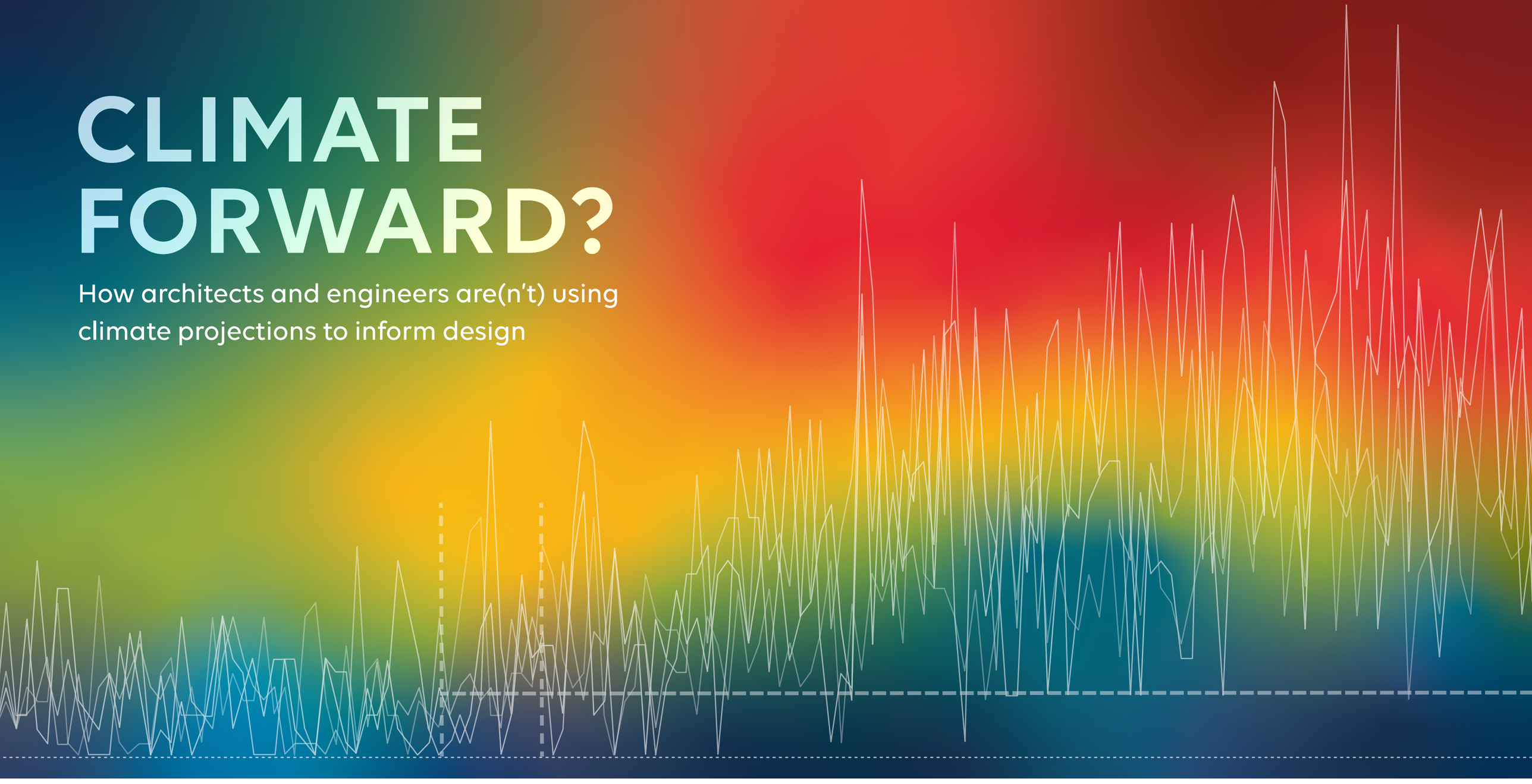
CLIMATE FORWARD?

How architects and engineers are(n't) using climate projections to inform design



HGA

Climate Adaptation Partnership

University of Minnesota

Driven to Discover®

THE DATA GAP:

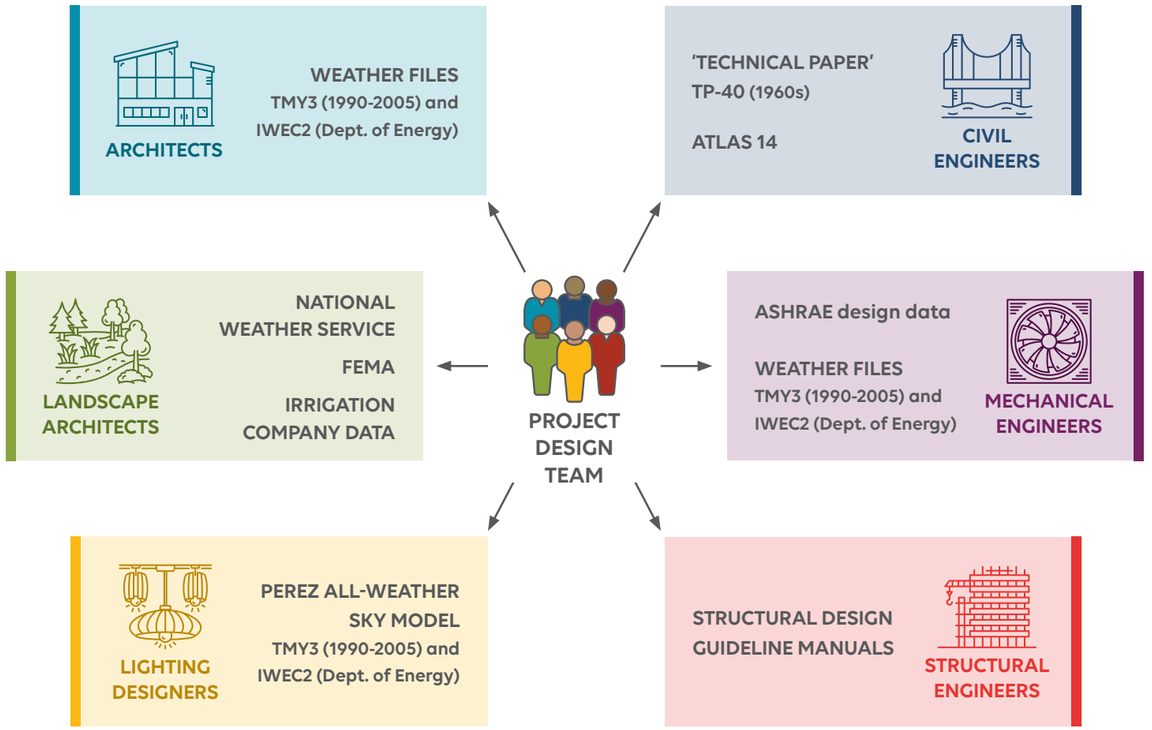
CLIMATE PROJECTION DATA FOR A&E PROFESSIONALS

Architecture and Engineering (A&E) professionals are well-positioned to use climate projection data to inform design and provide clients with climate adaptive solutions. Sources of these data are becoming more widely available, yet are often not well-suited for immediate A&E applications and their results are often difficult to interpret (Rastogi & Kahn, 2022; Rastogi et al., 2022). The University of Minnesota Climate Adaptation Partnership (MCAP) and HGA conducted this study to understand current A&E practices related to the use of climate projection data; challenges encountered accessing, understanding, and applying these data to inform design; and opportunities to advance climate resilience services and expertise in the A&E industry.

STANDARD PRACTICE IS INSUFFICIENT

Climate change impacts are growing, threatening lives, business continuity, and infrastructure, and costing an average of $152.9 billion dollars per year in the U.S. alone (NOAA, 2022). **Yet the A&E industry still relies on historical weather data** for performance analysis, system sizing, and other design decisions, as climate projection data are not available in the formats used by A&E workflows. For example, energy modelers most often use the Typical Meteorological Year (TMY3) dataset produced by the National Renewable Energy Laboratory (NREL)—based on past median weather conditions for a given location that is sometimes more than three decades old (Wilcox and Marion, 2008)—which has been considered sufficient for establishing 'climate normals', and is reinforced by existing standards and codes. Our changing climate makes 'climate normals' less useful for designers, poorly reflecting the range, frequency, and intensity of potential future weather conditions that a building will need to withstand during its lifespan (Rastogi et al., 2022). Further, the Intergovernmental Panel on Climate Change notes that key global systems and infrastructure will be increasingly vulnerable unless design standards change to specifically account for the changing climate (IPCC, 2022). Yet climate projection data are rarely available at a suitable temporal resolution (i.e. hourly) or in a suitable file format (e.g. EPW files containing TMY3 data), requiring post-processing to make projection data usable by energy modelers.

SOURCES OF WEATHER DATA USED BY A&E PROFESSIONALS



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ABOUT THE AUTHORS

The University of Minnesota Climate Adaptation Partnership (MCAP) is a partnership among university, public, non-profit, and private sector groups organized to support Minnesota's ability to adapt to a changing climate. MCAP conducts cutting-edge climate and adaptation research, champions climate leadership, develops the next generation of adaptation professionals, and advances implementation of effective, equitable adaptation actions across sectors, communities, and levels of government. Learn more about MCAP.

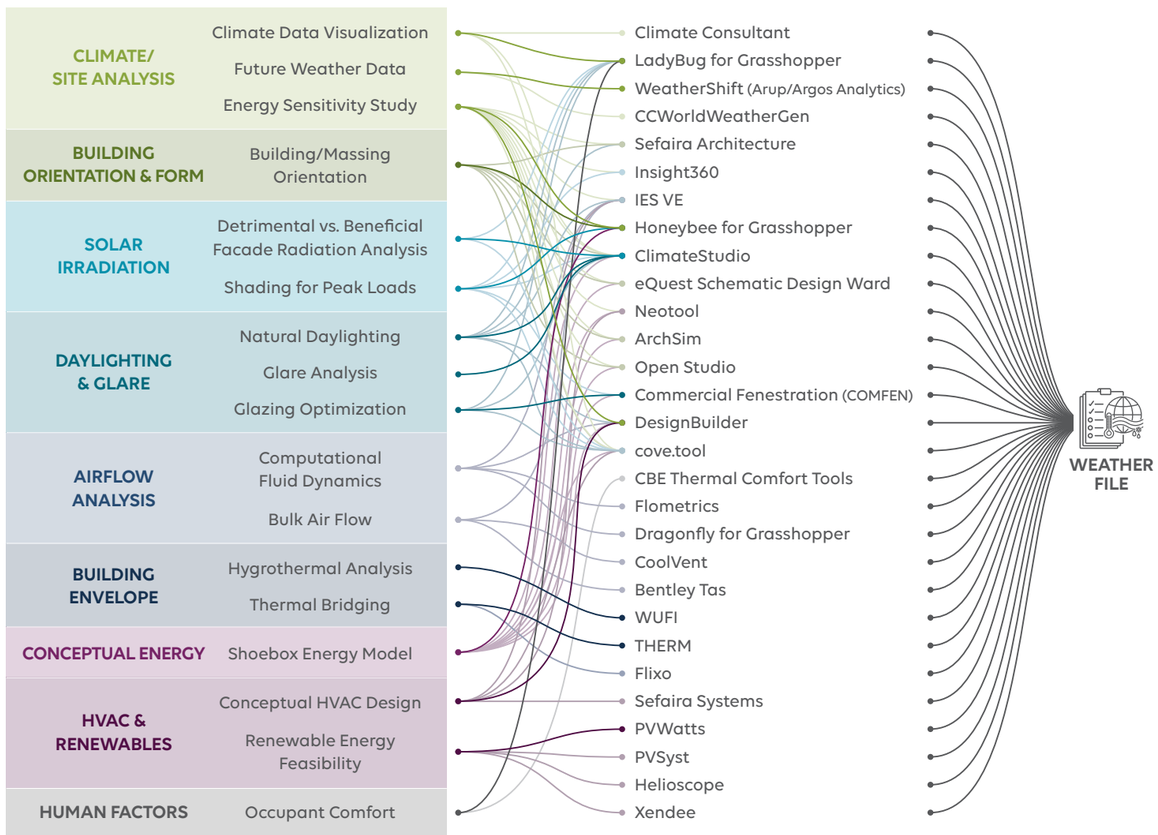
HGA is a national interdisciplinary design firm rooted in architecture and engineering. More than 1000 people in 12 offices from coast to coast work to make a positive, lasting impact for clients in healthcare, arts and culture, community, corporate, education, government, science and technology, and energy markets. HGA has been a leader in an industry-wide conversation around how to better inform projects with climate projection data and use these data for climate adaptive design solutions. Learn more about HGA.

HOW WEATHER DATA INFORMS DESIGN

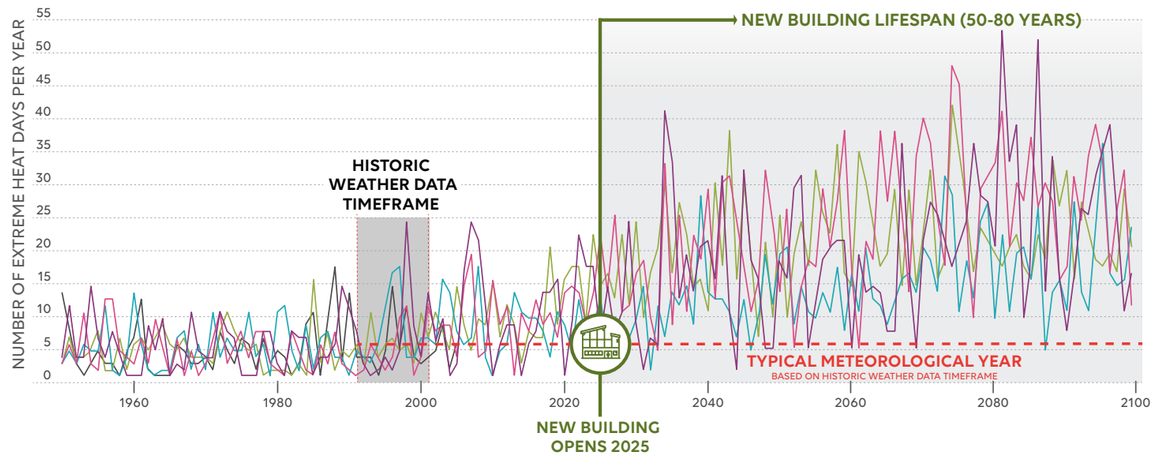
Architects and engineers use simulation tools early in design to inform decisions such as building massing, orientation, window locations, and system selections. The software tools used for simulation all rely on local weather files to provide results appropriate for the project site. These weather files typically show historic weather patterns only; if future projection files were to be used, specific data formats are required. Design decisions are being made every day using only historical weather information, resulting in buildings that are designed to perform under past weather conditions, not future climate.

> "The words 'weather' and 'climate' are often incorrectly used interchangeably in building design and analysis."
> (Rao & Rastogi, 2020)

> "Climate is the synthesis of weather events over the whole of a period statistically long enough to establish its statistical ensemble properties (mean value, variation, probabilities of extreme events, etc.) and is largely independent of any instantaneous events."
> (Essenwanger, 2001)



RISKS OF USING HISTORIC WEATHER DATA FOR BUILDING DESIGN



MODELS: Observed | Warm/Dry | Cool/Wet | Average | Complement

Typical meteorological year (TMY) based on historic weather data

Model location: Sacramento, CA with a daily maximum temperature above 103.9 °F and a medium emissions (RCP 4.5) scenario. Source: Cal-Adapt. Data: LOCA Downscaled CMIP5 Climate Projections (Scripps Institution of Oceanography), Gridded Observed Meteorological Data (University of Colorado Boulder), LOCA Derived Products (Geospatial Innovation Facility).

In recent years, interest in and resources for resilient and climate adaptive design have grown, yet the majority of these resources do not address the procurement of climate projection data to use in design workflows. Results from a 2018 unpublished survey of A&E professionals by UC Berkeley's Center for the Built Environment indicated that while there was a general awareness that climate projection data existed, **most A&E professionals did not anticipate using projection data unless mandated by codes and standards to do so** (Aijazi, 2018).

Despite the lack of code or industry standards requiring the use of climate projection data, the American Institute of Architects (AIA) Code of Ethics and Professional Conduct states the obligations of architects to maintain and advance the standard of care, which as of 2018 includes preparing the built environment for a changing climate. Canon II: Obligations to the Public states that architects should provide their clients with a built environment that "is resistant to climate change" (E.S. 2.4). In a 2018 report, the Conservation Law Foundation states that "failure to act in the face of climate risk could result in legal liability" (Moran and Mihaley, 2018).

SELECT INDUSTRY RESOURCES ON CLIMATE RESILIENCE

- 2021 ASHRAE Handbook—Fundamentals includes a new chapter on global climate change
- AIA Resilience Resources, including:
  - Resilient Project Process Guide
  - Resilience and Adaptation Online Certificate Program
- Building Green Knowledge Base on Resilient Design
- LEED Resilient Design Pilot Credits
- ULI resources for Developing Urban Resilience

STUDY METHODOLOGY

To better understand how A&E professionals are addressing this tension between the lack of codified climate projection data and the obligation to design a built environment prepared for climate risks, MCAP and HGA conducted a study to understand current practice, barriers and opportunities related to their use of climate projection data, and the state of current climate change resilience client services by A&E professionals in the United States. This mixed-methods study was conducted from April 2022 through November 2022 and involved a tiered approach.

LITERATURE REVIEW

Literature review on A&E use of climate projection data that established a baseline of knowledge and current state of climate change resilience services.

- 43 total sources: 31 peer-reviewed and 12 industry sources
- Search terms included: climate resilience, climate projection data, resilient design, adaptation planning, architecture, engineering, planning
- Themes included: climate services, uncertainty, and resilience planning

ONLINE SURVEY

A national online survey that captured direct input from A&E professionals to assess the current state of knowledge and use of climate projection data.

- 144 respondents
- 27 U.S. States, Canada, and the United Kingdom
- Architects, Engineers, Planners, Sustainability Specialists, and other A&E roles
- Distribution included AIA COTE, AIA MN, AIA HI, USGBC, Building Green Forums
- Open August - September 2022

FOCUS GROUPS

Focus groups to capture deeper insights on the state of practice, barriers and opportunities to improve access to and use of climate projection data.

- 4 focus groups
- 14 total participants
- Architects, Engineers, Sustainability and Resiliency Specialists
- Intermediate and advanced climate projection data users
- September 2022

KEY FINDINGS

This study aims to characterize the climate projection data needs of A&E professionals; understand the challenges they encounter accessing, understanding, and applying these data; and identify opportunities to advance A&E climate resilience services. The key findings demonstrate a gap between the current state of A&E practice and climate science and highlight an important role for boundary organizations and climate data developers to build partnerships and capacities to bridge this gap alongside A&E professionals.

1. Sustainable design services do not generally include designing for climate change adaptation
2. Few firms are regularly using projections to inform design decisions
3. Barriers to using climate projection data include lack of client requests, data gaps, and lack of expertise
4. Codes, standards, and training are needed

FINDING 1

A&E clients are generally interested in and supportive of sustainability measures. However, sustainable design is primarily focused on climate change mitigation (reducing carbon emissions) and does not often include designing for climate change resilience (design measures that factor in the projected climate over the lifespan of the building and systems).

In the AIA Best Practice article *Incorporating Sustainability Into Practice*, sustainable design is defined as "a built environment that protects the planet and enhances human health while creating equitable and resilient communities" (Love, 2019). Many A&E firms offer sustainability services both as stand-alone services and integrated into other architecture, engineering, and design services, but few offer climate resilience services.

Survey respondents identified the sustainability and climate resilience services offered by their organization, and while four of the twelve response options related to climate resilience, only one appeared in the top five selected responses. Several respondents stated in their "other" responses that none of the offered services were in demand with their clients, indicating that even sustainability services are not fully integrated into standard practice across the industry.

> Sustainability has transpired into a basic service.

Still, many clients have come to expect sustainability services from their A&E consultants. This demand has been advanced through the promotion of best practices and ethical criteria by industry organizations, such as the AIA; municipalities and government agencies, such as the GSA elevating sustainability expectations on their projects; and building codes, such as CALGreen or the Minnesota SB 2030 Energy Standard, which aim to reduce the energy and carbon in Minnesota commercial, institutional, and industrial buildings and is required on all projects that receive general obligation bond funding from the State of Minnesota (Minnesota B3, 2017).

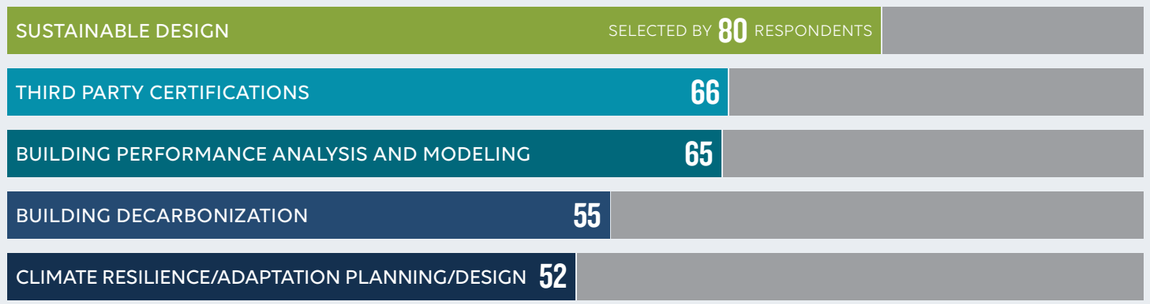
The IPCC reports that mitigation strategies, including solar and wind energy, electrification of urban systems, urban green infrastructure, and energy efficiency, are technically viable, increasingly cost effective, and generally supported by the public, allowing increased use of these strategies (IPCC, 2022). An industry-wide focus on climate change mitigation has gained recent momentum with more firms signing onto commitments such as AIA2030, SE2050, and MEP2040, all targeting carbon reduction in the A&E industry.

While demand for sustainable design services has grown, **firms are not factoring in the projected climate over the lifespan of the building and systems through the use of climate projection data**. Focus group participants acknowledged this opportunity, but cited several barriers, outlined in Key Finding #3, to using climate projection data in their workflows.

> ...we're running energy models on every project using historic weather data. So we're making decisions...energy efficiency measurements, based on data that could be wrong.

SERVICES OFFERED TO CLIENTS

Respondents could select all services offered by their companies. *n=104*



A&E SUSTAINABILITY AND CLIMATE RESILIENCE SERVICES

SUSTAINABILITY SERVICES

Professional services related to building performance analysis, triple bottom line sustainability, and/or climate change mitigation, typically using historic weather data. Most often does not factor in the projected climate over the lifespan of the building, landscape, and systems.

EXAMPLES:

- Sustainability planning
- Third-party certifications (ex: LEED, WELL)
- Passive strategies
- Energy benchmarking
- Energy modeling
- Envelope and glazing thermal modeling
- Daylight analysis
- Indoor air quality analysis
- Carbon neutral planning
- Life cycle assessment

CLIMATE RESILIENCE SERVICES

Professional services related to climate change resilience and/or adaptation using climate projection data, factoring in the projected climate over the lifespan of the building, landscape, and systems.

EXAMPLES:

- Climate vulnerability assessment
- Climate risk assessment
- Climate resilience or adaptation planning
- Infrastructure resilience
- Climate resilient or adaptive design
- Stress testing the design against climate projections
- Energy modeling using climate projection data
- Using climate projection data for the modeling and analysis services listed under Sustainability Services above to inform design decisions for performance under future climate conditions

FINDING 2

While A&E professionals are aware of and interested in using climate projection data in their work, **few firms are regularly using projections to inform design decisions.**

A&E professionals understand that the climate is rapidly changing and that there are serious problems with continuing to rely on historical data to design infrastructure that will need to function under evolving future climate conditions.

> ...we have a complete disconnect between what people are directing us to build and what may make sense in the shifting climate.

Approximately 93% of survey respondents noted some familiarity with climate projections (Figure 1) and 48% of respondents report that their firms already use climate projection data to inform planning and design decisions (Figure 2). This result likely does not represent the A&E industry as a whole, as those currently or interested in using climate projection data may have been more likely to take the survey than those who have no familiarity.

Feedback from focus group participants suggest that in reality, few A&E firms are consistently using climate projection data as part of standard practice or for impactful decision-making about building design and construction. Many report using climate projection data in their work use coarse, high-level data to get a big picture view of future conditions and how their projects may be impacted, and several identified regional or downscaled climate projection data sources. The data is used for a range of purposes, from from high level conversations with clients to system sizing.

FIGURE 1

WHAT IS YOUR PERSONAL FAMILIARITY WITH CLIMATE PROJECTION DATA/INFORMATION?

n=106

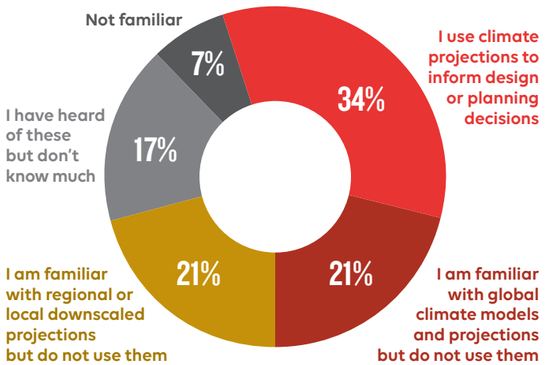
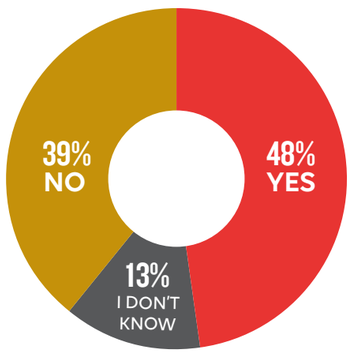
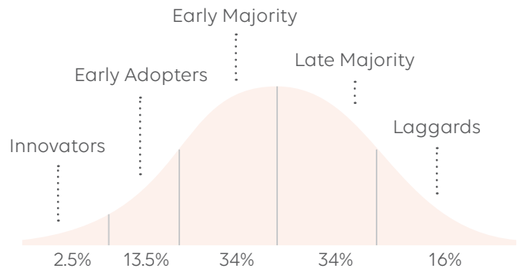


FIGURE 2

DOES YOUR ORGANIZATION USE CLIMATE PROJECTION DATA/INFORMATION IN ANY OF ITS WORK/SERVICES? *n=106*



Respondents that stated they are already adopting projection data for design and planning decisions would be considered "Innovators" or "Early Adopters" (Rogers, 2003) and represent an essential group of end-users to tap for case studies, lessons learned, and nascent formation of industry best practices.



INNOVATION ADOPTION LIFECYCLE

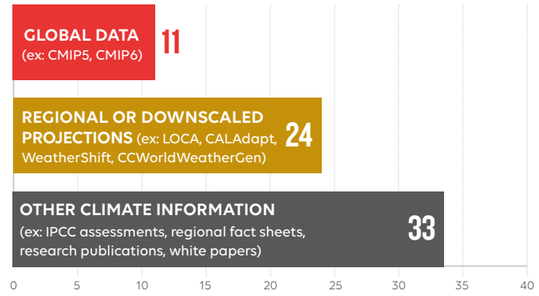
Given that A&E projects have a multi-decadal lifespan, decisions made today on how to construct or retrofit existing infrastructure will have long-lasting repercussions. Leadership by early adopters and innovators on how to apply climate projections to improve these decisions is especially meaningful given that "best practices" regarding use of this information are just starting to be developed and in some cases, codified, for the A&E sector. These early leaders are charting a path forward for the development, dissemination, and adoption of climate projection data for the nation's built environment, a broad service category offered by a rapidly growing field of consultants. Early adopting firms and professionals stand to benefit from this role by helping to determine these best practices for others to follow and shoring up internal expertise that is likely to become increasingly marketable among clients—and profitable. Bank of America analysts estimate that the climate adaptation market could be worth $2 trillion a year within the next five years (Chidambaram and Khanna, 2022).

> We're putting [climate projection data] out there whether or not [clients] are asking.

FIGURE 3

WHAT TYPE(S) OF CLIMATE PROJECTION DATA ARE USED?

n=44

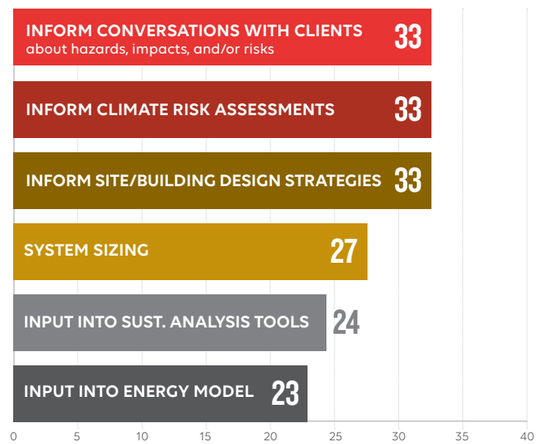


> [We use climate projection data] just to understand...what...changes in heating and cooling loads that we're looking at here...like order of magnitude...understanding that there are high error bars still on a lot of these projections...

FIGURE 4

HOW ARE CLIMATE PROJECTION DATA BEING USED?

n=44



FINDING 3

A&E professionals identify a number of barriers to using climate projection data, including a lack of client requests; a lack of standards and codes; resolution needs; format, content, and cost; trust of the data; and a need for internal expertise to use the data.

Few A&E professionals are using climate projection data to inform design. To understand why, survey respondents were asked for the top three barriers their organization faces to using climate projection data. The survey responses and focus group comments expanded on these four barriers outlined by Rastogi et al. (2022):

1. Lack of consensus on the methodology for creating climate data for buildings
2. Lack of a publicly available platform for providing climate projections in a format suitable for building analysis
3. Lack of consensus on a standardized framework for communicating the results of simulation with long-term climate data projections
4. Liability concerns with using projection data

LACK OF CLIENT REQUESTS

The barrier selected by the largest number of respondents was "our clients aren't asking for climate projection data." With a few exceptions, this was reiterated in the focus groups, where participants emphasized that clients are open to the use of climate projection data on their projects, but aren't generally proactive in requesting its use as part of A&E services.

Interestingly, one of the top reported uses of climate projection data was to inform conversations with clients (Figure 4), indicating a need to raise awareness among A&E clients regarding climate projections and how their use can inform the design and operations of their real estate assets.

FIGURE 5

BARRIERS TO USING CLIMATE PROJECTION DATA

Respondents could select up to three.

n=87

Our clients aren't asking for climate projection data	23.5%
Don't know what products/services are available	10.3%
We would need to hire an individual or team to have capacity for these services	10.3%
Liability concerns with using climate projection data to inform design decisions	9.4%
Data are not in the format(s) used by building analysis/design tools	8.5%
Interpreting the output of these products/services (ex: what the data means for design) requires special knowledge that we do not have	7.9%
Aware of these products/services, but don't know how to use them	7.5%
Using climate projection data/ information is not part of the standard of care	6.6%
Other	8.5%

FOCUS GROUP RESPONSES

Yet should the lack of client requests to use climate projection data really be a barrier to using the data? **Clients generally assume that A&E professionals will apply the right data and decision-making to projects, trusting that the clients' own lack of knowledge will be filled by the training and expertise of the licensed A&E professionals with whom they are collaborating.** The AIA Code of Ethics Rule of Conduct states: "Members should incorporate adaptation strategies with their clients to anticipate extreme weather events and minimize adverse effects on the environment, economy and public health" (ES 6.5). Given the known impacts of climate change already visible today, A&E professionals have an ethical responsibility to inform clients of likely climate change related risks and to incorporate climate projection data into the design process, regardless of client demand.

LACK OF STANDARDS AND CODES

Standards bodies establish design and process guidelines that become standard practice in the industry. Building codes establish the baseline of safety and performance expected by a municipality, creating minimum performance expectations that all A&E professionals must follow. **Currently, there are no U.S. standards bodies that require the use of climate projection data in building design**, nor guidance from standards bodies around how to obtain and use climate projection data in the design process.

Several focus group participants called for creation of a standard for climate projection data that would provide guidance for what data A&E professionals should use and how to use it. The CIBSE weather data set was mentioned more than once, which is available in the United Kingdom and makes historic and projected future data available for energy modelers. In the National Calculation Modelling Guide, the use of CIBSE future files is recommended for energy modelers, making clear what data to use and how to use it. One focus group participant suggested that University of Minnesota Climate Adaptation Partnership collaborate with the Center for Sustainable Building Research to integrate Minnesota's forthcoming climate projection data set (and guidance on how to use it) into the Minnesota B3 standard.

> "[We need] a standard for future weather data that we can point to as engineers...published by ASHRAE.

DATA RESOLUTION DISCONNECT

Climate projection data tend to be available at a relatively coarse resolution, while the A&E industry's tools and methods require more granular data for decision making at the scale of a project site.

There is a data disconnect between the granularity, or spatial resolution, needed by the A&E industry and available climate model output (Tikul et al., 2022). Global climate model projections have been available for decades, providing projections for future climate at a relatively coarse spatial resolution (global/national/regional scale). Since microclimates can dramatically change the design requirements for buildings separated only by a few miles, the more granular the climate data, the better the design can respond to and work within those conditions. In the A&E industry, observed and historical climate data from a weather station close to the project site is typically used to inform design decisions.

To produce climate projection data at a finer spatial resolution (region/state/county/city scale), global climate models are downscaled using either dynamical or statistical modeling techniques (McSweeney and Hausfather, 2018). These finer spatial resolution models tend to provide more accurate simulations of local physics and dynamics influencing the climate system. Some climate models contain biases, e.g., the average temperatures are too low when compared to historical records, and these can be corrected during downscaling. By ensuring that the historical output of a model matches measured data, systematic errors in the projections are removed.

Dynamical and statistical downscaling techniques can provide plausible and accurate regional projections. Dynamically downscaled climate projection data, in many contexts, are preferred over statistically downscaled data. However, dynamically downscaled climate projection data are computationally expensive to generate, not widely available, and are less likely to be output in formats that are directly usable by the software tools preferred by architects and engineers. Statistically downscaled climate projection data are currently more readily available, with some sources providing outputs in the formats needed for A&E applications. Both survey and focus group respondents indicated using climate projection data provided by WeatherShift™, which was developed specifically for the A&E industry and uses statistical downscaling to produce files appropriate for use in energy modeling software. **Ideally, climate data developers would evaluate the needs of the A&E industry as end users of the data and address those needs in the format and delivery of climate projection data.**

METHODS FOR DOWNSCALING CLIMATE PROJECTION DATA

DYNAMICAL DOWNSCALING

Uses a high-resolution regional climate model to simulate local dynamics over a defined area of interest. Links process-based physical relationships between small and large scale behavior using global general circulation model (GCM) boundary outputs.

PROS:

- Better represents complex topography
- Assumes dynamical relationship between local and predictor variables
- No stationarity assumptions

CONS:

- Computationally expensive
- Publicly available data are more limited
- Requires use of greater number of model ensembles

EXAMPLE: With support from the Minnesota State Legislature, MCAP is generating dynamically downscaled climate projections at ~3 mile resolution through the end of the century. MCAP is engaging with data users, including the A&E industry, to facilitate broad use of these data.

Adapted from Copernicus, 2021 and Vano, 2019

STATISTICAL DOWNSCALING

Establishes a statistical relationship between local observed climate records (historical climate) and global climate model output for the same period. These statistical relationships are used to simulate future climate characteristics.

PROS:

- Less computationally demanding
- Large datasets are publicly available
- Output is consistent with observations

CONS:

- Usually assumes stationarity
- Interpolates global climate model output so may not represent climate change signal correctly

EXAMPLE: WeatherShift™ provides statistical downscaled climate projection files for Heat and Rain in formats required for A&E modeling and analysis applications.

FORMAT, CONTENT, AND COST NEEDS

A&E professionals have specific format, content, and cost needs that are currently not standard for climate modelers or the climate science community.

Architects and engineering professionals, including structural, mechanical, electrical, and plumbing engineers, use a variety of methodologies and tools to inform building design, most of which are not aligned with the format of climate projection files, and often are designed to use historic weather files only.

> "Often the analysis tools we're using don't allow us to change the source climate data file to use future climate projection data."

For example, the files used for energy modeling include **hourly** time series for climate variables (i.e., temperature and humidity), while climate projection files most often provide **daily** values based on computational and cost limitations and uncertainty associated with projection at that timescale.

Focus group respondents with mechanical engineering expertise expressed a need for:

- Typical (or average) data for energy modeling
- Climatic design data, expanding on the design conditions tables in the ASHRAE Handbook - Fundamentals, for systems selection and sizing
- Extreme data for stress testing

When asked about the incentives that would motivate greater use of climate projection data, funding was selected by 25% of respondents (n=85). While this response may include multiple factors, including tight project fees and tight margins leading to a general hesitation to offer services outside of standard practice, focus group respondents suggested low cost or free climate projection data, especially when discussing scalability across projects of different sizes and budgets.

> "If there was a place where we can get some of this projection data for free, that would certainly be helpful, especially on smaller scale projects."

While free climate projection data are available from sources such as LOCA, CalAdapt, ResilientMA and NOAA, the format and resolution are barriers that limit their use by A&E professionals. Importantly, not all climate projection data can be suitably reformatted to meet the data format and use needs of A&E end users. A collaborative dialogue is needed between the A&E industry and climate science community to build shared language and improved workflows to enable broader use of climate projection data in the built environment and to build understanding on limitations and appropriate uses of climate projections.

LACK OF TRUST IN THE DATA

There are a range of climate modeling methodologies, scenarios, temporal and spatial resolutions of data, making it hard to know what data are the 'best' or which projections and scenarios are most appropriate for a given project or geography.

> Frankly, I'm not sure how much we can trust future climate projections at a micro (local) scale.

Conversion of climate projection data into usable formats for A&E users can be technical and requires detailed understanding of the data and associated uncertainties. Further, WeatherShift™ and other common sources of climate projection data for A&E "are not regularly or systematically updated by a professional body and have not been systematically compared. No standard exists to compare providers using different models and data sources, especially when black-box models are used. Neither are the datasets released and updated in a systematic and traceable manner agreed upon by all actors" (Rastogi et al., 2022). Without an agreed-upon methodology, many A&E professionals question the trustworthiness of climate projections downscaled to a regional or local resolution.

Since A&E professional practice has involved using historic weather averages to inform design decisions, the consideration of future possible climate conditions as a range is a difficult transition for many practitioners and clients. This highlights the need for new ways of thinking, using and applying climate projection data, and more discussion around climate scenario planning approaches within the A&E sector.

> If you don't know the future, your best answer is many answers—you have to have a range. It's very hard to communicate a range to a client... when I try to tell people that this is the range, they thought that was less credible than giving a single number.

NEED FOR INTERNAL EXPERTISE TO USE THE DATA

In most regions, the changing climate is resulting in both gradual changes (e.g. increasing air temperature) and extremes (e.g. extreme precipitation events). Even if climate projection data were available in formats easily used by A&E professionals, considering a range of plausible future climates requires a shift in design practice. While weather patterns have never been static, the use of historic weather data to inform design has generally assumed weather to be 'typical' or stationary in a given region. Focus group participants described the challenges associated with using a range of possible future climate conditions, with larger firms acknowledging that they have the resources to hire the expertise needed to use climate projection data and shift their practice towards climate adaptive design, which is more difficult for smaller firms with fewer resources.

FOCUS GROUP RESPONSES

FINDING 4

There is a strong need for the development and promotion of industry standards, mandates (including building codes), guidance and training for using climate projections in A&E applications.

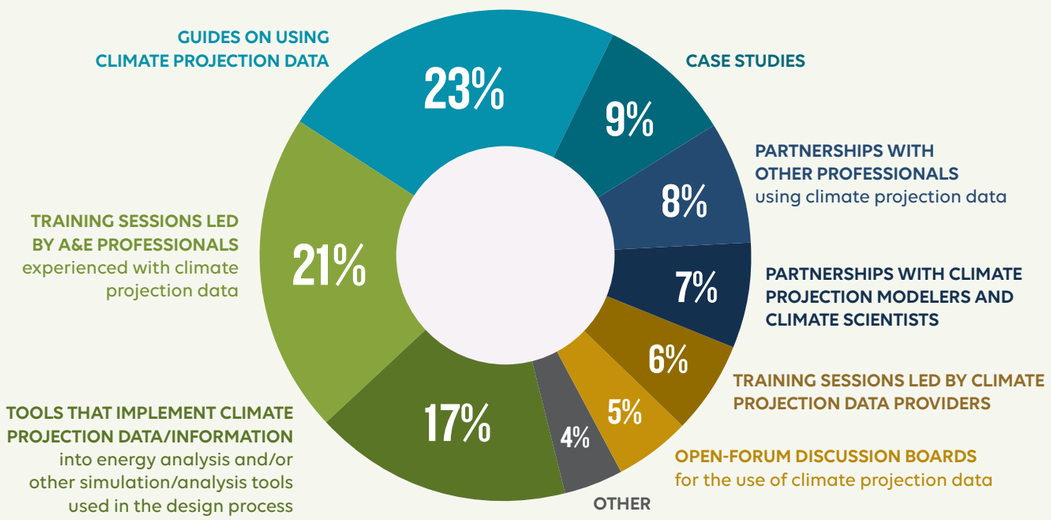
A&E professionals acknowledge that the climate is changing and the built environment is at risk, yet they need guidance, mandates, and training in order to overcome the many identified barriers and use climate projection data more consistently in the design process. When asked what resources would be needed to build or grow the climate adaptation expertise and services in their practice, survey respondents prioritized how-to guides on using climate projection data, training sessions with peers, and tools that integrate climate projections into the software programs used in the design process.

> Ideally, we want somebody to tell us 'this is the way to do it right.' Just like ASHRAE 90.1 tells you how to do modeling—there's a standard. As a preface to that, a guidance document could be developed to really think through specifically how to model and what data to use.

FIGURE 6

RESOURCES NEEDED TO GROW CLIMATE ADAPTATION EXPERTISE AND SERVICES IN A&E PRACTICE

n=85



> I have plenty of data that shows it's getting warmer every winter. On average, heating degree days go down every year as a general trend, but we'll still get a -25 or -30°F day. How to make those two things work together? It would be nice to have some more data on this, but generally we're seeing a trend that the weather is becoming less stable. Generally it's warmer, but you're going to get cold shocks. How do you deal with that from a climate adaptation perspective?

Training sessions led by peers in the A&E industry who have experience using climate projection data were preferred over sessions led by climate projection data providers, demonstrating a need for technical expertise in how to apply the data to A&E applications. Focus group participants described the confusion around how to handle multiple plausible future climates, expanding on this need for technical guidance and a shift in practice.

> The data does not have the 'blessing' of industry authority groups, like ASHRAE. CIBSE provides a uniform set of predicted climate data for the UK. We need the same in the US and other countries for a common source of 'truth'.

Respondents desire professional associations and standards bodies to provide direction in what climate projection data to use and how to use that data in practice, and for building codes to require climate adaptive design solutions to continuously protect the health, safety, and welfare of building occupants under the conditions of a changing climate.

> There are different scenarios, right? Are we going to run all these scenarios? Are there different probabilities that we should be associating with them? We need a methodology as design professionals...it's not just what data we have but also how we actually use it. I'm not a climate scientist and I find myself diving down these rabbit holes to answer these sorts of questions. I want people who are smarter than me who know this stuff more than me to come up with a process that I can just follow and know that there's at least some legitimacy to the numbers that I'm getting out at the end of the day.

The 2022 version of the ASHRAE Handbook included a chapter on climate change for the first time, yet it fell short of addressing the need for a guidance document or standard for sourcing and using climate projection data. In *Resiliency in the Built Environment: Current State, Considerations, and Influence Factors*, the AIA stated that "stronger building codes and standards will drive resiliency, but so will making the business case to clients" (Mentz and Russo, 2022). Guidance around using climate projection data in design is notably missing from the AIA's multiple guidance documents and training resources published in recent years.

These results are a clear call to action for A&E industry associations and standards bodies to create guidance for the sourcing and use of climate projection data in design applications, and for building codes to require the use of those standards.

RECOMMENDED ACTIONS

A&E professionals recognize the urgent need to evolve practice to better prepare for and adapt to a changing climate. Actions must be taken by industry associations to provide guidance and standards to their members and by code bodies to require these new workflows are followed. In addition, these results communicate to climate experts and agencies, like the USGCRP, and boundary organizations, like MCAP, that the research and reports they release—providing information on population-level climate risks and impacts—are being utilized by A&E professionals motivated to increase resilience in the built environment. This should be a motivation to bolster direct A&E involvement in these influential reports to continue capturing A&E concerns and perspectives.

These recommended actions below could close the gap between climate science and the A&E professionals who are designing buildings and infrastructure that must withstand climate change. Future lawsuits may force action. One focus group participant questioned whether it would take a large lawsuit against a building design team for failing to use forward-looking information in design to change practice. Elena Mihaly, staff attorney at the Conservation Law Foundation agrees: "failure to act in the face of known climate risk could come with legal liability" (Melton, 2020).

> "I would say the industry risk right now is kind of unknown…it's certainly going to come…as building owners start to get…fines levied on them for not hitting certain performance targets… as soon as someone starts to pay money they're going to start looking to someone else to understand why, right? And if the energy model is based on old data, that's not a really good excuse.

The climate is changing rapidly. Action must be taken now and must involve substantive collaboration with climate data developers, boundary organizations, A&E associations and professionals, policy makers, building code and standards bodies, higher education institutions, and any organization that hires A&E professionals.

TOGETHER, WE CAN BUILD A MORE RESILIENT FUTURE.

A&E ASSOCIATIONS (EX: ASHRAE, AIA, ASCE)

- Rather than considering weather as static, A&E professionals—and the associations and standards bodies that govern their codes and standard of care—should develop methodologies to design for uncertainty, considering a range of plausible future climates that their clients' buildings and infrastructure may face.
- ASHRAE design conditions tables should include a range of future climate conditions.
- Provide guidance on scenario planning/stress testing for a range of plausible future climates.
- Provide standardized criteria for climate files to be used in simulation and modeling tools in partnership with climate data developers.
- Existing design process guidance documents, such as the AIA Resilient Design Process Guide, should be expanded to include guidance for obtaining and using climate projection data to inform design.
- The AIA Framework for Design Excellence section on Design for Change should integrate recommendations for climate projection data and climate adaptive design.
- Include climate resilience in AIA contract language, outlining how clients can expect their architects to integrate forward-looking climate data into the design process.

A&E HIGHER EDUCATION INSTITUTIONS & RESEARCH CENTERS

- Develop curriculum for A&E students about climate change and how to consider a range of plausible futures using climate projection data for climate adaptive design.
- Research centers for the built environment and climate adaptation/climate science, such as the University of Minnesota's Center for Sustainable Building Research and MCAP, should:
  - Create a shared research agenda and collaborate on advancing climate adaptation and resilience with industry professionals, researchers, students, and policymakers.
  - Include climate resilience in sustainability and environmental design curriculum.
  - Increase coordination and collaboration across academic and professional disciplines.
- A&E internship programs should encourage exposure to sources of climate projection data and application of those data.

ORGANIZATIONS HIRING A&E PROFESSIONALS

- Include climate resilience expertise in selection criteria when hiring A&E teams.
- Require climate projection data be considered in design.
- Ask your consultant teams how your project will mitigate and adapt to climate change.
- Review design intent for adaptive capacity.

CLIMATE DATA DEVELOPERS & BOUNDARY ORGANIZATIONS

- Involve A&E professionals in the development of climate change data and reports.
- Include A&E professionals when identifying end users of climate projection data.
- Partner with A&E end users to identify data output formats needed to inform the design of the built environment and create opportunities for shared learning. Since not all climate projection data can be suitably reformatted to meet current data format and use needs, broader use of these data could be enabled by building shared language, improved workflows, trainings, and dialogue between A&E professionals and the climate science community and boundary organizations that support the use of climate projection data.

POLICY MAKERS, BUILDING CODE & STANDARDS BODIES

- Building codes for new construction and renovation/retrofits, should require consideration of climate projection data.
- As best practices for utilizing climate projection data in design are updated by A&E professional bodies, those practices should be adopted into building code.
- Energy code should be performance based using performance criteria for today's climate and plausible future climate.
- Integrate climate resilience expectations into policy-driven sustainability standards, such as Minnesota B3, which will help fuel client awareness of, and subsequent demand for, climate data and climate services.
- Increase funding support for climate scientists and climate service providers to ensure resources and capacity are available to meet the growing demand for data, training, and technical support in how to appropriately use and apply climate projection data.

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