Energy in Buildings and Communities Programme

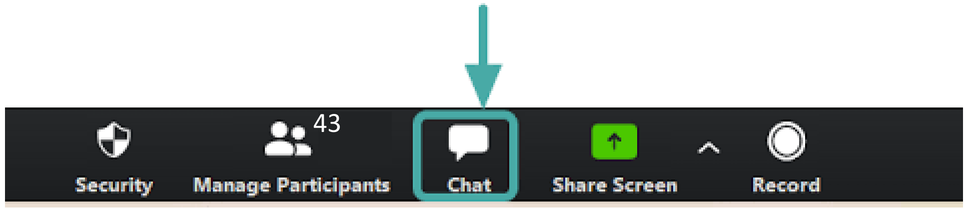
Building Energy Codes and Resilience – an international review

EBC Building Energy Codes Working Group (BECWG) Webinar Series
20 September 2023

Webinar Reminders

EBC
Energy in Buildings and
Communities Programme

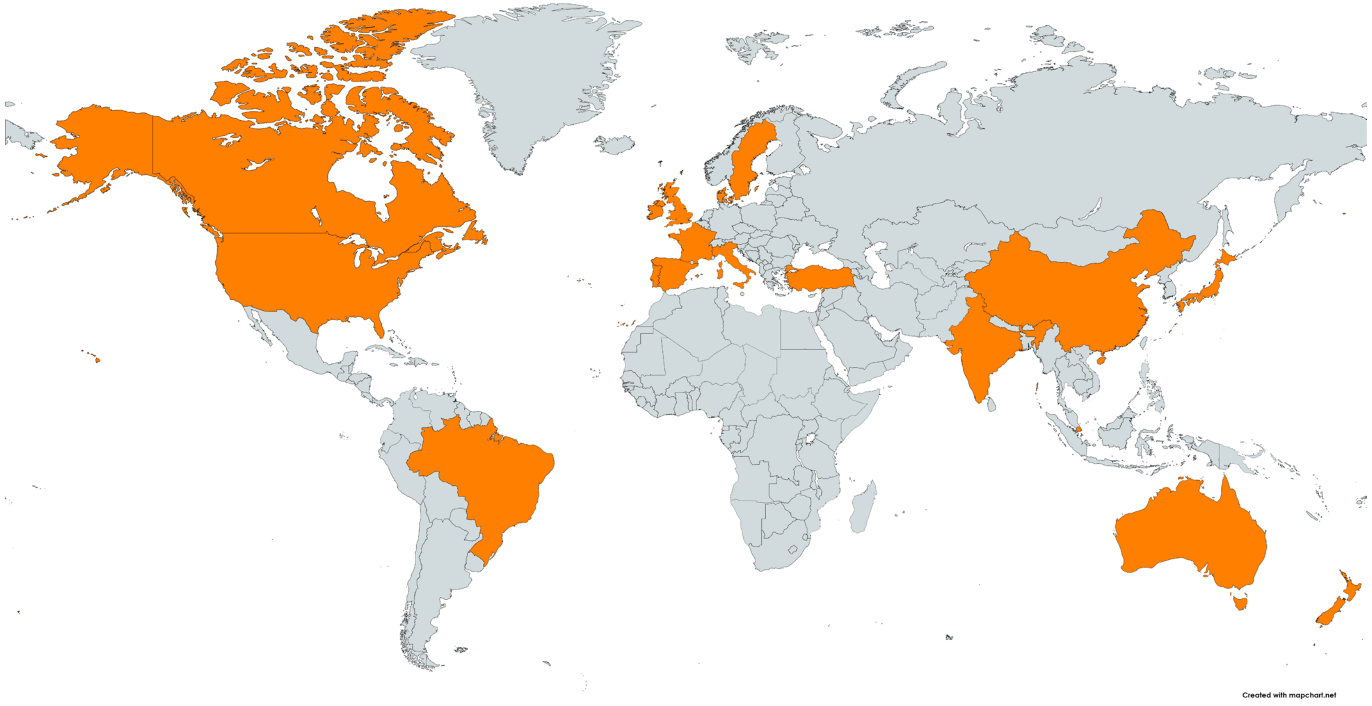
- We are recording this webinar so that we can make it available on the EBC website. Your participation indicates your consent.
- We would like everyone to mute themselves to minimize extraneous noise and disable their video.
- Please put questions in comments and we will go over as many as possible during the discussion section (see the chat function at the bottom of the screen).



IEA EBC Building Energy Codes Working Group

Types of exchange:

- ✓ Research/analysis on innovative code practices
- ✓ Webinars on latest code developments
- ✓ Quarterly newsletters highlighting BECWG activities and emerging research
- ✓ Outreach/dialog to disseminate findings and encourage improvements and innovation in practices
- ✓ Free and open access



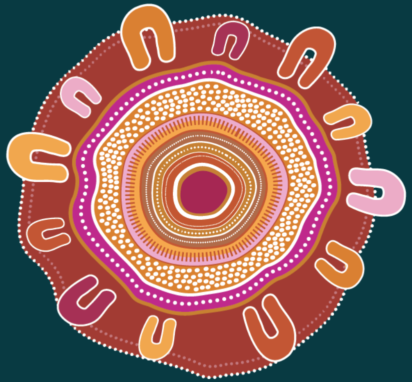
18 member countries. 69 Working Group members/delegates and ~110 regular participants (webinars, newsletters)

https://www.iea-ebc.org/working-group/building-energy-codes

Dev Vrat Bhardwaj
Australian Government

Australian Government

Department of Climate Change, Energy, the Environment and Water

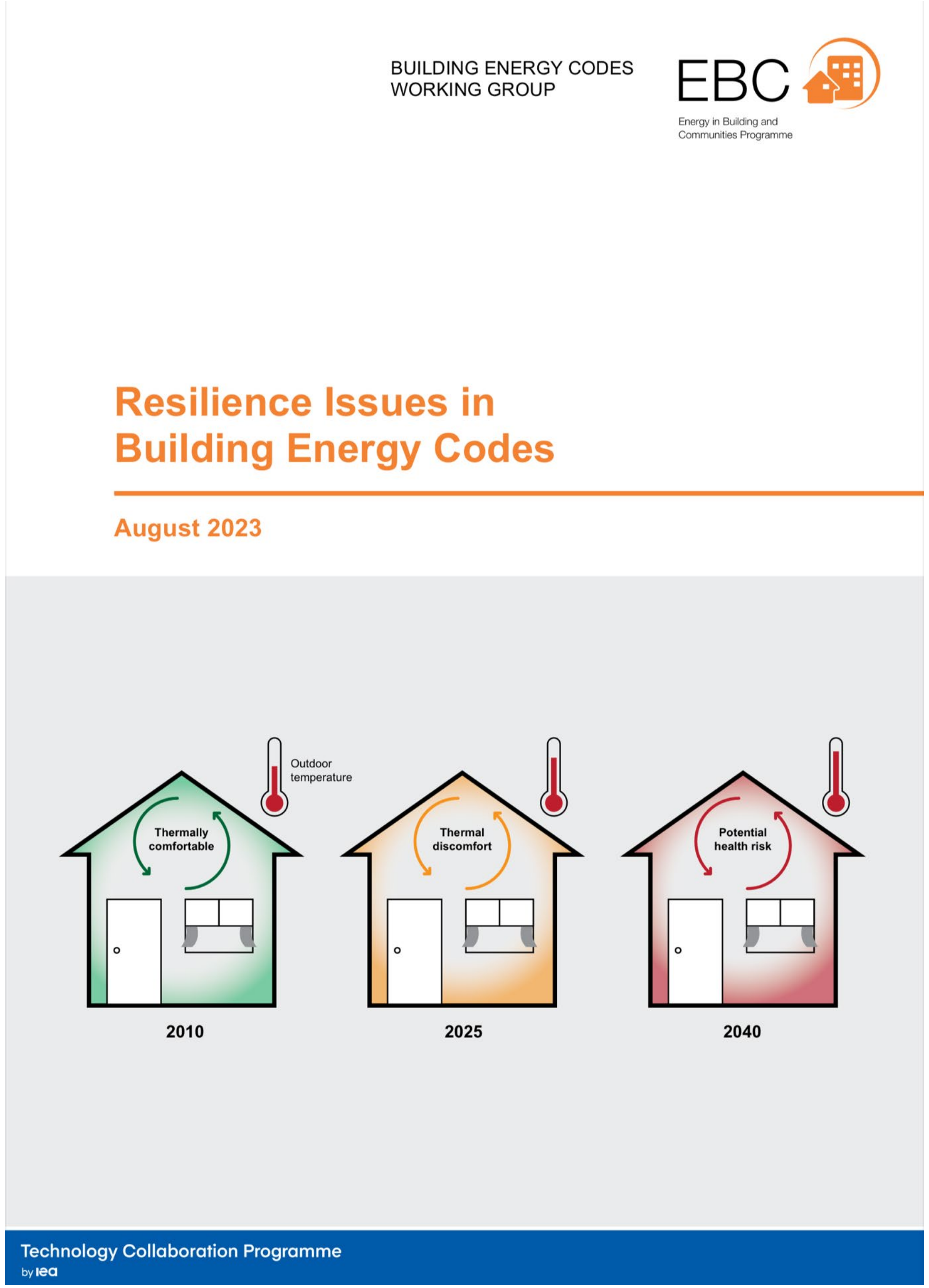


Acknowledgment of Country

Our department recognises the First Peoples of this nation and their ongoing connection to culture and country. We acknowledge Aboriginal and Torres Strait Peoples as the Traditional Owners, Custodians and Lore Keepers of the world's oldest living culture and pay respects to their Elders past, present and emerging.

Adam Hinge

Sustainable Energy Partnerships



BECWG Webinar:
Building Energy Codes and Resilience –
An international review

Resilience Issues in Building Energy Codes

Adam Hinge
Sustainable Energy Partnerships

19/20 September 2023

Building Energy Codes and Other Mandatory Policies Applied to Existing Buildings

- Commissioned by the Australian Department of Climate Change, Energy, the Environment and Water as an Australian input to the BECWG
- Project direction and oversight by
  - Dev Bhardwaj and Stanford Harrison, Australian Commercial Buildings Policy Section, and
  - Meredydd Evans, US Pacific Northwest National Laboratory (BECWG Operating Agent)

Impacts of Climate Change Becoming More Evident

Growing incidence of extreme weather events including heat waves, massive flooding, and wildfires that are having severe impacts on human health and buildings

Risks include:

- More and longer duration heat waves
- Extreme cold snaps
- Stressed energy utility systems leading to service outages
- Damage and pollution from wild/bushfires

Need for additional climate resilience policies

Focus for Report

Role of Building Energy Codes, as complement to broader building resilience policies and strategies

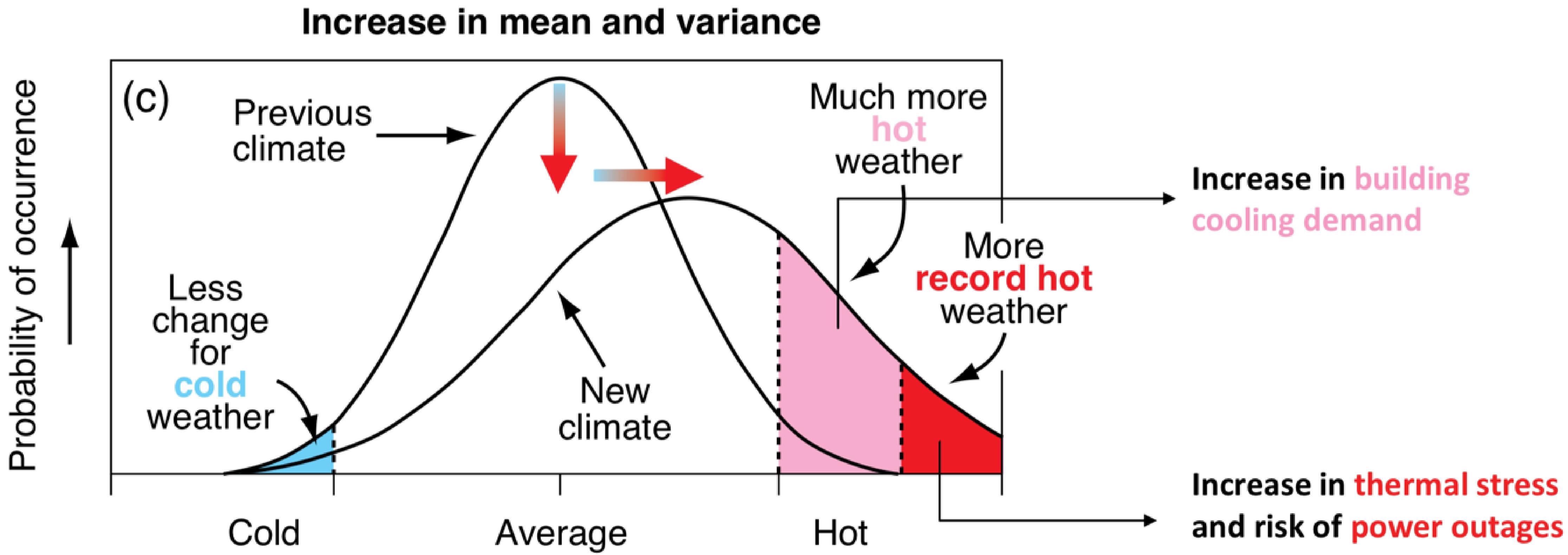
- Focuses on application of building energy codes to improve the building stock’s ability to provide safe indoor thermal conditions and function during extreme weather event
- Reviews codes and other regulations currently in place addressing resilience issues through building energy codes
- Significant emphasis: keeping occupants safe during extended duration heatwaves

Resilience Benefits of Energy Efficiency

Benefit type	Energy efficiency outcome	Resilience benefit
Emergency response and recovery	Reduced electric demand	Increased reliability during times of stress on electric system and increased ability to respond to system emergencies
	Backup power supply from combined heat and power (CHP) and microgrids	Ability to maintain energy supply during emergency or disruption
	Efficient buildings that maintain temperatures	Residents can shelter in place as long as buildings' structural integrity is maintained
	Multiple modes of transportation and efficient vehicles	Several travel options that can be used during evacuations and disruptions
Social and economic	Local economic resources may stay in the community	Stronger local economy that is less susceptible to hazards and disruptions
	Reduced exposure to energy price volatility	Economy is better positioned to manage energy price increases, and households and businesses are better able to plan for future
	Reduced spending on energy	Ability to spend income on other needs, increasing disposable income (especially important for low-income families)
	Improved indoor air quality and emission of fewer local pollutants	Fewer public health stressors
Climate mitigation and adaptation	Reduced greenhouse gas emissions from power sector	Mitigation of climate change
	Cost-effective efficiency investments	More leeway to maximize investment in resilient redundancy measures, including adaptation measures

Source: Ribeiro et.al. 2015

Future weather and heatwaves



Source: Salvati 2022

Issues for Building Energy Codes and Regulations

- Resilience risks to thermal comfort and safety
- Heat waves and building overheating
- Urban heat islands
- Resilient cooling
- Passive survivability
- Indoor air quality issues from wildfires
- Including future weather data/design conditions in codes
- Metrics of resilience for codes

Report **Highlights** Four Leading Jurisdictions

- New York City Climate Resiliency Design Guidelines, that apply to all New York City funded capital projects, including new buildings and substantial renovation to existing buildings
- UK Building Regulations on Overheating Mitigation that apply to new residential buildings
- British Columbia Energy Step Code Design Supplement S3 on Overheating and Indoor Air Quality
- Stretch Energy Codes that include resilience requirements

New York City Resilience Guidelines

- Following Superstorm Sandy in 2012, New York City (NYC) strengthened resilience provisions in codes, and set out to develop Climate Resiliency Guidelines to establish consistent approach for City’s capital plan
- Adherence to Guidelines required for all types of NYC funded capital projects, including new build and substantial improvements to buildings (residential, commercial/institutional), infrastructure and landscapes

NYC Resilience Guidelines

Climate change projections (time period covered)	Examples of building, infrastructure, landscape, and components grouped by typical useful life	
2020s (through to 2039)	Temporary or rapidly replaced components and finishings	– Interim and deployable flood protection measures – Asphalt pavement, pavers, and other ROW finishings – Green infrastructure – Street furniture – Temporary building structures – Storage facilities – Developing technology components (e.g., telecommunications equipment, batteries, solar photovoltatics, fuel cells)
2050s (2040–2069)	Facility improvements, and components on a regular replacement cycle	– Electrical, HVAC, and mechanical components – Most building retrofits (substantial improvements) – Concrete paving – Infrastructural mechanical components (e.g., compressors, lifts, pumps) – Outdoor recreational facilities – At-site energy equipment (e.g., fuel tanks, conduit, emergency generators) – Stormwater detention systems
2080s (2070–2099)	Long-lived buildings and infrastructure	– Most buildings (e.g., public, office, residential) – Piers, wharfs, and bulkheads – Plazas – Retaining walls – Culverts – On-site energy generation/co-generation plants
2100+	Assets that cannot be relocated	– Major infrastructure (e.g., tunnels, bridges, wastewater treatment plants)

ch basins,

Table 5. Current and projected extreme heat events and design criteria (adapted from NYC 2020)

Select period that aligns with end of useful life	Extreme Heat Events				Design Criteria		
	# of heat waves per year	# of days at or above 32oC (90oF)	Average annual temperature		1% Dry Bulb Temperature		Cooling Degree Days Base 32°C (90°F)
			°C	°F	°C	°F	
Historic Trend (1971–2000)	2	18	12.2	54	32.8	91	1,149
2020s (through to 2039)	4	33	14	57.2	—	—	—
2050s (2040–2069)	7	57	15.9	60.6	36.7	98	2,149
2080s (2070–2099)	9	87	17.9	64.3	—	—	—

Note: Due to HVAC system typical useful life of around 25 years, only design criteria projections for the 2050s are shown. Projections for the 2020s are not shown because it is anticipated that enough of a safety margin is employed already in current systems to withstand the temperature rise expected through the 2020s. The NPCC is developing projections of 1% Wet Bulb temperatures, which are expected to increase. This design criteria will be added in a later version of the Guidelines.

Building Regulations for Overheating in England

Took effect in June 2022 and applies to new residential buildings (both dwelling houses and flats). Provides two methods for compliance:

- Simplified method that is quite prescriptive
- Dynamic modeling option, generally following CIBSE TM59 (Design methodology for the assessment of overheating risk in homes)


ONLINE VERSION

HM Government

The Building Regulations 2010

Overheating

APPROVED DOCUMENT

O

Requirement O1: Overheating mitigation

Regulations: 40B

2021 edition – for use in England

ONLINE VERSION

British Columbia Energy Step Code

Compliance path established by province of British Columbia (Canada) in 2017 to support the market transition to net-zero energy ready buildings

To overcome concerns about potential over heating, the Step Code Council prepared Design Guide Supplement S3 on Overheating and Air Quality; addresses:

- Risk and resilience in building design
- Modeling for a Future Climate
- Key Design Strategies for these issues

“Stretch” Codes Addressing Resilience

Some governments allow local jurisdictions to develop more stringent/ambitious “stretch” or “reach” codes, going beyond the requirements of the base energy code or regulation for that region.

Some of these stretch codes require Passive House building efficiency requirements, that are aimed to address passive survivability. The jurisdictions highlighted in the report:

- Brussels (Belgium)
- Massachusetts (USA)
- Vancouver, British Columbia (Canada)

Report Conclusions

- Several energy related codes are currently in place to make buildings more livable during extreme weather events and extended power supply disruptions
- Assessing how these codes and policies work in practice will take time and data and will be complex
- More research will be needed in coming years to understand how we can learn from climate induced event and respond with appropriate building regulations

Full Report at:

https://www.pnnl.gov/sites/default/files/media/file/ResilienceIssuesBuildingEnergyCodes_BECWG_Aug2023.pdf

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Valuing Energy Efficiency for Energy Resilience

Ellen Franconi
Pacific Northwest National Laboratory

September 19, 2023

U.S. DEPARTMENT OF ENERGY
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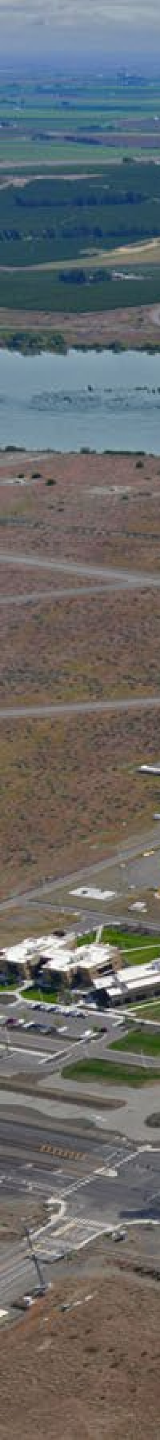

Project Team and Technical Advisory Group

Project Team and DOE Advisors

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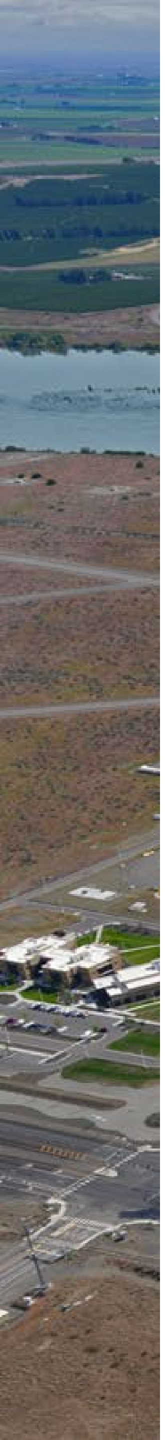

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Valuation of Energy Efficiency for Energy Resilience

A collaborative **PNNL, NREL, and LBNL** project guided by a **technical advisory group** and **US DOE Building Energy Codes Program**

Purpose
- Expand energy efficiency cost effectiveness assessment to include resilience considerations
  - develop a **standardized** methodology to **quantitatively** assess how building efficiency impacts energy resilience
  - calculate **metrics** to support the quantification of impact

Focus
- Extreme heat and cold events **coincident with a power outage**

Application for investment decision making
- **Benefit cost ratio** annualized cost effectiveness calculation
- Metrics included as part of a **decision matrix**

Project Scope

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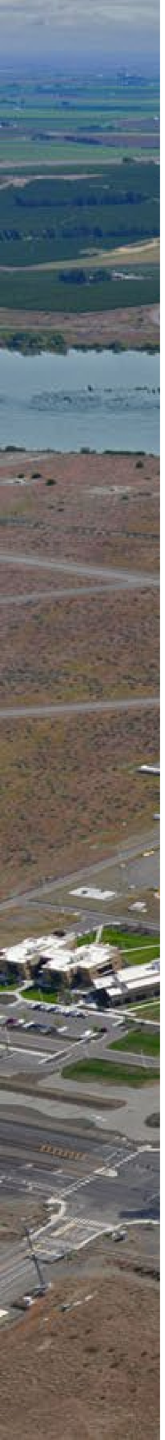
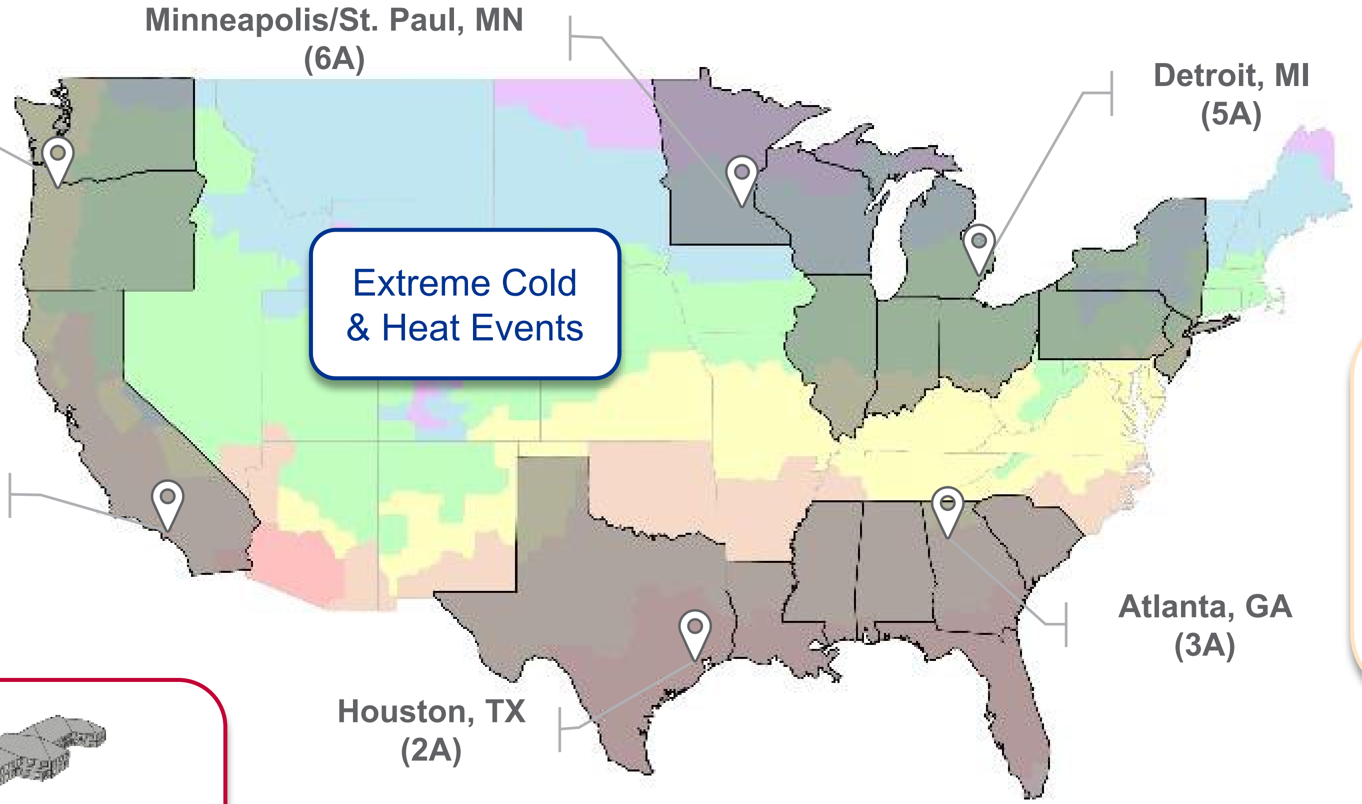
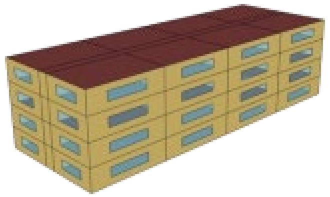




Multi-Family

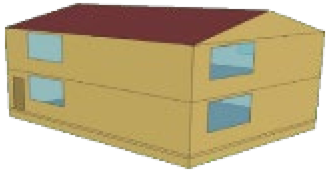


New & Existing

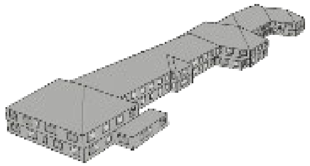
Baseline Condition
Historic Code/Existing Stock

Current Code
ASHRAE 90.1-2019 & IECC-R 2021

Beyond Code
Informed by 2021 Passive House



Single-Family



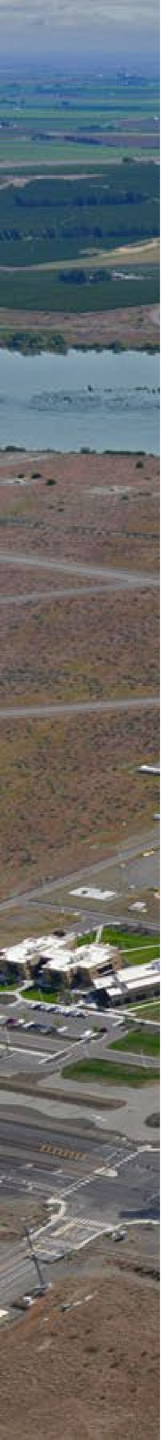
Assisted Living Facility

Counterfactual Case Study

2021 Texas Winter Storm and
Extreme Heat Event

Metrics & Valuation

Thermal Resilience: Standard Effective Temperature, Heat Index
Mortality: Gasparrini Relative Rate Model
Investment: Benefit Cost Ratio (BCR),



Key metrics applied in study

Metrics are calculated for base case and improved conditons

Thermal resilience metrics indicating occupant exposure	
Standard Effective Temperature (SET)	Indoor conditions measurement that considers of temperature and relative humidity
SET Degree Hours	Cumulative hourly SET degrees that fall outside of a specified threshold (54°F and 86°)
Days of Safety	The time elapsed over a seven day period when the SET Degree Hours does not exceed a value of 216.
Occupant damage metrics	
Excess deaths	Deaths attributed to the extreme event
Economic metrics (for annualized net present value calculation)	
Measure investment costs	First costs for installation of measure package
Measure annual energy cost savings	Evaluated based on a typical weather year
Societal value of emissions reduction	Associated with annual energy use savings
Losses associated with excess deaths	Based on $10 million per excess death
Losses associated with property damage	Based on FEMA national risk data base values
Benefit cost ratio	Based on **annual coincident risk of extreme temperature events** and above economic values

Project Approach

Hazard Risk Analysis

- Historical extreme temperature event identification
- Severe weather - power outage data review

Coincident probability

Exposure Analysis

- Baseline and efficiency packages
- Building energy simulation models and analysis

Indoor condition effect on habitability

Damage Analysis

- Historical property damage data
- Epidemiological fragility models
- Related to extreme temperatures

Property damage and excess mortality

Mitigation Valuation

- Valuation of loss
- Mitigation costs
- Annualized impacts
- Net present value analysis

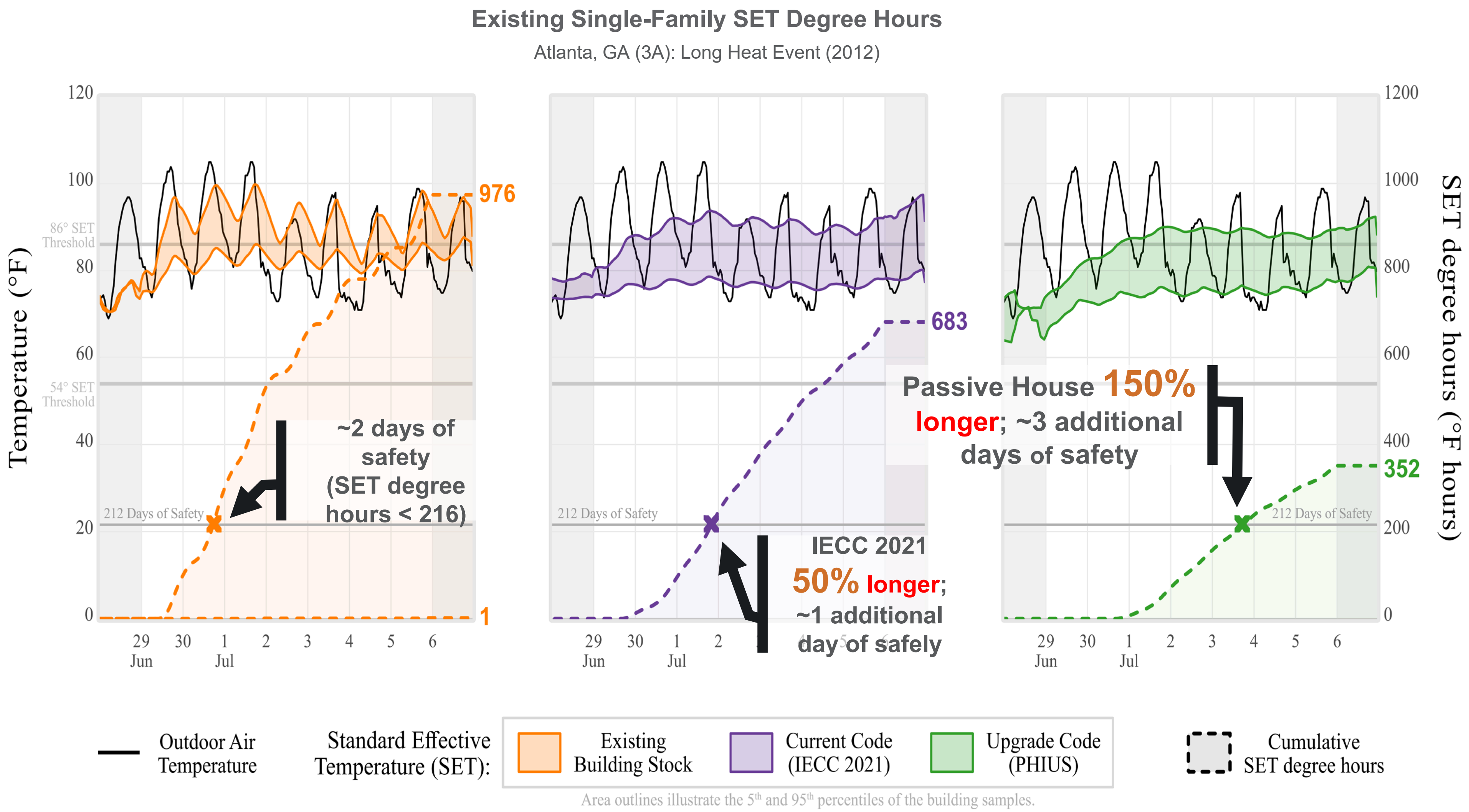
Return on investment

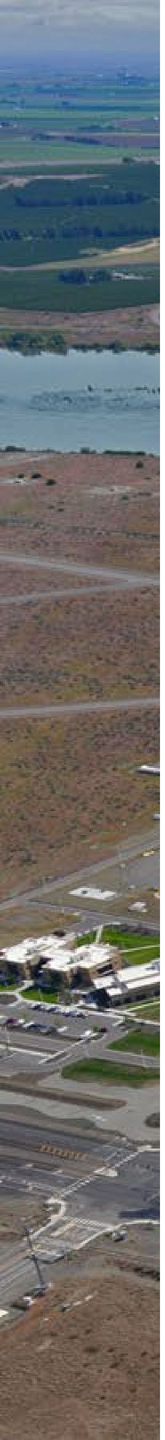
Exposure Analysis

Three thermal resilience metrics reported in the study include:

- SET
- SET degree hours
- Days of safety

What is the fluctuation in indoor comfort conditions extreme temperature events? How does it affect habitability?





Damage Analysis

How do the study estimates compare to published data?

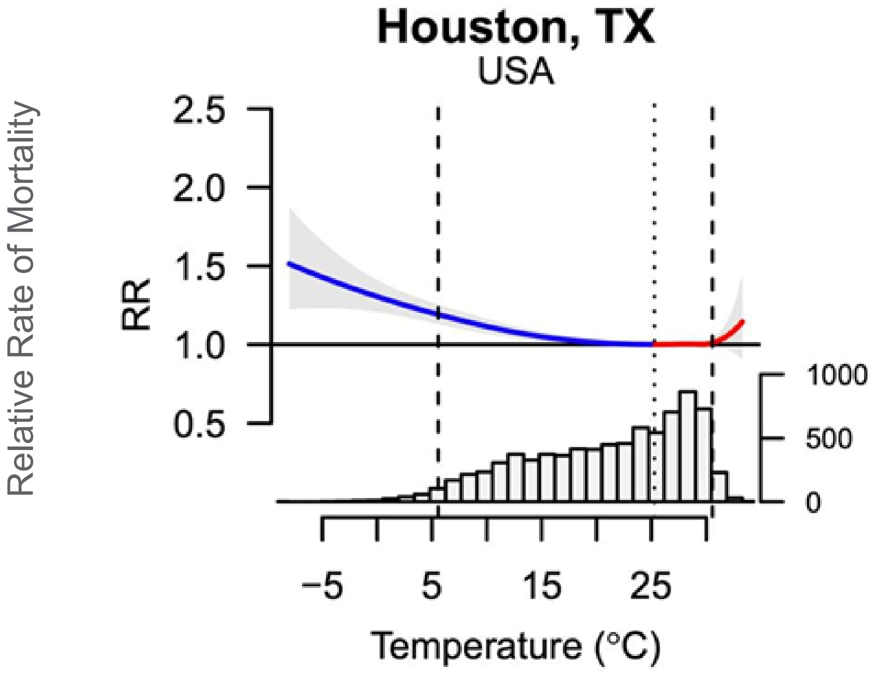
2021 Texas Winter Storm Event Case Study

	Texas	Harris County	Harris County
	Published	Published Prorated	Study Estimate
Excess mortality	755	249	202

Notes: The published value for excess mortality for Texas is 755 per Aldhous P, and Z Hirji. 2022. "Texas Is Still Not Recognizing the Full Death Toll of Last Year's Devastating Winter Storm." Buzzfeednews.com. Accessed June 1, 2022. The event occurred from February 13 to February 24, 2021. The study excess mortality analysis is for the entire event period over the 12 days.

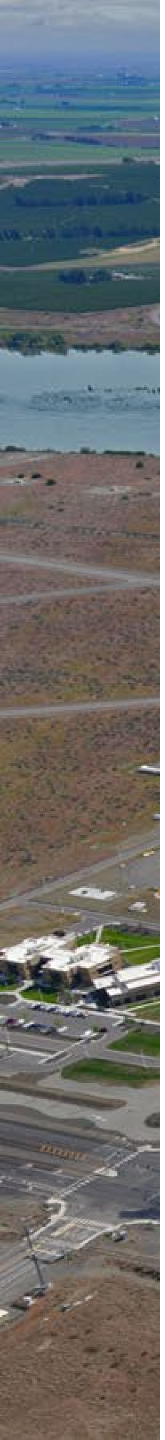
How does extreme heat and cold impact mortality rate?

Relative rate of death curves as a function of **outdoor temperature** published by Gasparrini available for over 130 U.S. cities



Mean Daily Outdoor Air Temperature (C)

Notes: Vertical dashed lines indicate the temperature at 2.5th percentile and 97.5th percentile. The vertical dotted line indicates the temperature at which the relative rate of death is one or the temperature at which deaths are not attributed to severe temperatures



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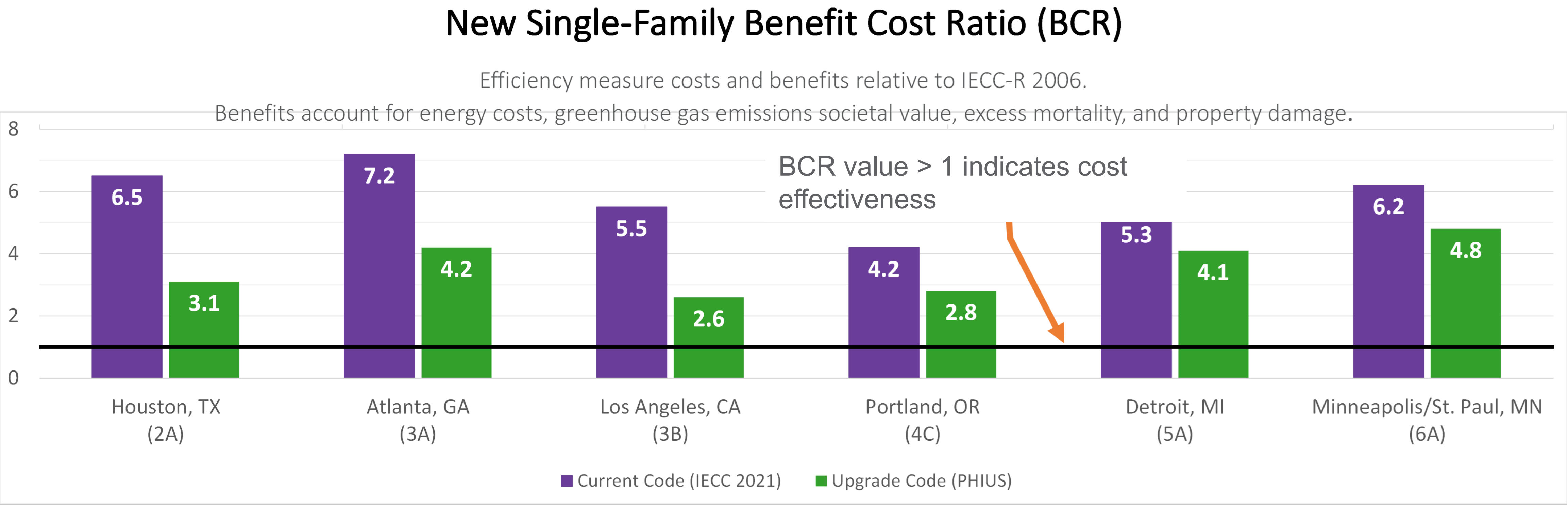
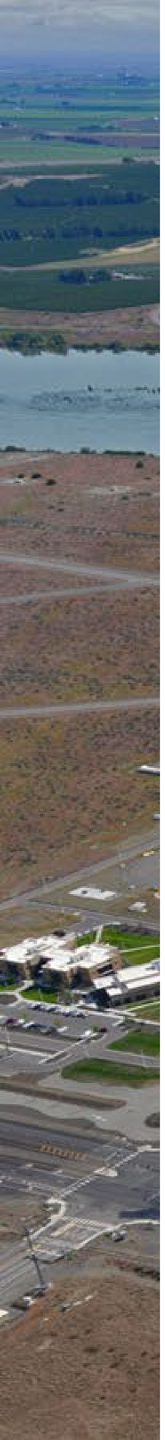
Methodology Robustness Assessment

Category	Component	Robustness
1. Hazard Risk Identification	Develop weather data files representative of extreme temperature events	
	Develop coincident probability risk factors to annualize event losses and benefits	
2. Exposure Analysis	Assess relative impact of efficiency measures on habitability	
	Determine indoor habitability conditions exceeding thresholds	
3. Vulnerability Assessment	Evaluate occupant exposure effect on mortality, health, and well-being	
	Evaluate property exposure effect on active building state and systems	FUTURE
4. Mitigation Valuation	Quantify the monetary value of resilience	
	Inform resilience planning efforts	

Example Benefit Cost Ratio Results

What is the return on building efficiency investment with **annual energy cost saving, societal value of reduced CO2e emissions, and annualized excess deaths?**

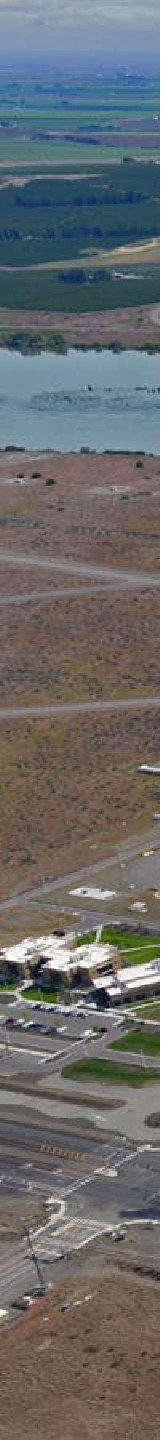




Example Decision Matrix

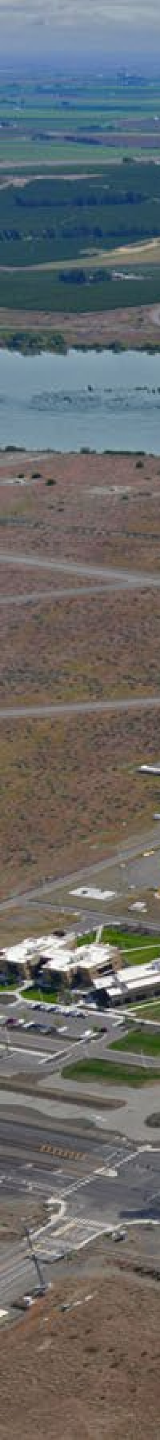
How can resilience metrics be used to inform investment decision-making?

Metric	Value: Current Code IECC 2021	Value: Beyond Code PHIUS	Assigned Weights	Normalized: Current Code IECC 2021	Normalized: Beyond Code PHIUS
BCR	0.63	0.68	30%	0.92	1.00
Levelized First Costs ($/ft^2/year)	0.63	0.77	15%	1.00	0.82
Energy Savings (kWh/ft^2/year)	3.1	4.1	15%	1.00	0.76
Lives Saved	62	93	10%	0.66	1.00
SET Degree Hours Saved	985	1348	30%	0.73	1.00
			Weighted Total	**0.86**	**0.94**



Key Take-Aways

- Improving envelope efficiency to meet or exceed code requirements extends occupant habitability during extreme temperatures.
- In nearly every situation, improving envelope efficiency saves lives during extreme temperature events.
- Increasing efficiency at the time of construction provides a good investment opportunity for addressing resilience.
- There are application limitations associated with some of the method components, which may lead to an underestimation of benefits. These components, which can be improved with better supporting data and application refinements.
    - Coincident probability of occurrence of power outage –extreme temperature events
    - Gasparrini relative rate of mortality fragility curves
    - Property damage estimation
    - Building performance based on future weather data



Questions

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Final report is available at
https://www.energycodes.gov/energy-resilience

Neil Savery

International Code Council - Oceania

Global Building Resilience

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Managing Director, ICC Oceania

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19/20 September 2023

Global Building Resilience Guidelines

- A collaboration of building code development & research organizations from Australia, Canada, New Zealand & United States
- Released for COP27 in 2022 and had regard to the results of two global surveys undertaken in 2020-21:
  - *The Use of Climate Data and Assessment of Extreme Weather Event Risks in Building Codes Around the World*
  - *Delivering Climate Responsive Resilient Building Codes and Standards*
- High-level principles for consideration by ANY country
- Not designed as a policy tool, but to enable flexibility of use

Problem Statement

- The world's atmosphere is warming, causing increasingly frequent and severe weather events, particularly extreme wind, extreme rainfall, wildfire/bushfire, and extreme heat
- These conditions will continue for some time into the future, regardless of mitigation efforts currently being implemented or discussed
- Buildings constructed today face the prospect of experiencing different and potentially more extreme weather than in the past during their expected service life
- Lack of resilience to future extreme weather events threatens the ability of buildings to perform their primary functions of shelter and some degree of re-occupation post-disaster
- Most building codes are based on historical climate and weather risk data

Climate-related data in building codes

Most advanced codes rely on historical data to support requirements related to structural/atmospheric loads for wind and snow/ice, energy use/heat stress, flooding, and wildfire/bushfire protection

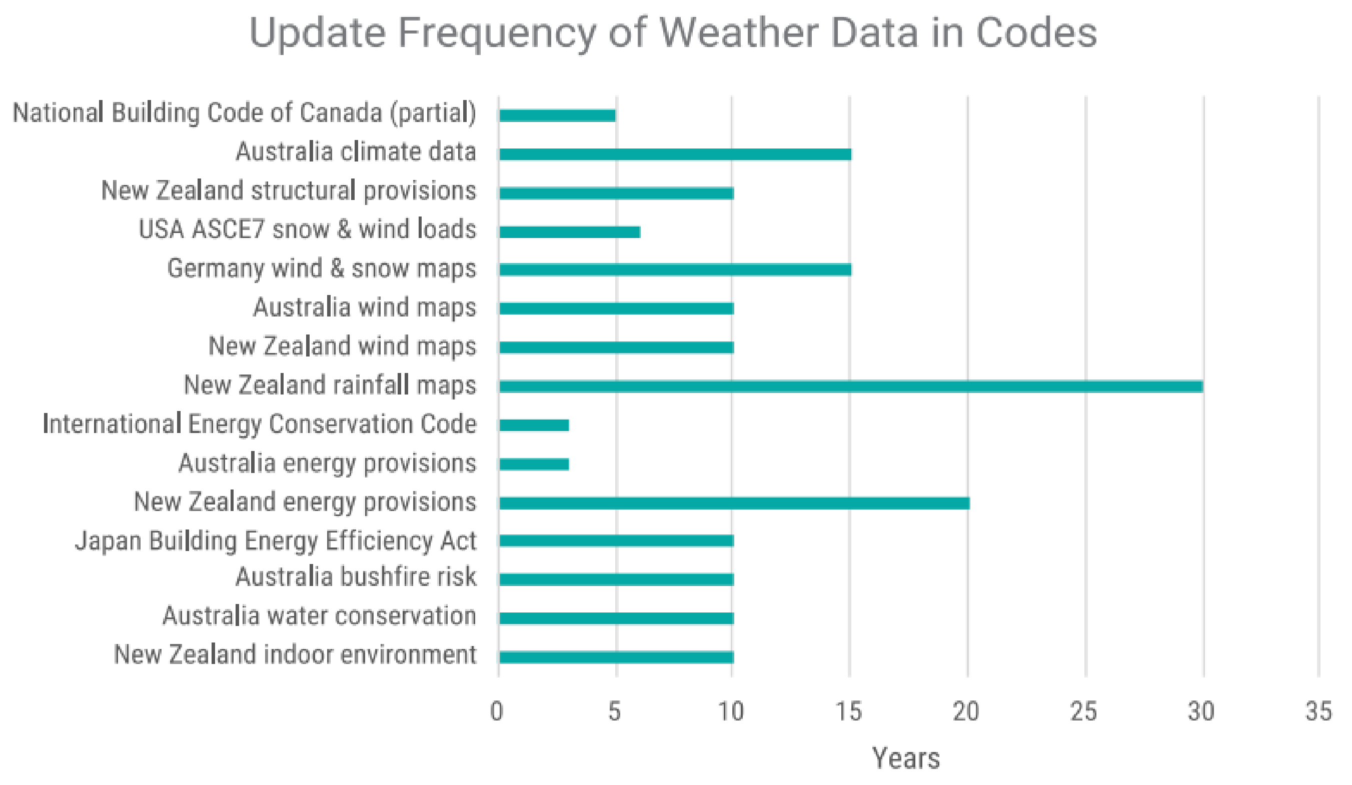


Figure 1: Sampling of the frequency of which the underlying weather/climate data in building codes is updated

INTERNATIONAL CODE COUNCIL®

Building Science + Climate Science

- Recognizing the need to deliver technical constructability that is cost effective and avoids unintended consequences
- Recognizing the importance of maintaining the expected level of a building's resilience to hazards throughout its anticipated service life
- Leveraging climate science to define what is needed, recognizing:
    - Increased frequency, intensity and duration of events
    - Changing geography
    - Increased risk of compound extremes, where multiple events occur in sequence or together, magnifying their impacts

Building Resilience - Defined

The ability of a building, structure and its component parts to withstand current and future climatic conditions (including wildfire/bushfires, extreme wind, extreme rainfall and extreme heat), to minimize the loss of functionality and recovery time without being damaged to an extent that is disproportionate to the intensity of the events experienced, and to preserve the intended level of performance at the time of construction over the proposed service life of the building.

Existing Codes and Standards

- It is important to recognize that contemporary building codes do make provision for most natural hazard events, including those related to extreme weather
- Typically, the priority of today's codes and standards is to protect the building occupants, not property, which to achieve involves a level of resilience to a point of redundancy
- Resilience to the extent of performing design functionality after an event is often a secondary benefit
- In the context of extreme weather events, building resilience that involves preserving a level of structural performance following an event can save lives.

Developing Resilient Building Codes and Standards

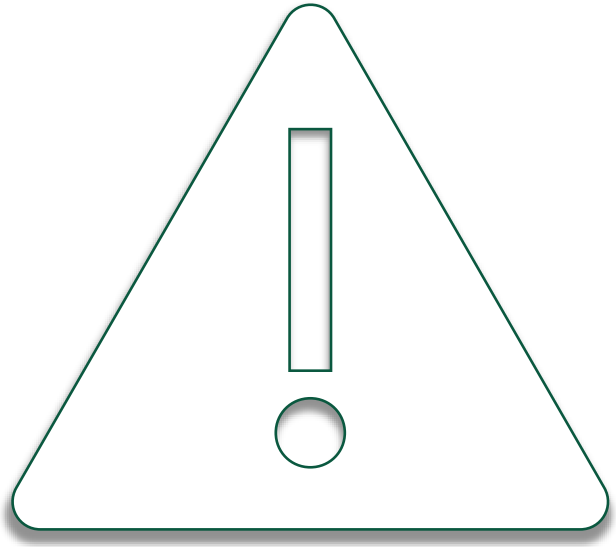
- Global Building Resilience Guidelines provide a series of considerations for regulators to draw upon to provide a higher level of resilience of buildings to future climate risk
- Viewing the minimum requirements for providing occupant health and safety set forth in building codes and standards in the context of ongoing performance and functional recovery following more extreme weather events
- Implementing a novel reliance on climate science and downscaled modeling to avoid a ‘one-size-fits-all’ approach
- Caution that even with improved codes and standards, these cannot serve as a guarantee of occupant health and on-going building performance following an extreme weather event

15 Principles for Advancing Building Resilience through Building Codes

Urgency	Clarity of objectives	Robust climate science	Risk clarity	Future focus
Durability	Holistic approach	Affordability	Existing buildings	Building maintenance
Compliance	Implementation	Continuous improvement	Engagement	Emissions reductions

1. Urgency

The need to respond to the associated impacts of climate change and extreme weather events on buildings and building occupants is more urgent than ever.



4. Risk clarity

Risk informed thinking and decision making is important in providing support for design decisions to balance cost, energy performance, greenhouse gas emissions and resilience, where changing risks can be balanced against certainty of performance for building development and maintenance.

5. Future focus

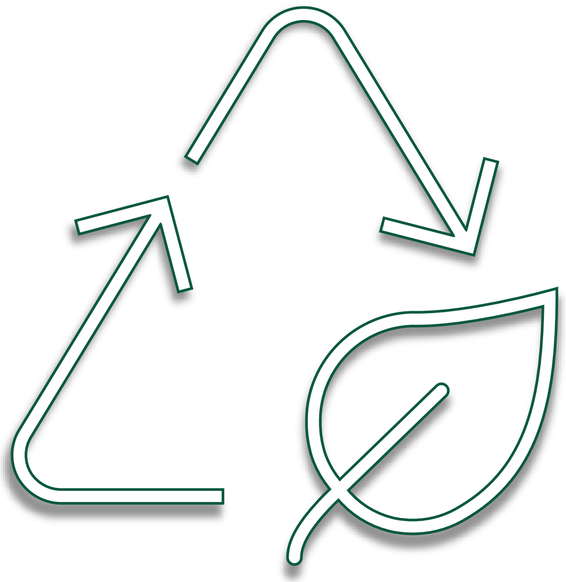
A baseline assessment of current technical construction standards, where they exist, enables a comparison to be made with modeling and scenarios for future climate to help determine if they remain adequate or new ones need to be developed.

7. Holistic approach

Building codes can contribute to improving building resilience as part of a broad suite of regulatory and non-regulatory measures, which in some cases will be inter-dependent and take account of multi-hazard weather related events.

15. Emissions reductions

*Mitigating the causes of climate change remains vital to addressing long term building resilience, for which building codes can make an important contribution.**



* There is a diminishing return in what building resilience can achieve if mitigation objectives not met

Other Examples

Global Alliance for Building and Construction (GlobalABC)

ICC INTERNATIONAL CODE COUNCIL®

10 PRINCIPLES FOR EFFECTIVE ACTION

FOR THE ADAPTATION OF THE BUILDING SECTOR TO CLIMATE CHANGE

1. **Urgency/** *Act now.*
2. **Stakeholders/** *Consider a systemic integration of measures for adaptation across the entire value chain.*
3. **Process/** *Consider adaptation along the entire lifecycle of an asset.*
4. **Mitigation/** *Implement adaptation and mitigation in tandem.*
5. **Data/** *Understand climate risk data and accept uncertainty.*
6. **Scale/** *Think beyond asset-level.*
7. **Green/** *Consider nature-based solutions.*
8. **People/** *Promote a "just adaptation" of the building sector.*
9. **Finance/** *Enable adaptation of the building sector.*
10. **Local/** *Fit adaptation measures to the local context.*

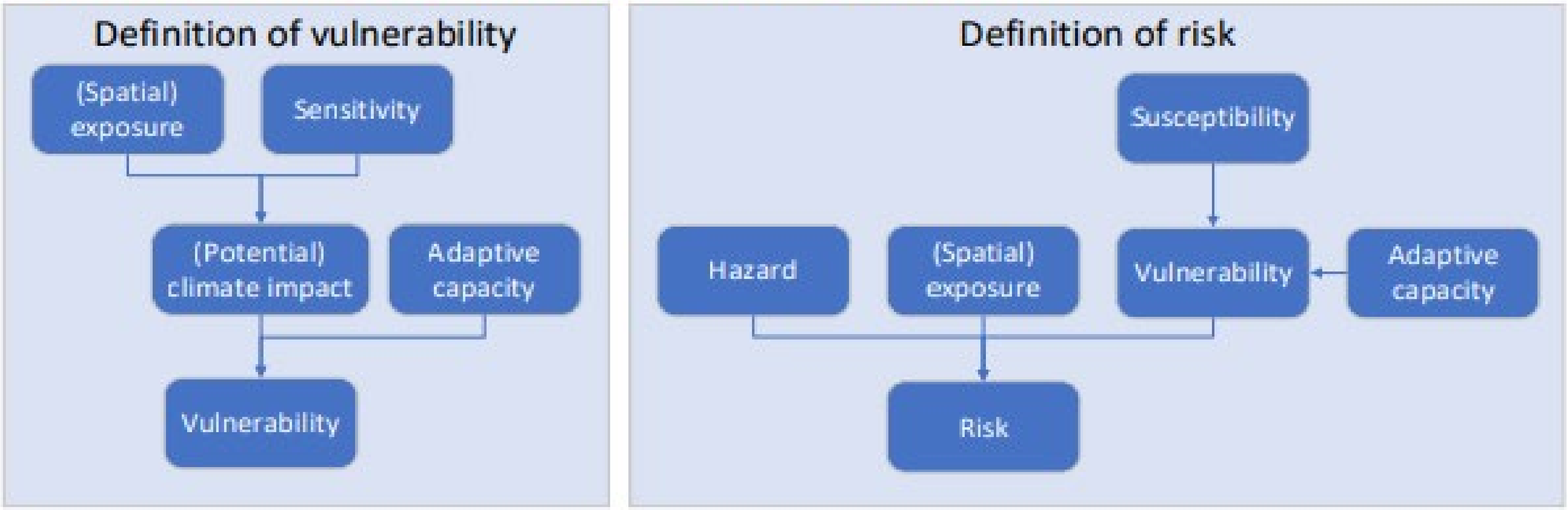
Organisations listed below are member of GlobalABC Adaptation Working Group and initial supporters of the 10 Principles for Effective Action, for Adaptation of the Building sector to climate change.

AFD AGENCE FRANÇAISE DE DÉVELOPPEMENT · afnor NORMALISATION · ÉNERGIES 2050 · FIDIC · CRESP

EU - Climate Vulnerability and Risk Assessments

In its March 2023 publication, *'EU-level technical guidance on adapting buildings to climate'*, the EU is looking at a specific and widely applicable methodology, for the application of CVRA's for buildings, which would allow for more appropriate and targeted adaptation measures to be identified and implemented to improve resilience to climate change.

Figure 3.1 Vulnerability as per IPCC 2007 and risk as per IPCC 2014[41]



ICA Theory of Change

Competence and compliance: State and territory governments ensure those responsible for land use development, building design and construction are fully competent and conduct themselves in accordance with regulated codes, standards and land-use planning requirements. Each level of government takes clear ownership and accountability for their role in uplifting building codes and land-use planning. To help achieve this, they adequately resource their agencies to educate, monitor and if necessary, penalise those who don't comply.

National Construction Code: Federal, state and territory governments, via the Building Ministers' Meeting and ABCB board, support changes that ensure building resilience and durability are principles embedded within the technical provisions and referenced standards of the NCC. These principles drive consideration of current and extreme weather and predictive climate science to improve the construction of new buildings in areas with a high risk of extreme weather events. These provisions to remain under constant review to be ratcheted up over the next decade.

Australian Standards: Standards Australia to support the ABCB in concurrently reviewing, and where necessary updating, relevant referenced standards in the NCC. This review is to ensure the standards consider current events and predictive climate science to improve the resilience and durability of new buildings in areas with a high risk of extreme weather events. These standards to remain under constant review.

Land-use planning: State and territory governments must amend planning legislation so that it includes a mandatory requirement for strategic and statutory planning arrangements to consider property and community resilience to extreme weather events, including limiting development in high-risk areas.

Land-Use Risk Concept Model

Concept model: Risk-based flood insurance

	Severity	Risk Rating	Government response	Insurance response
Less desirable	Land is consistently impacted by floods for extended periods of time	Extreme	Local, State and Federal Government response over the short, medium and long term (emergency response, support from Australian Defence Force, temporary housing, housing relocation, and frequent replacement of infrastructure	Insurance products are limited, if at all available. Premiums will be near unaffordable for most people.
	Land is regularly impacted by floods	High	Local, State and Federal Government response over the short-to-medium term (emergency response, temporary housing, repair and occasional replacement of infrastructure)	A lower amount of insurance products are available. Premiums will be higher; however, proven mitigation measures may slightly reduce the premium.
	Land is occasionally impacted by floods	Moderate	State and Local Government may respond with short term emergency response measures	Insurance products are readily available; however, premiums may be higher unless risk mitigation measures are adequately implemented
Desirable	Land is rarely, if ever, impacted by floods	Low	Localised response (i.e. Local Government only, not State or Federal involvement)	Affordable insurance products are readily available

Energy in Buildings and
Communities Programme

Discussion – Q&A

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Thank you

Webinar slides & recording

https://www.iea-ebc.org/
working-group/building-energy-codes