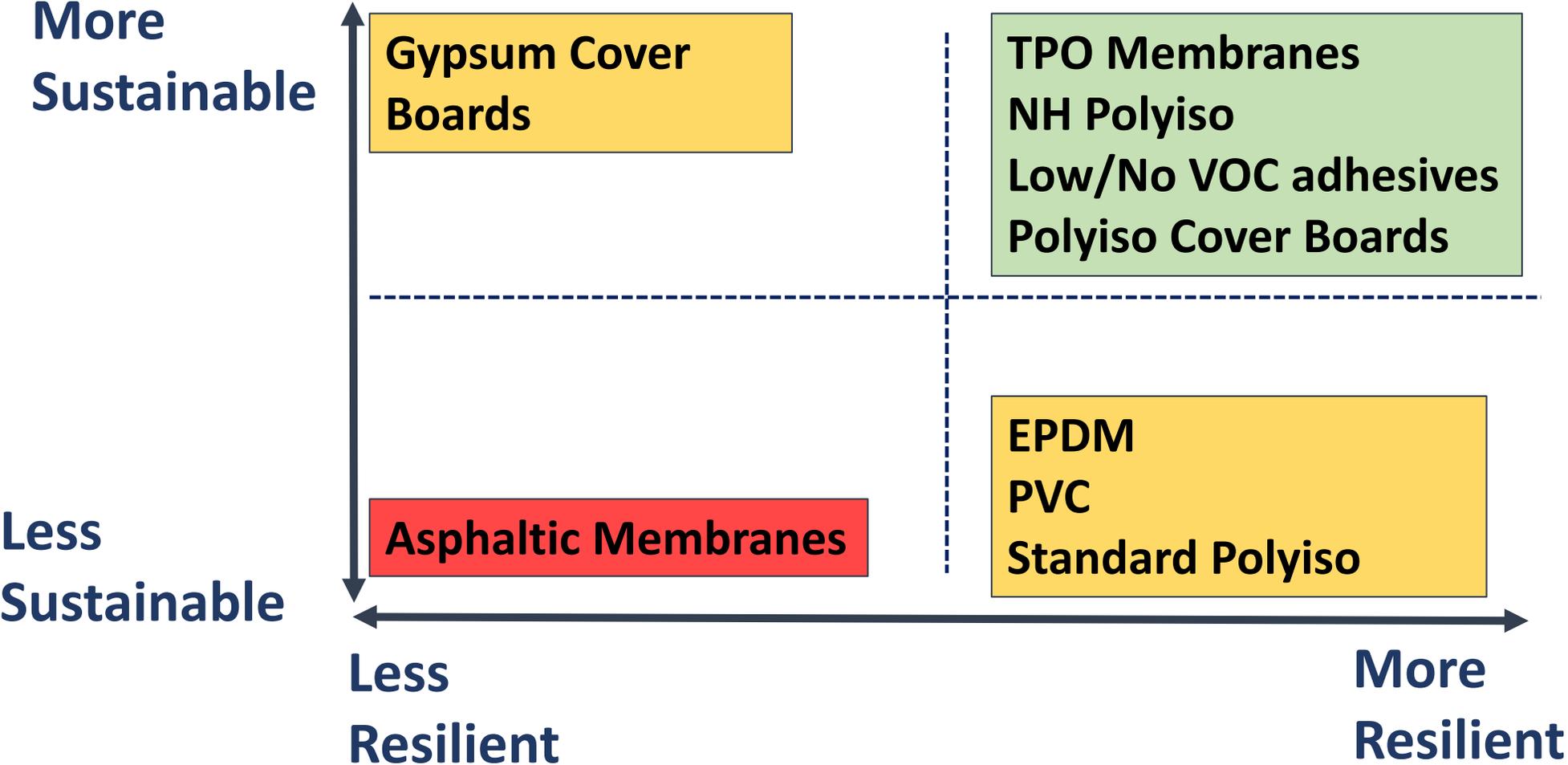
- Overcome unexpected problems
- Continue or rapidly bounce back from extreme events
- Prepare for and survive catastrophes

Let's Recap...

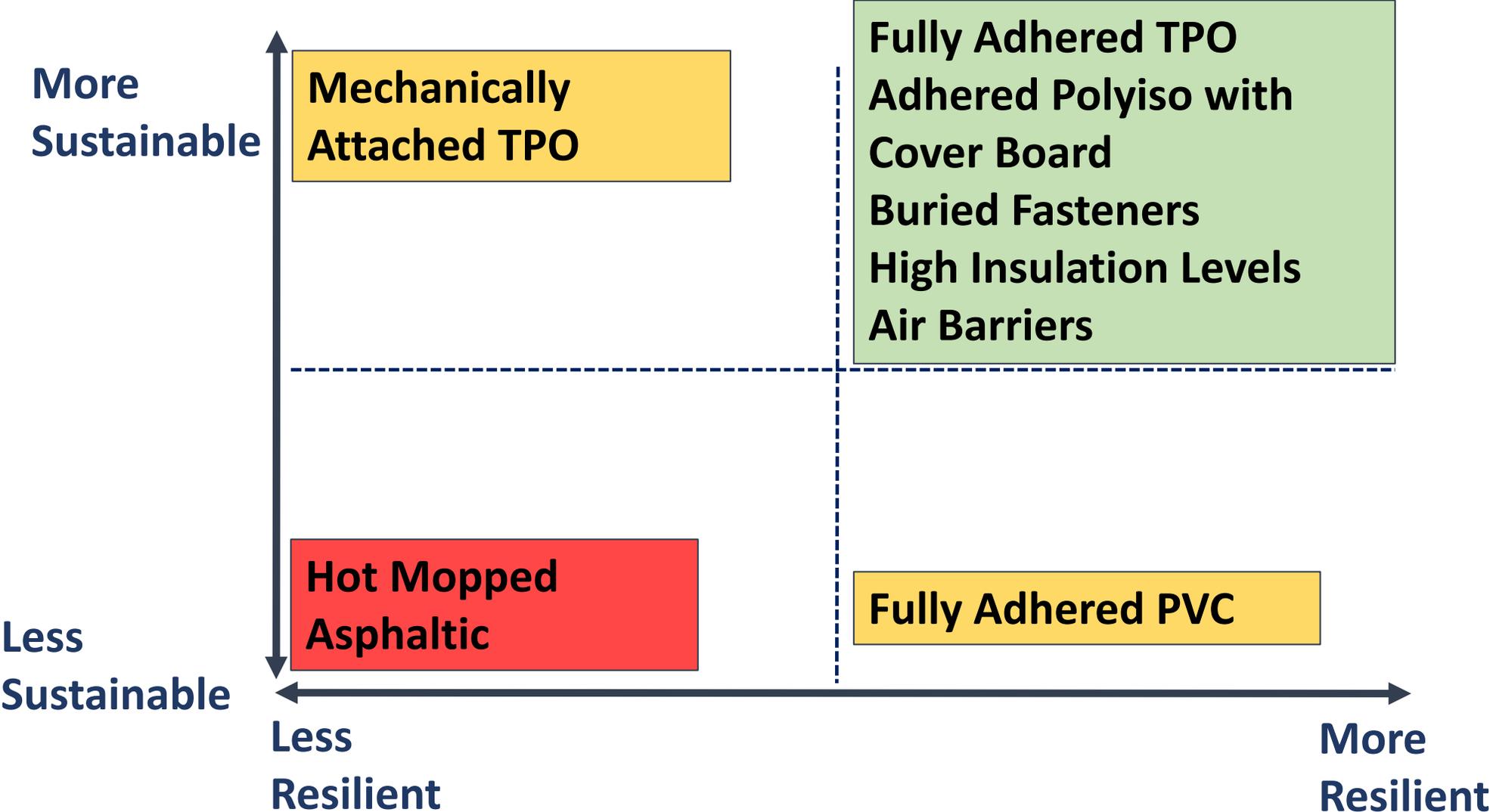
- We've reviewed resiliency and sustainability
- For roofing
 - Sustainability tends to be a product discussion
 - Resilience is more about system design

Lets return to the Sustainability versus Resilience Four Blocks....

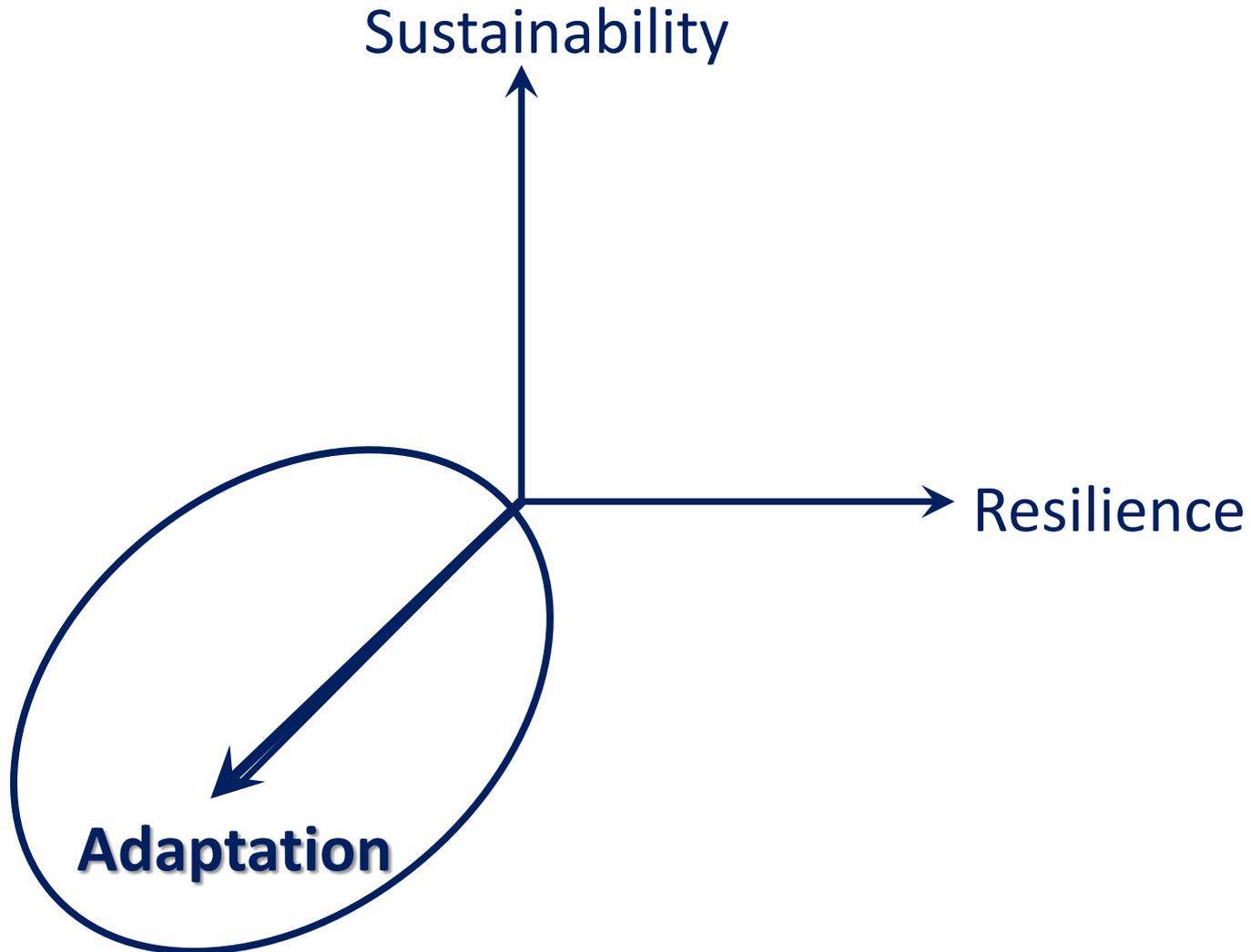
Considering Products...



Considering System Design...



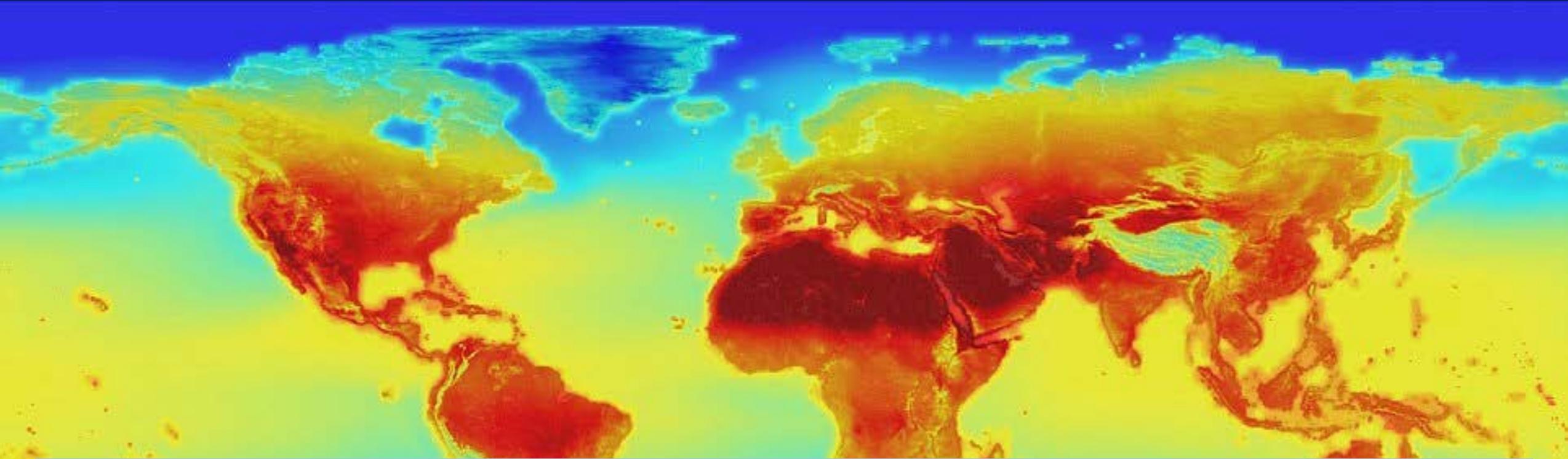
Let's Examine the Third Axis...



Recap:

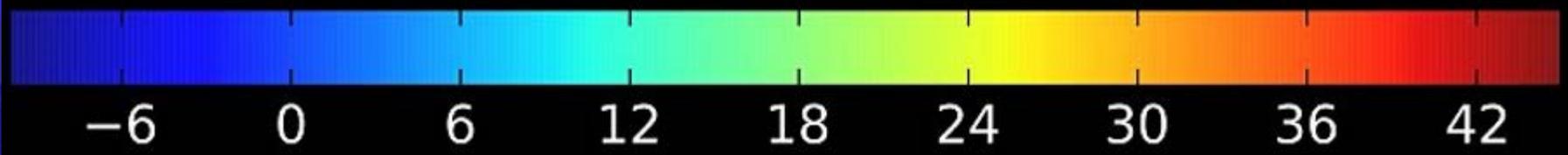
Adaptation is the ability to:

- Adjust to changing conditions
- Modify behavior in response to new circumstances
- Prepare for and survive long term change



Today's lessons will not be sufficient for future changes!

Daily peak temperature increases between now and July 2100 (Source – NASA)

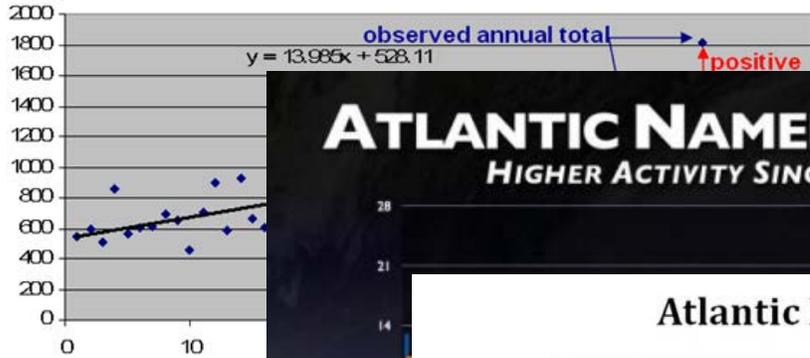


Changes We Have Already Adapted to Will Continue

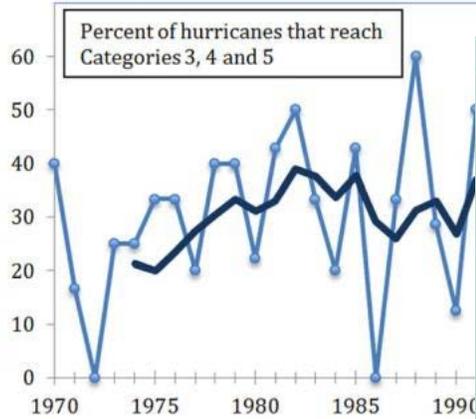
The world's weather has changed from being driven by predictable climate cycles...

Climate change is superimposing unknowns and creating a clear threat to the status quo.

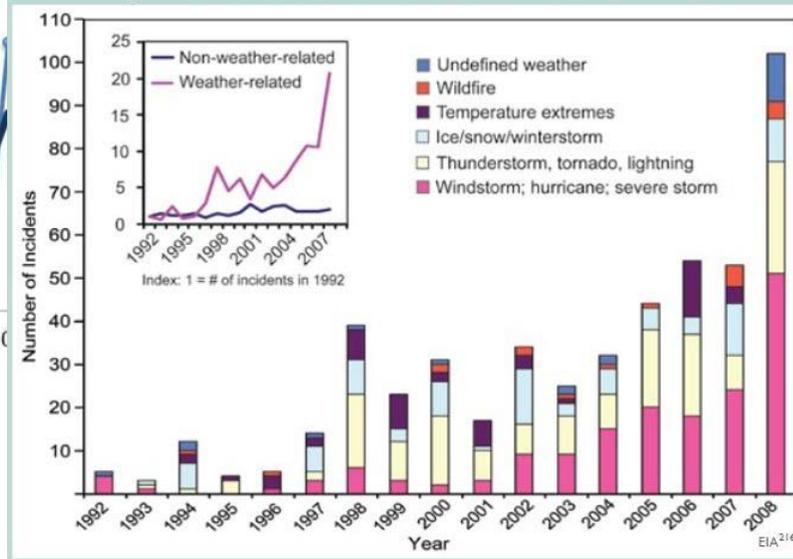
Tornadoes per year and linear trend



Atlantic Hurricanes Grow Stronger



Significant Weather-Related U.S. Electric Grid Disturbances



Roof System “Challenges” – Tomorrow’s Issues

Urban Temperatures

- Increased severity of urban heat islands

Storms

- Increased risk of high wind events
- Continued increase in power outages

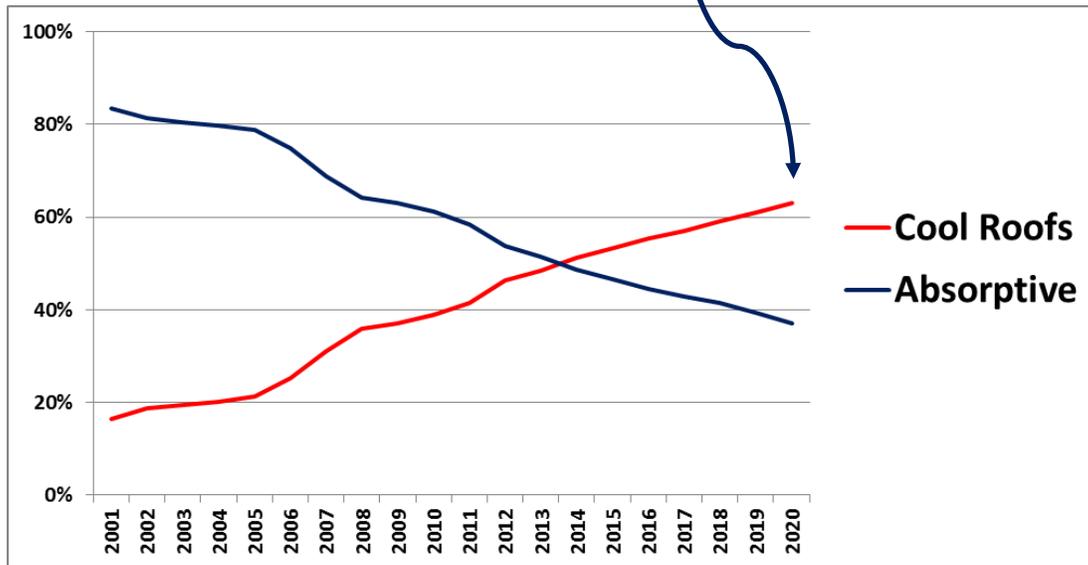
Water

- Run-off control as urban areas get larger
- Water availability after system disruptions

Cool Roofs

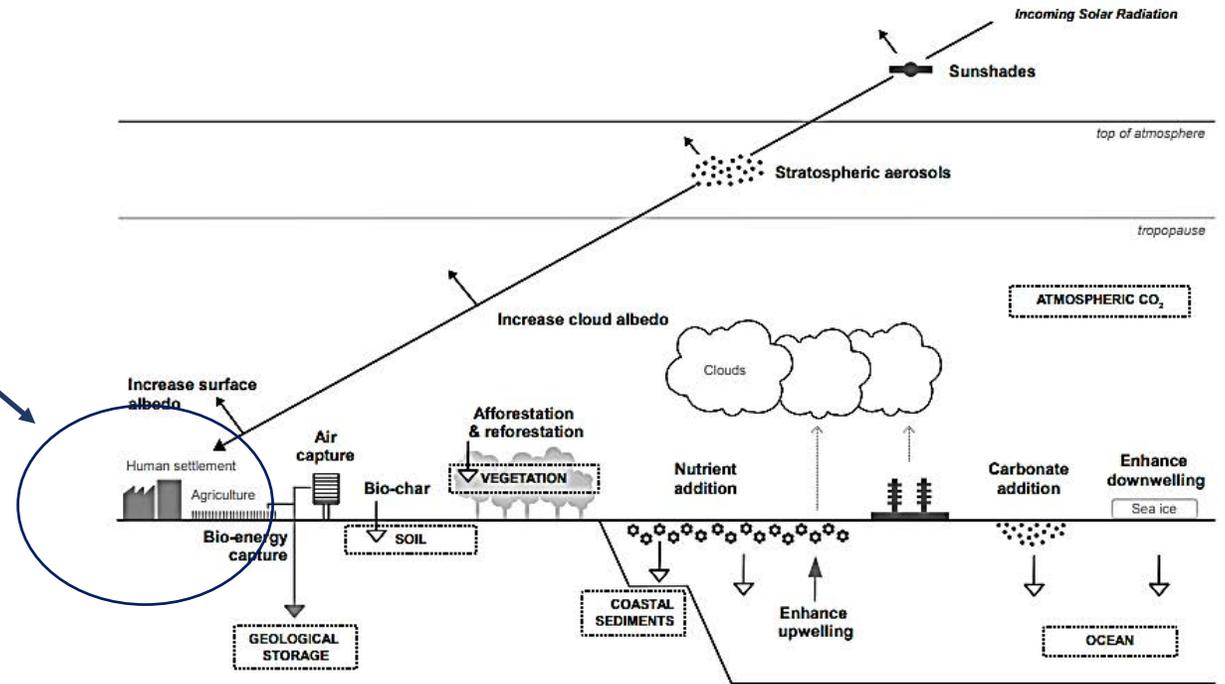
Lenton & Vaughan recognized that cool roofs are a simple “adaptation strategy to long-term global warming”, in 2009

But, we still have further to go



T. M. Lenton and N. E. Vaughan: Radiative forcing potential of climate geoengineering

5541



Can Cool Roofs be Cold Roofs? The “Super Cool” Roof!

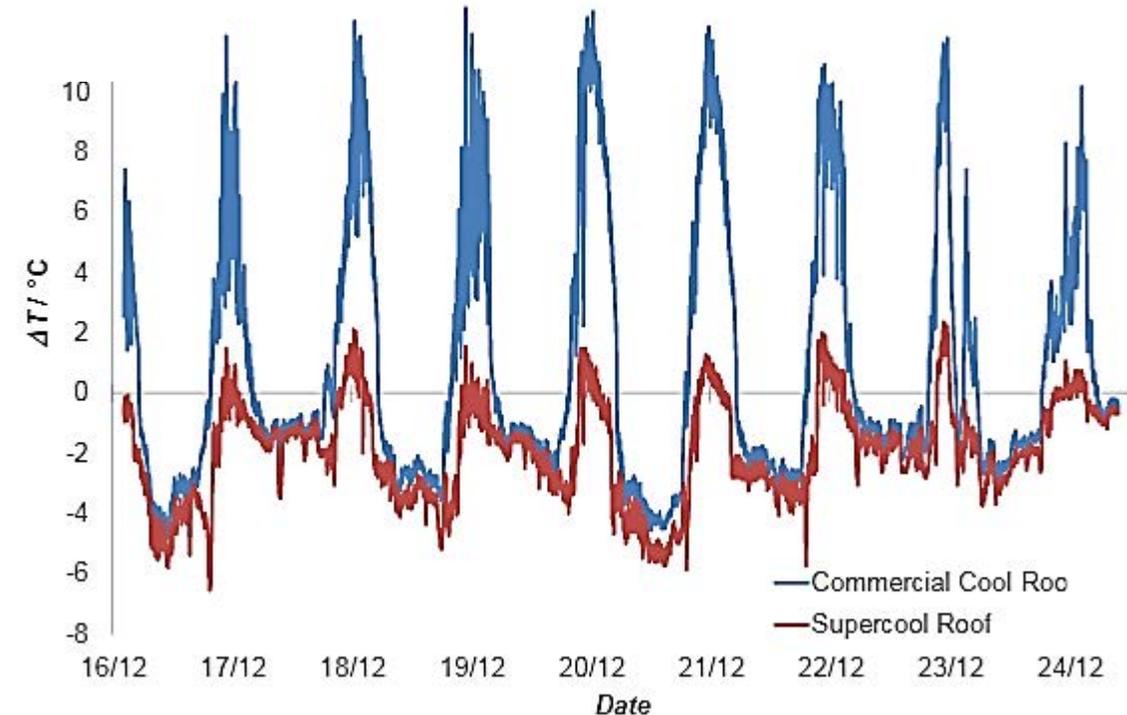
A Subambient Open Roof Surface under the Mid-Summer Sun

Angus R. Gentle, Geoff B. Smith ✉

First published: 26 May 2015 | <https://doi.org/10.1002/adv.201500119> | Cited by:26

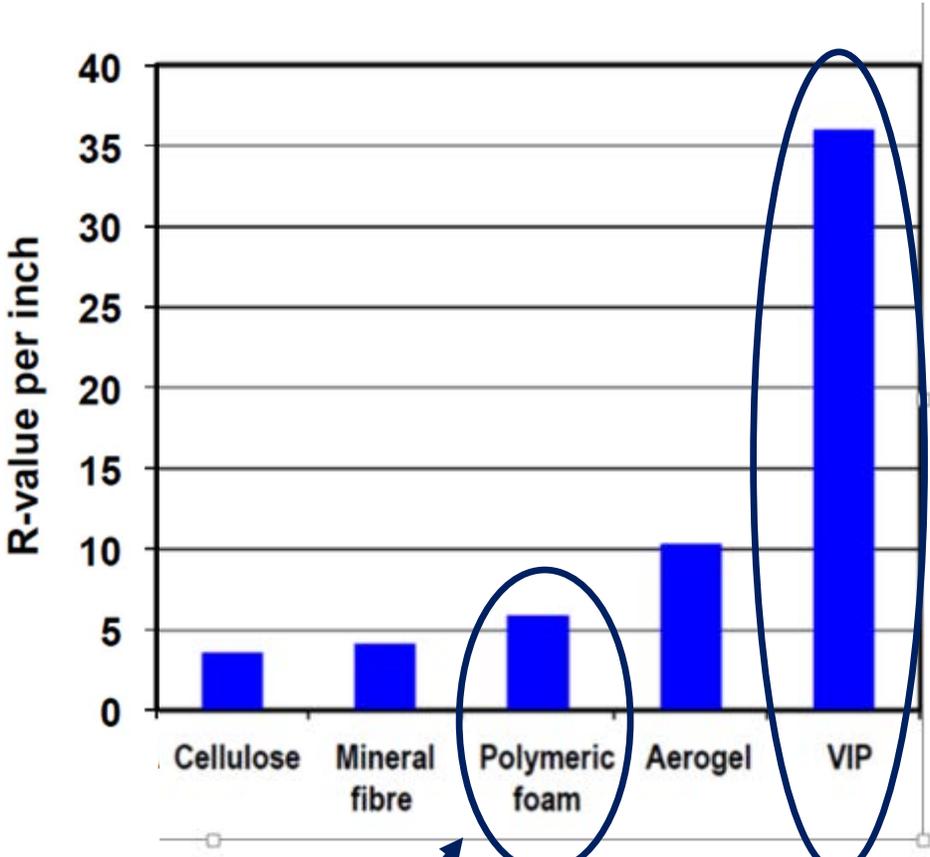
A novel material open to warm air stays below ambient temperature under maximum solar intensities of mid-summer. It is found to be 11 °C cooler than a commercial white cool roof nearby. A combination of specially chosen polymers and a silver thin film yields values near 100% for both solar reflectance, and thermal emittance at infrared wavelengths from 7.9 to 13 μm .

New research into roof materials that can keep a roof below ambient temperatures!



Temperature Compared to Ambient

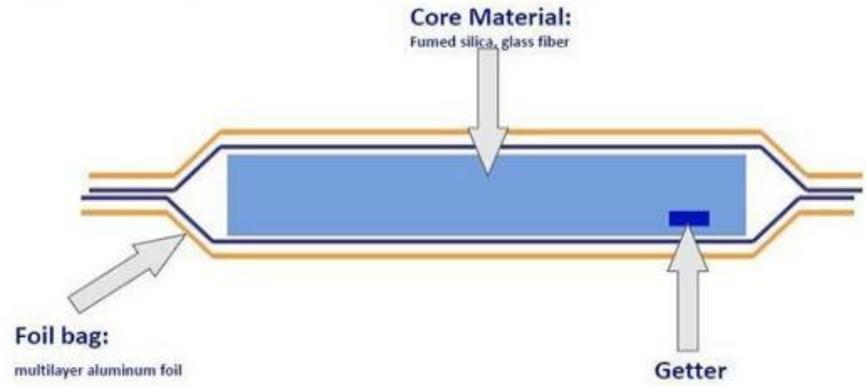
Step Changes in Thermal Insulation



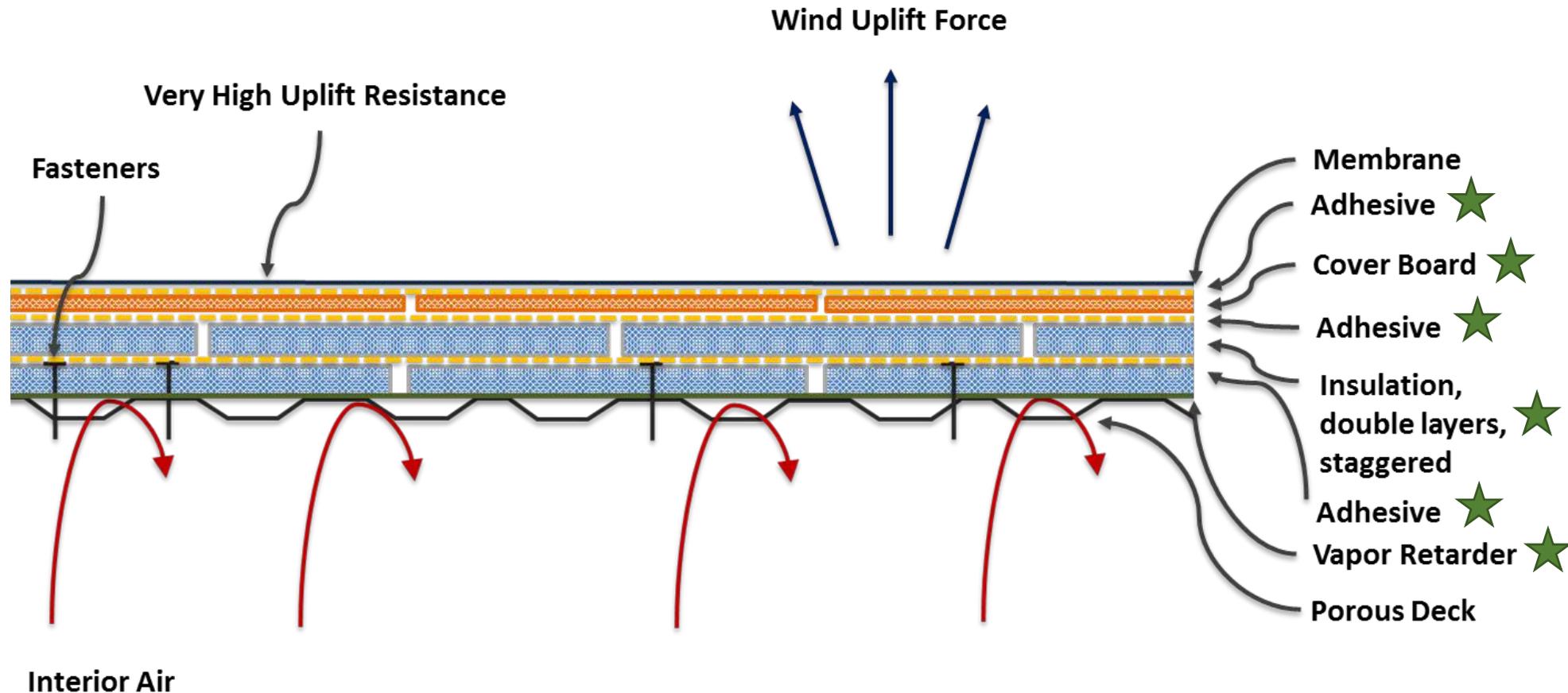
Where we are today

Where we could be tomorrow

Vacuum Insulated Panels



Looking at Future, Unknown Wind Events...

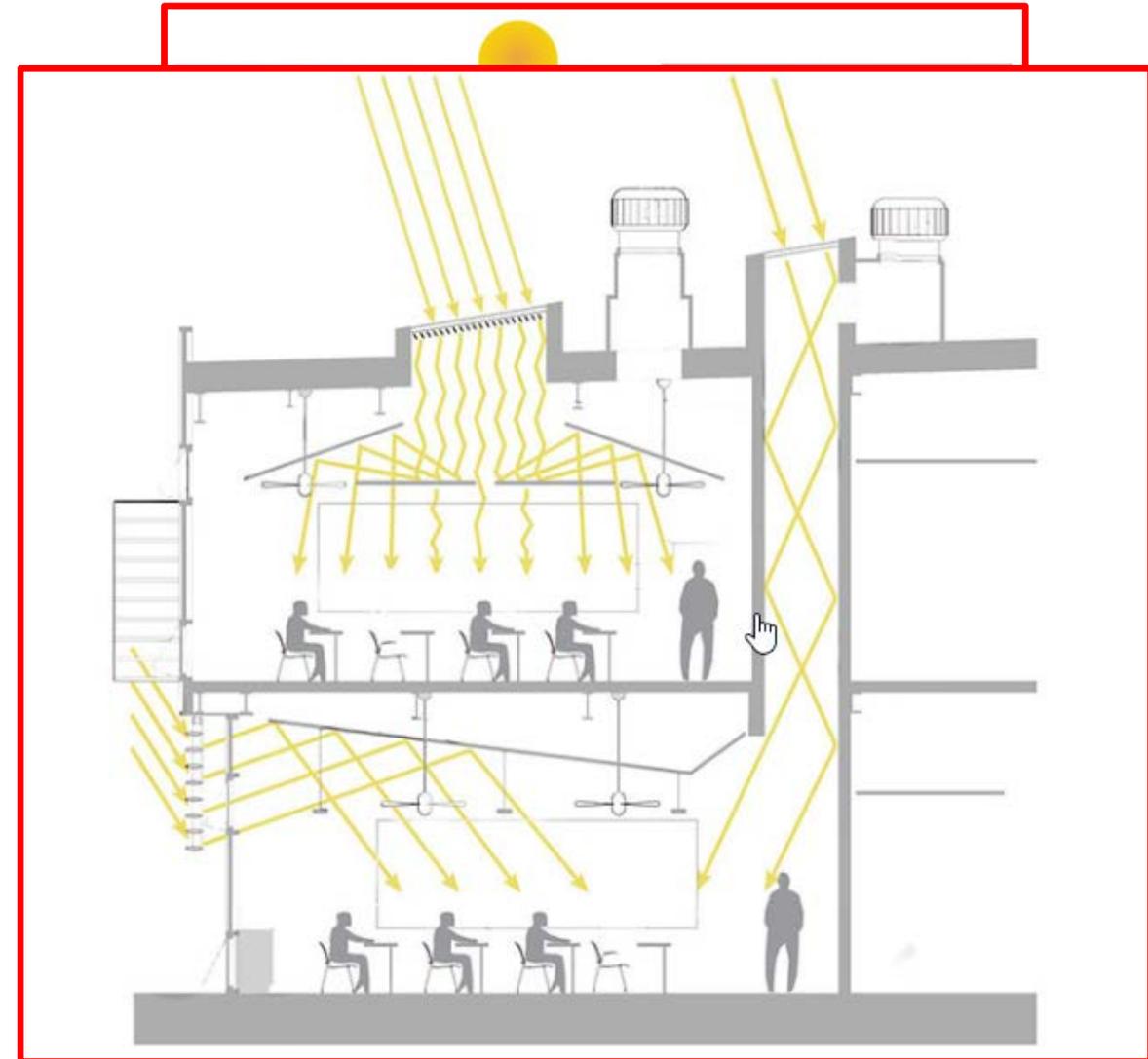


Basic roof design needs to be far more robust.

Today we know how to design almost monolithic assemblies with a distributed load path. ★ Elements that contribute to a monolithic system

Daylighting

- Daylight-optimized building footprint
- Climate-responsive window-to-wall area ratio
- High-performance glazing
- Daylighting-optimized fenestration design
- **Skylights (passive or active)**
- **Tubular daylight devices**
- Daylight redirection devices
- Solar shading devices
- Daylight-responsive electric lighting controls
- Daylight-optimized interior design (such as furniture design, space planning, and room surface finishes).

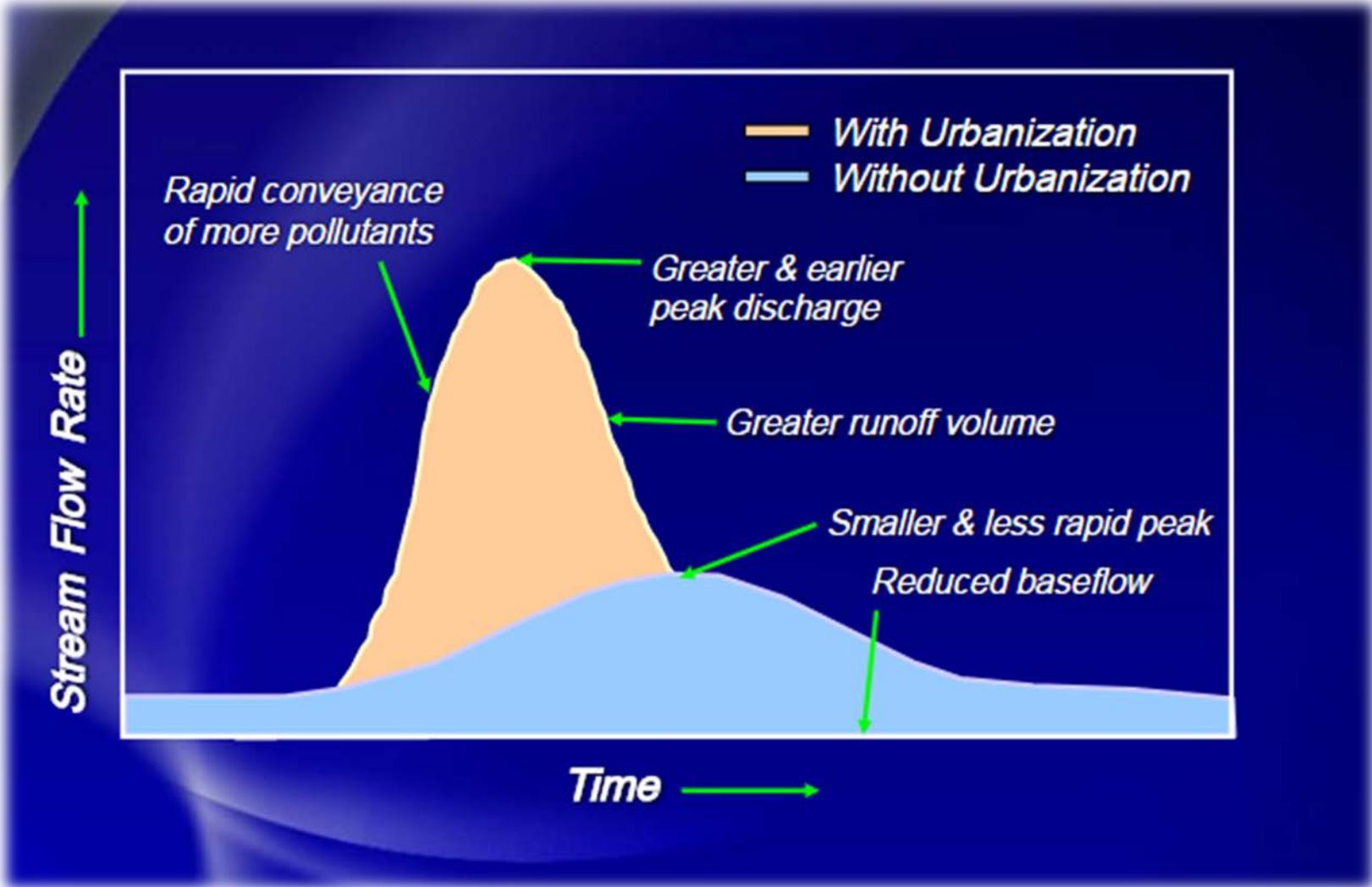


Changing the Function of Roofs...

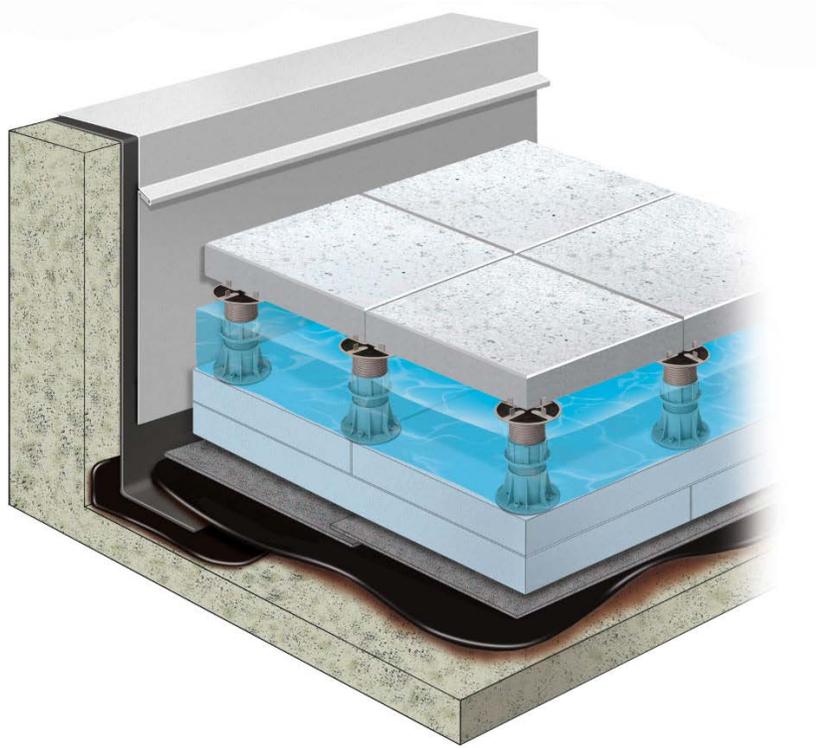
- Cool Roofs – not yet universally adopted
 - Radiative forcing by changing urban albedo*
 - Cool roofs are spec'd for energy efficiency, but climate change is a larger reason
- Water Capture
 - Large urban cities need to reduce/slow water run-off
 - Water supply is increasingly in jeopardy after large storms
- Energy Generation and Storage
 - Reduces power outage risks
 - Supports “micro-grid” concept for increased system resilience
 - Reduces societies reliance on carbon emitting generation – with a multiplier!

* T. M. Lenton and N. E. Vaughan, The radiative forcing potential of different climate geoengineering options, Atmos. Chem. Phys., 9, 2009, pp. 5539 - 5561

Water Run Off During Storms is Overwhelming Urban Storm Drains



Blue Roofs – Controlling Storm Water Before it Reaches Drains



Systems are already available –
this one shown courtesy of
Hydrotech Membrane.ca



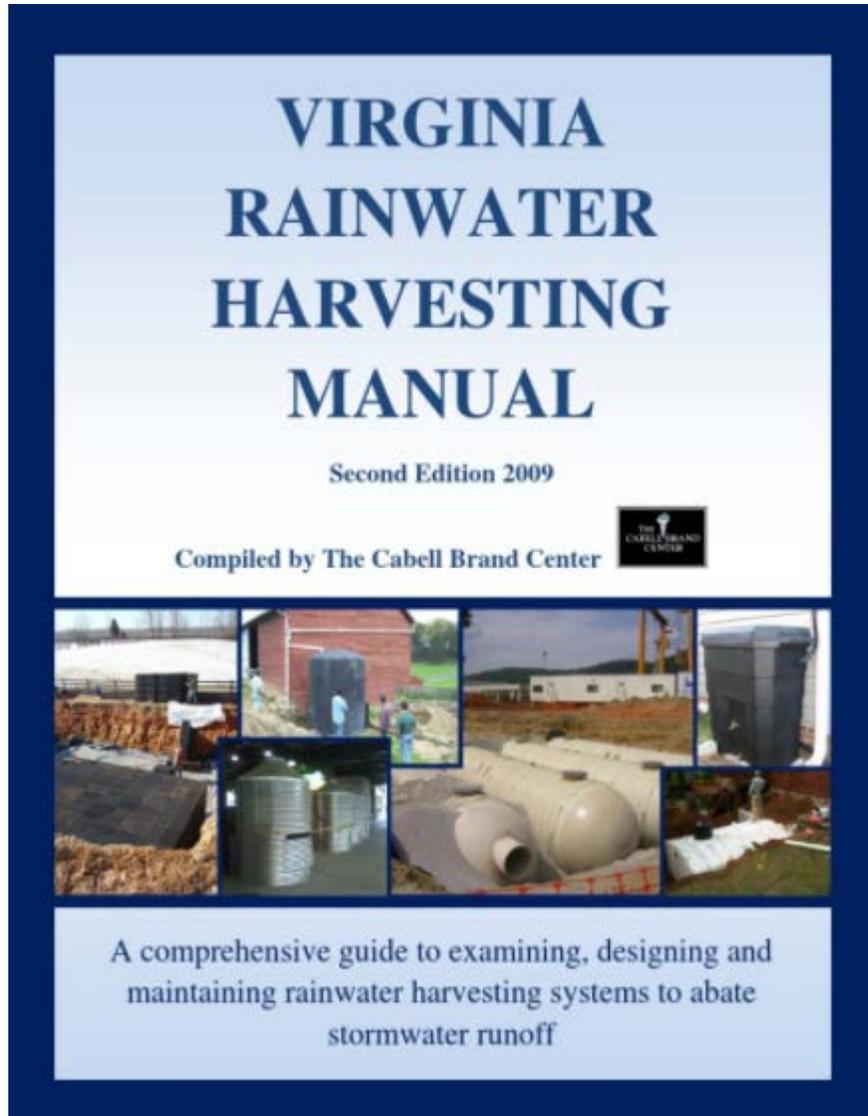
A New York City weir based approach

Green Roofs – Proven to Control Water Run Off

Bringing vegetation back to the living environment



Storm Water Capture and Use



Already practiced in some areas of the US

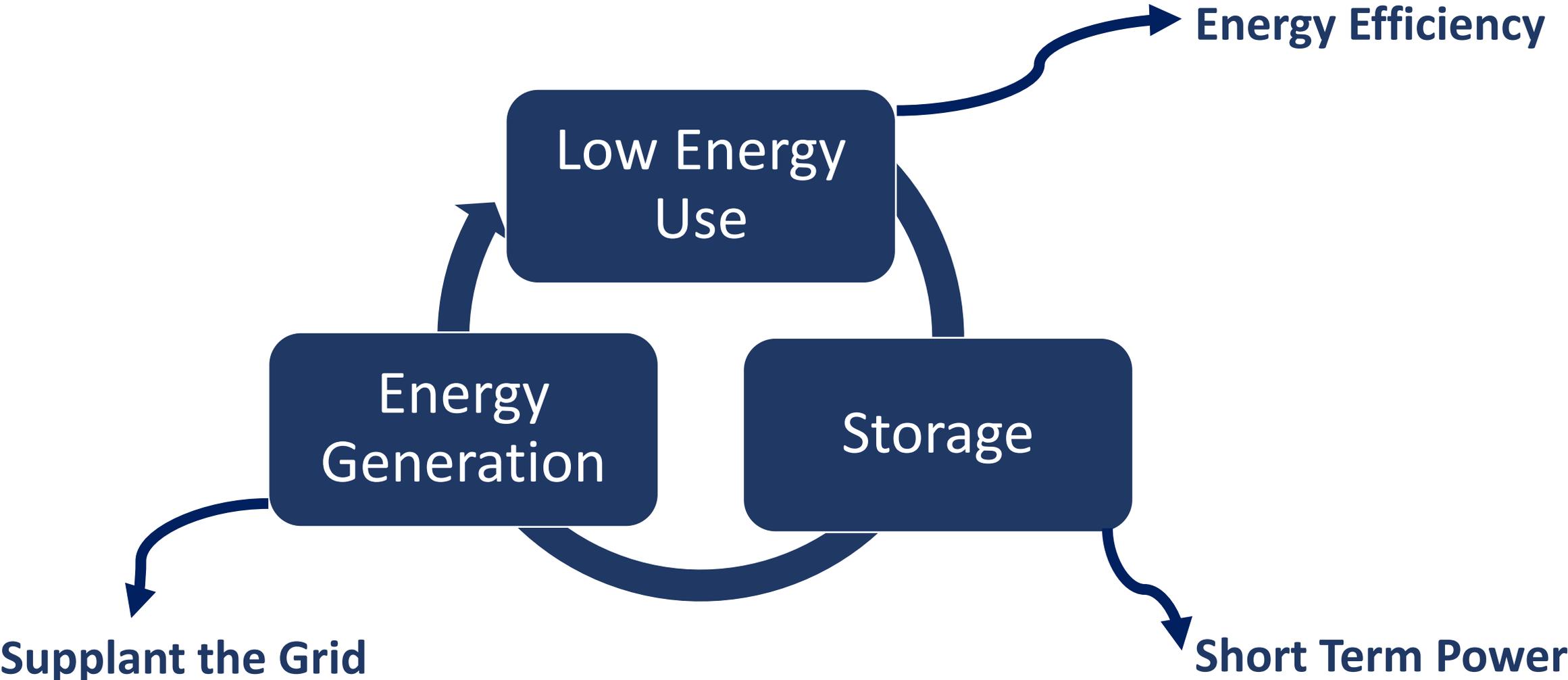


Today, Solar is Becoming Mainstream

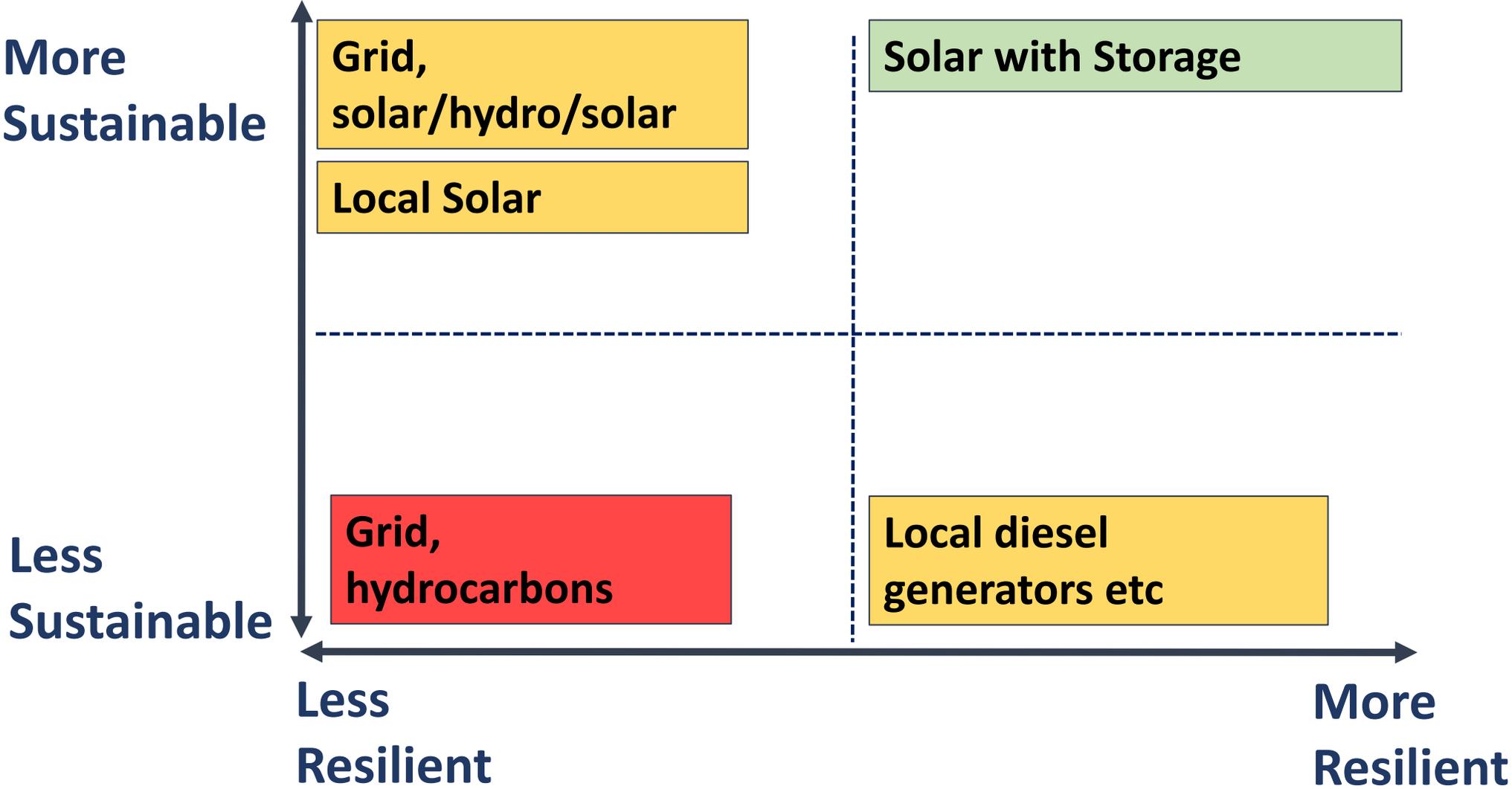


But, Without Storage it Doesn't Improve Resiliency

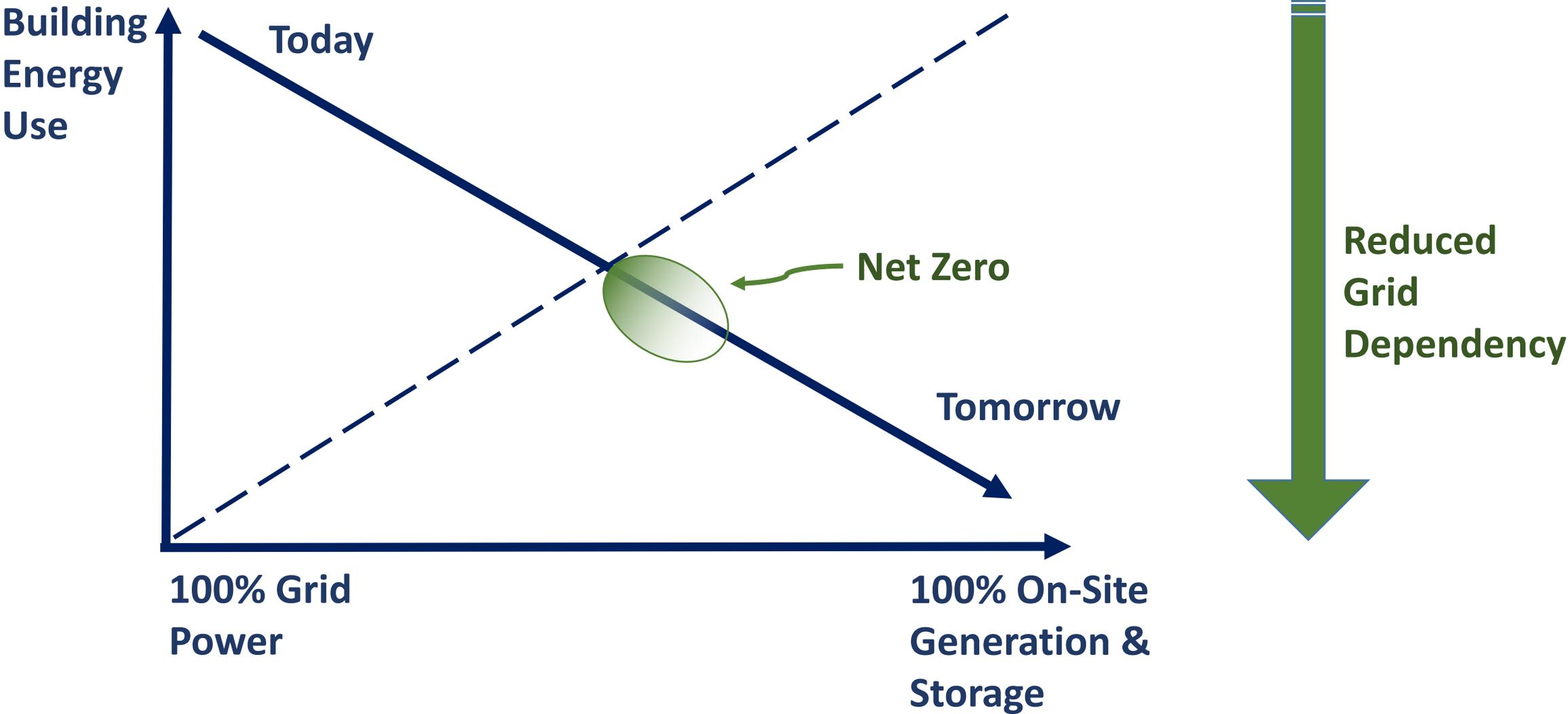
Energy Resilience



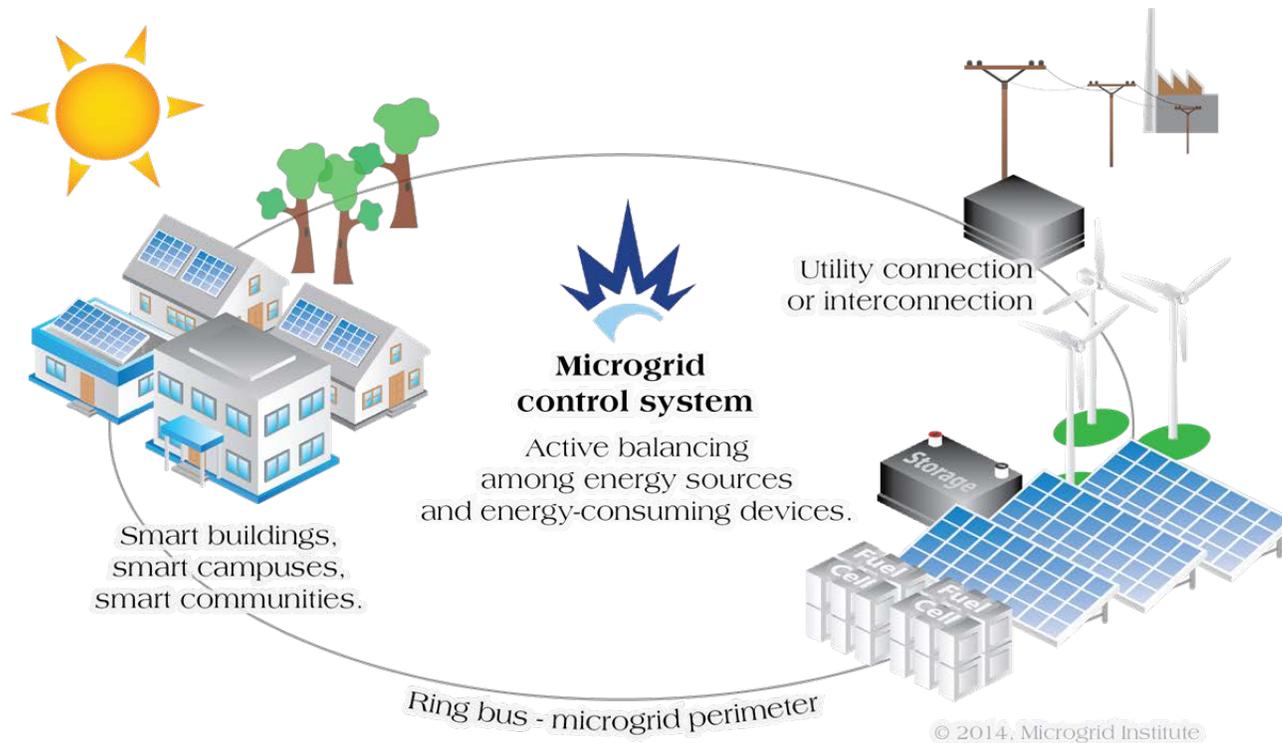
Considering Energy Sourcing...



Low Energy Use – The Transition to Net Zero



Paradigm Shift – Energy Resilience



Lower energy use

Insulation

Reflective Surfaces

Air Barriers

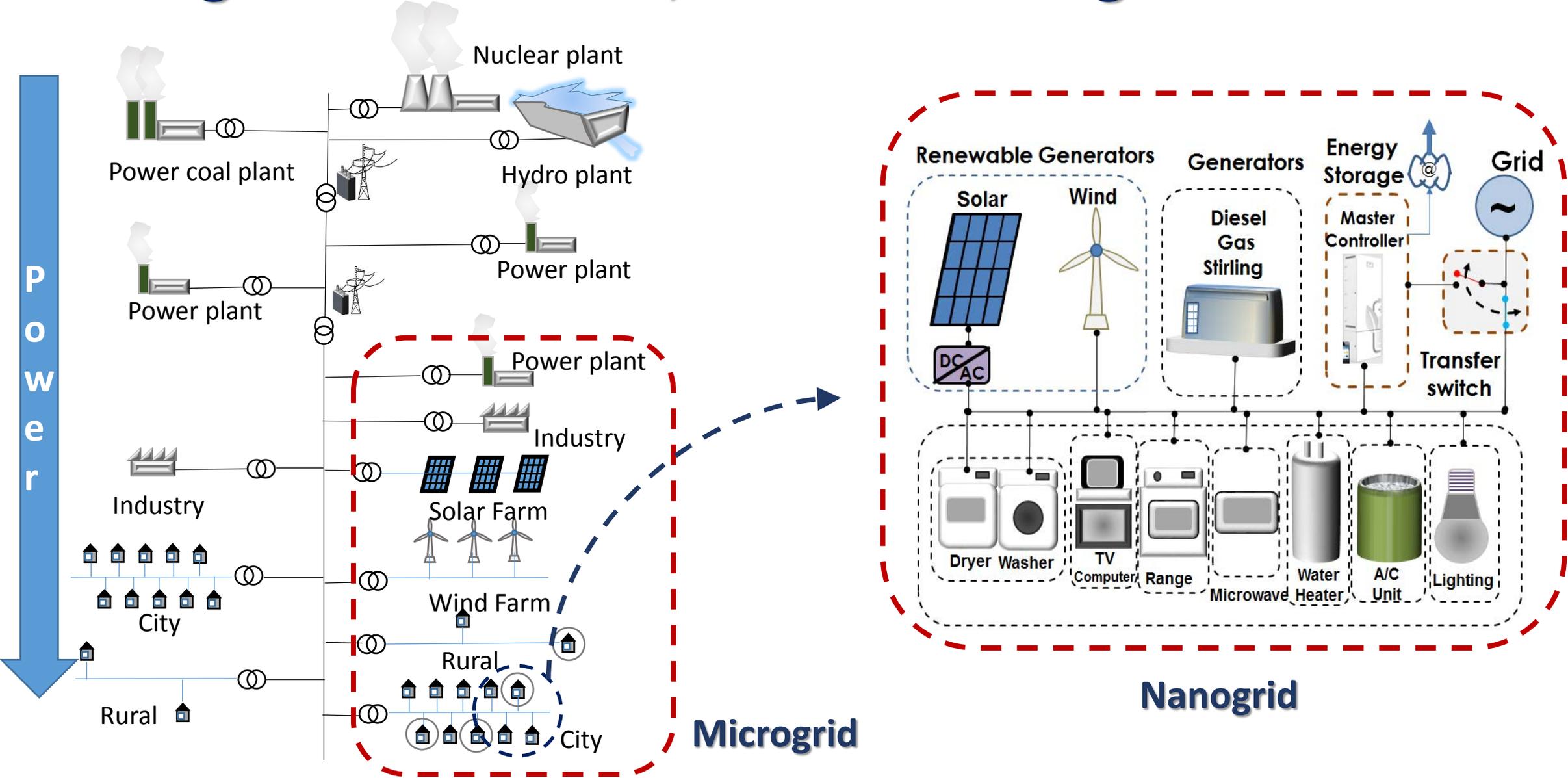
Efficient lighting / heating / appliances etc

Withstand loss of grid

Solar

Storage

Nanogrids – site based, are the building blocks!



Energy Storage with Solar Enables Community NanoGrids

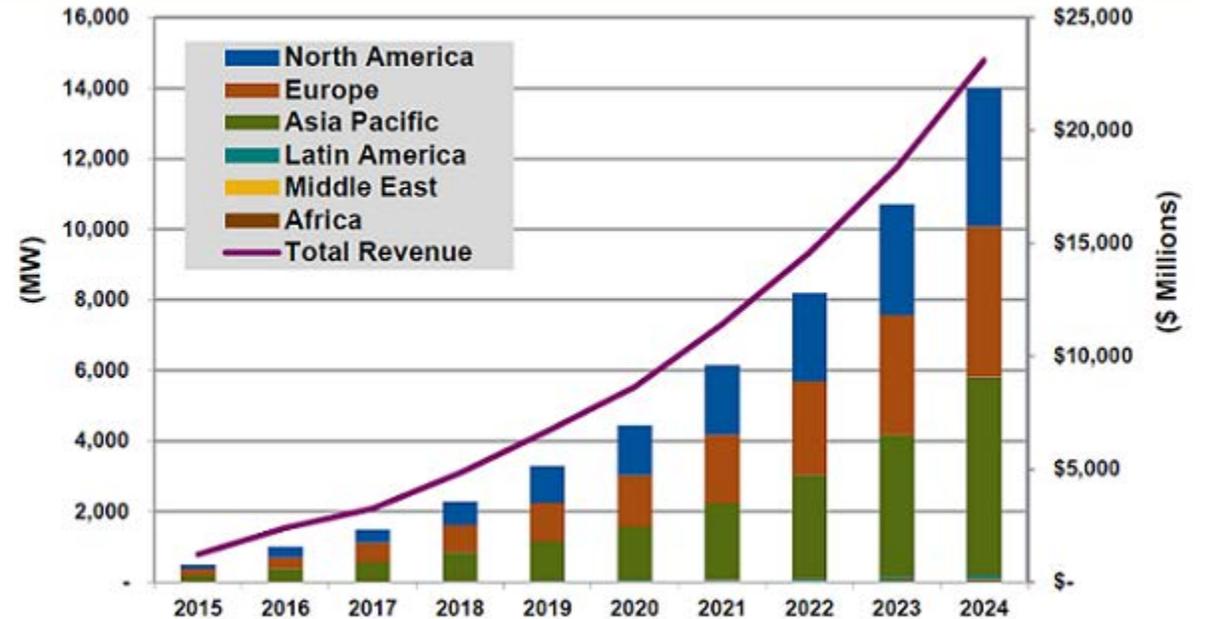
Energy Storage Product Overview



Product Line	Automotive	Residential	Commercial
Power/Energy	310 kW / 85 kWh	5 kW / 10 kWh	200 kW / 400 kWh+

Listed →
 Outdoor Rated →

Chart 1.1 Total Solar PV plus Energy Storage Nanogrid Capacity and Revenue by Region, World Markets: 2015-2024



(Source: Navigant Research)

Summary – Big Picture!

- The built environment is increasingly urban
- Urbanization could compound the effects of climate change
- Urbanization makes resilience more difficult
- Sustainable choices are available and readily made
- Resilience is about
 - Stronger / tougher buildings
 - Energy independence
- We can no longer build to known challenges but have to consider future unpredictability

Conclusions – For the Roofing Designer!

- **Sustainability**
 - TPO & Non Halogenated Poly Iso with Water based or low VOC/foamed adhesives are reasonable choices.
- **Resilience**
 - Use Conservative Wind Design – totally fully adhered systems
- **Resilience**
 - Robust Impact Design (fully adhered 80+ mil fleeceback membrane and cover board)
 - Enhanced Thermal Design (fully adhered or buried fasteners vs MA; account for future code increases through adaptable design)
 - Air Barrier Continuity (maintain conditioned air through proper parapet detailing)
- **Adaptation**
 - Consider Roof Function to include Energy Generation and Water Storage
 - Daylighting
 - Encourage more advanced membranes and insulations