Taking Comfort to the Extreme

The objective of this challenge is to improve occupant indoor thermal comfort in buildings in the United States located in extreme climates or locations prone to extreme weather events by focusing on the environmental factors that determine individual satisfaction within indoor atmospheres.

Background

Have you ever had to wear a sweater indoors in the middle of summer because of a cold building? In winter, do you feel too warm inside because of the interior temperature? These reactions point to your **indoor thermal comfort**, or the personal perception of being too hot or cold in a building which is also "inextricably linked to health".[1] Thermal comfort can be assessed qualitatively by polling occupants (e.g., using the ASHRAE seven-point thermal sensation scale)[2] or quantitatively via measurements (e.g., infrared coupled with computer vision)[3], and is often determined by six elements. These include environmental factors such as air temperature, the temperature of surrounding surfaces, relative humidity, and air movement, along with personal factors like clothing level and level of activity.[4]

Thermal comfort goes beyond having a properly sized heating/cooling system that meets a temperature setpoint in a room. Thermal gradients in a "well-conditioned" space (e.g., due to poor air mixing, the exterior façade, or outdoor environmental conditions) as well as occupant-specific characteristics can result in discomfort.[5] The degree of discomfort varies depending on climatic and weather conditions, as well as the innate resilience of a building or an energy grid. The U.S. is composed of eight climate zones ranging from very hot-humid regions (e.g., Hawaii, Southern Texas) to subarctic (e.g., Alaska).[6] In extreme cold climates where the use of hydronic heating systems are common, thermal imbalance can reach as high as 48 °F (56 °F – 104 °F) leading to significant occupant discomfort.[7] Extreme weather events, or the occurrence of unusually severe weather conditions compared to historical distributions, can also cause conditions found in extreme climates to occur in traditionally mild environments.[5,8] The Great Texas Freeze[9,10] and the 2021 Northwest Heat Dome[11], which ravaged regions in the U.S., are two such examples. With heating, ventilation, and air conditioning systems already taxed, failure of the electric grid and the lack of resilient building design (e.g., use of walls as thermal storage, lack of radiant slab heating/cooling, or dedicated conditioned rooms) made it very difficult for communities to withstand and recover from these stresses.[12]

Negative health outcomes are a result of poor indoor thermal comfort. Excessive exposure to heat can exacerbate underlying illnesses including cardiovascular disease and asthma and resulted in ~500,000 deaths globally each year between 2000-2019.[13] Similar risks are faced by occupants experiencing extreme cold, resulting in an estimated 38,000 deaths yearly.[14] Though causal research is ongoing, many studies indicate that children and elderly population over 65 years of age are especially vulnerable to poor indoor thermal comfort conditions.[15] It is vital to identify resilient solutions that address occupant needs for indoor thermal comfort.

Currently, personal comfort devices such as space heaters or tabletop fans are commonly used. In some cases, advanced equipment controls (e.g., enhanced humidity control[16], IoT-based comfort control[17]) are implemented or mechanical heating and cooling systems are oversized to address the need. These existing solutions can be difficult to implement due to cost, installation logistics, effectiveness, or practicality. A tiered approach is recommended and should first prioritize basic building design (e.g., site location, form, shape, orientation, window sizes, etc.), followed by passive strategies appropriate for local climate (e.g., use of thermal mass, dedicated solar rooms, and natural ventilation), and lastly mechanical heating and cooling systems.[4] Care must be taken not to increase the operational cost of buildings as a result of the proposed technology since major challenges to adoption typically include upfront costs and long payback periods.[18] It is essential that solutions are affordable and address needs for all communities, especially ones that are historically vulnerable and suffer disproportionate harm.[19]

The Challenge

This challenge asks student teams to improve occupant indoor thermal comfort in U.S. buildings (residential, commercial, new, or existing) located in extreme climates or locations prone to extreme weather events by focusing on the environmental factors that determine individual satisfaction within indoor atmospheres. Teams should first build out a focused problem statement for a specific stakeholder group (i.e., by climate zone) and then develop a technical solution that meets the needs of the population. For example, students may consider solutions that can measure real-time thermal comfort in subarctic climates and adjust environmental controls accordingly. Innovative solutions should also prioritize grid and building resilience, especially for occupants in vulnerable communities. Teams must develop technical and holistic solutions to address the problem and should include at least one nontechnical component (e.g., an economic, policy, commercialization, codes, or standards component). However, solutions only considering stand-alone nontechnical components will not be considered.

Suggestions for the student teams include (but are not limited to) the following:

- Real-time sensing and response to occupant indoor thermal comfort needs.
- Advanced humidity control and measurement of occupant comfort in high humidity climates.
- Passive approaches such as solar spaces and radiant slabs that extend the period of thermal comfort following an extreme weather event.

Student submissions should:

- Describe the scope and context of the chosen problem.
- Identify affected stakeholders, making sure to research stakeholder backgrounds and understand the stakeholders' needs, especially regarding the problem.
- Develop a technical solution to the chosen problem for the targeted stakeholder group. The solution may also include policy solutions, supply chain and manufacturing processes, economic solutions, or other aspects critical to identified stakeholder barriers, but a technical solution must be proposed.
- Discuss appropriate and expected impacts and benefits of the proposed solution. This should include expected carbon reduction analysis, a cost/benefit analysis, a market adoption analysis, and should also consider non-economic costs and benefits, such as occupant health, productivity, well-being, and others.
- Develop a plan that describes how the team envisions bringing its idea to scale in the market, including sales or distribution channels, outreach mechanisms, stakeholder engagement, and other relevant details.

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