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Integrating Climate Change Data into Codes and Standards

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1. Introduction

Safety and resilience are common goals for societies adapting to climate change-related risks. According to the Second Assessment Report on Climate Change and Cities [Rosenzweig et al. 2015], disaster risk reduction and climate change adaptation are the cornerstones of making communities and their infrastructure resilient to a changing climate. Human-caused climate change presents significant risks to communities beyond the familiar risks from natural climate variations and seasonal weather patterns. Integrating these activities with a city's development vision requires a new, systems-oriented approach to risk assessments and planning.

The Global Resiliency Dialogue recognizes that the building codes adopted in most countries, based on historical climate and weather data, cannot provide the same safety and performance level as in past years and decades [Zakresky 2020]. Since past hazard events are inadequate in conveying emerging and increasing climate risks, systems-based risk assessments should be based on current conditions and forward-looking climate projections.

Codes and standards are fundamental to assuring that buildings support communities' health, safety, and welfare. One of the foundations for effective adaptation planning is co-developing plans with stakeholders and the scientists who can provide community-scale information about climate risks—both current risks and projections of future changes in hazard events. To advance beyond local efforts to address climate issues, codes and standards require an approved mechanism to incorporate the latest research and data from both building science and climate science to maintain or improve the expected levels of safety and performance.

1.1. Objective

The workshop's main objective was to bring the building codes and climate science communities together to take stock of climate data needs, especially the type, format, and scale of climate projections at pertinent spatiotemporal scales and tools. The goal is to advance how codes and standards will account for climate risks that buildings will face in the years and decades to come.

1.1.1. Background

The NIST workshop was convened at the request of the U.S. House of Representatives' Committee on Appropriations. NIST, in consultation with the U. S. Global Change Research Program (USGCRP) and the Mitigation Framework Leadership Group (MitFLG), convened an ongoing government-wide effort to provide forward-looking climate information to Standard Development Organizations (SDO) and to reduce federal fiscal exposure by enhancing the resilience of infrastructure to the consequence of climate change [GAO 2016]. A steering committee of experts on climate science and codes and standards developed an agenda and identified the workshop speakers to focus on two topics:

- Provide an overview of SDO needs for climate change data.

- Provide an overview of climate projection data, tools, and reports available from federal climate agencies and non-governmental organizations.

The workshop included speakers from federal agencies, communities, universities, nonprofits, and the private sector. It also featured panel discussions to identify gaps in the implementation of climate information in building codes and to identify future actions to address these gaps.

The report presents pertinent background information on building codes and climate data and projections, and the main findings and recommendations from workshop presentations and panel discussions.

1.2. Building Codes

National building codes address public health, safety and welfare and provide minimum requirements for the design, construction, alteration, and repair of buildings. National model building codes are maintained by the International Code Council (ICC), and new editions of the International Codes are published every three years. The ICC's family of International Codes[1] includes the following:

- International Building Code
- International Energy Conservation Code
- International Existing Building Code
- International Fire Code
- International Fuel Gas Code
- International Green Construction Code
- International Mechanical Code
- International Plumbing Code
- International Residential Code
- International Wildland Urban Interface Code
- International Zoning Code

One of the most cost-effective ways to safeguard communities against anticipated damage and losses from natural disasters is to adopt and enforce the latest version of the model building codes. Building codes help communities reduce casualties and building damage as well as indirect costs such as business interruptions and lost income [FEMA 2021].

It is the responsibility of state and local jurisdictions to adopt and enforce building codes. Today, all U.S. states, the District of Columbia, and territories have adopted one or more building codes at a state level [ICC 2021]. However, up to 65% of counties, cities, and towns across the U.S. still have not adopted modern building codes [FEMA 2020]. This disconnect is due to the variations among states in how building codes are adopted and enforced.

[1] www.iccsafe.org

Local building officials are responsible for enforcing building codes within a jurisdiction, which may not be based on the latest or recent national model building codes. Building code enforcement is achieved by reviewing design plans, inspecting construction work, and issuing building and occupancy permits. In areas that have not adopted building codes, it is the designer and general contractor's responsibility to ensure they incorporate building codes in design and construction documents.

A recent study [FEMA 2020], focused on buildings constructed since 2000 (~20% of the 100+ million buildings in the U.S.) and direct losses from earthquakes, flooding, and wind events. The analysis estimated that, from 2000 to 2040, cities and counties with modern building codes would avoid $132 billion in losses from natural disasters, and that avoiding losses is best addressed by expanding the national adoption of modern building codes.

Green construction and energy conservation codes seek to improve residential and commercial building efficiency in energy and water consumption and carbon emissions, and to diminish their negative impact on the environment. However, green codes do not currently address future climate issues.

At present, design criteria for natural hazards are based on historical data and statistical models for reliability and risk assessment, where past hazard events are considered representative of future hazard event frequency and magnitudes or intensity (referred to as stationary conditions). While global climate models are being used to identify greenhouse gas (GHG) effects, such as increasing air and water temperatures, their impact on natural hazard events may require new methods for characterizing future hazards due to the nonstationary effect of climate trends. For example, heating, ventilation, and air conditioning (HVAC) systems use outdoor temperature data for system performance analysis, which are available from the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Weather Data Center [ASHRAE 2020a]. ASHRAE Standard 169 provides climate data based on historic data for building design and sizing building energy systems and equipment [ASHRAE 2020b].

However, none of the building codes currently contain methods or guidance that allow designers to include the projected effects of climate change for future conditions or hazard events. The challenge is to develop building codes and standards that incorporate forward-looking climate information, so buildings can withstand the threats imposed by weather and climate extremes in the coming decades and over the life of buildings. While HVAC systems may have a nominal service life of 25 years or so, structural and building envelope systems may have a nominal service life of 50 to 100 years. The development of climate-informed building codes requires strengthened coordination between the SDOs and climate science community.

1.3. Climate Data

Weather and climate are closely related but have distinct characteristics. Weather is the state of the atmosphere (temperature, precipitation, humidity, wind, etc.) and water bodies (sea-level, waves, surface temperature, etc.) at a point in time, while climate refers to the characteristics of weather elements over periods of time through statistical properties (e.g., probability distributions and associated means and standard deviations). The averaging period is typically 30 years, as defined by the World Meteorological Organization (WMO). The 30-year weather data is referred to as the Climate Normal and is updated every ten years [WMO 2017]. The establishment of a climate normal allows comparisons between a specific day, month, season, or another period normal with the climate normal values. Such comparisons characterize anomalous weather and climate conditions, climate variability and change, and help define unusual or changing weather and climate events [Arguez et al. 2012].

Humans have adapted to natural climate variability occurring over thousands of years. However, industrial development at the beginning of the 20th century, and its accelerated continuance, generated greenhouse gases that have resulted in increasing rates of climate changes that are stressing natural, built, and human systems. According to the fifth assessment report from the Intergovernmental Panel on Climate Change [IPCC 2014] and the fourth National Climate Assessment (NCA4) [USGCRP 2017], human influence on climate is a direct consequence of anthropogenic greenhouse gas emissions that have reached their highest concentrations in history. The global climate has changed relative to the pre-industrial period (1850-1900), with multiple lines of evidence indicating that these changes have impacted organisms, ecosystems, and human systems and well-being [Hoegh-Guldberg et al. 2018]. Human-induced global warming has already caused observed changes in climate systems, including increases in both land and ocean temperatures, more frequent and prolonged heat waves over continental regions, increased hazard event frequency and intensity, and heavy precipitation events at the global scale, as well as an increased risk of drought.

The observed frequency, intensity, and duration of some extreme weather events have been changing as the climate system has warmed. Such changes also have been simulated in climate models, and some of the reasons are well understood. For example, global warming is expected to increase the likelihood of extremely hot days and nights, cause more evaporation that may increase atmospheric moisture and the frequency of heavy rainfall and snowfall events. The extent to which climate change influences an individual weather or climate event is more difficult to determine. Nonetheless, this relatively new area of science—often called event attribution—is advancing. The ultimate challenge is to estimate how much climate change has affected an individual event's magnitude or probability of occurrence. Such results remain subject to substantial uncertainty, with greater levels of uncertainty for events that are not directly temperature related (National Academies of Sciences, Engineering, and Medicine 2016).

As noted previously, building codes do not currently address future weather and climate conditions. This is in part due to the issues related to event attribution, moving from global models to local predictions.

Climate models are based on well-documented physical processes and seek to simulate the energy and materials transfer through the climate system, which consists of oceans, atmosphere, land, and the cryosphere. Climate models use mathematical equations to characterize the transfer processes using specified initial values of model variables, influenced by climate forcing changes, and solving these equations using powerful supercomputers [https://www.climate.gov/maps-data/primer/climate-models].

Climate models predict the future climate under various scenarios. The forward-looking data produced by the global climate models are known as climate projections. Climate research institutions generate climate projections for a range of assumed scenarios that capture the relationships between human choices, emissions and concentrations of greenhouse gases (GHG), and temperature changes. Some scenarios represent continued dependence on fossil fuels, while