Research Report

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Identifying Resilient, Sustainable Cooling Strategies for Los Angeles

How Might Landlords of Single-Family Homes Meet Indoor Temperature Thresholds?

As climate change intensifies, the world will have more-frequent, more-severe, and more-prolonged heat waves.[1] Recent research indicates that such events can be dangerous and, in some cases, deadly—especially for older adults and young children.[2] As these events get worse, they might lead to even more ill health effects and deaths than we have seen historically. Increasingly, individual communities are considering how to adapt to these heat risks in ways that account for their local context and populations.[3] One of these communities is the County of Los Angeles in California. Historically, Los Angeles County has had a mild climate; the mean daily maximum temperature generally stays below 80 degrees Fahrenheit (°F) at Los Angeles International Airport,[4] 91°F in Pasadena,[5] and 95°F in the San Fernando Valley.[6] More recently (such as in 2018 and again in 2024),[7] Los Angeles County has seen high temperatures of more than 110°F, with statistically significant increases in heat illnesses, emergency services, and hospitalization rates during these heat wave events.[8] Heat-related illnesses and deaths are preventable, and cooling indoor temperatures via air conditioning (A/C) is the most common protective measure.[9] However, more than 1.1 million units (or more than 30 percent of residential homes) in Los Angeles County lack any cooling devices,[10] and renters face more challenges than homeowners to access cooling in their homes. Given this context and the high level of renters in the county,[11] the Los Angeles County Board of Supervisors began working in 2024 to develop an ordinance that would establish a maximum indoor temperature for rental units, aiming to promote equitable access to cooling and safeguard vulnerable renters from extreme heat.[12]

KEY FINDINGS

- The Los Angeles County Board of Supervisors' ordinance to establish a maximum indoor temperature threshold should focus on safe temperatures for **at least one room** rather than the entire home.
- The ordinance, implementation plans, and incentives should **promote passive cooling** to reduce overall greenhouse gas emissions and energy bills and combine passive and active strategies to ensure safe indoor temperatures.
- If higher levels of passive cooling are costly and difficult to implement, it is crucial for the ordinance, implementation plans, and incentives to **prioritize higher efficiency ratings and zone control for air conditioning**.
- Implementation plans should include outreach that addresses different compliance options and their usage in a way that can promote safe indoor temperatures and address electricity bill concerns. People who are especially vulnerable to heat should **consider prioritizing their health over public requests to reduce energy demand** and should not increase the thermostat temperature to conserve electricity or enroll in programs that give the utilities the ability to modify air conditioning thermostat settings during heat waves. Instead, efforts for those especially vulnerable to heat should focus on reducing the cooling space to maintain safe temperatures and lower energy consumption.
- Related implementation plans and incentive structures should **reduce barriers to adopting strategies** that minimize installation cost, grid impact, energy bill impact, and greenhouse gas emissions while ensuring safe indoor conditions.

Background

The Los Angeles County Board of Supervisors seeks to gather input on the "maximum indoor temperature for rental dwellings in the County of Los Angeles and . . . how to equitably establish, define, implement, and enforce relevant policy for rental units."[13] This input could inform a county ordinance to specify the responsibility of landlords to maintain the temperature in all habitable rooms.[14] A *habitable room* is defined by the Los Angeles Code of Ordinances to include any room used for sleeping, living, cooking, or eating, excluding closets, bathrooms, corridors, and similar non-living spaces.[15] Officially, this new ordinance would affect only renters living in the unincorporated parts of Los Angeles County. Along with the county, however, the state of California is considering a policy recommendation to ensure that residential dwellings can maintain a safe indoor air temperature,[16] so cities across the county might join as well. The details of this new ordinance, including the exact maximum temperature permitted indoors, will not be finalized until early 2025.

The most obvious way for a landlord to comply might be to provide a form of window A/C. However, this choice would have repercussions for regional electricity, which becomes a scarce and limited resource during heat waves in California because of shortages in supply resources and limitations in infrastructure. A/C units already account for 60 to 70 percent of summertime peak electricity demand within residential buildings in Los Angeles County,[17] and they account for even more of the demand during the hottest days. This is because when outdoor temperatures are very high, A/C units must work hard to keep indoor spaces cool and people safe.[18] Further exacerbating the stress on the electric grid, A/C systems in old and under-insulated homes must work harder and longer, using more energy to achieve the same comfort level that a well-insulated building can have. At high air temperatures, the likelihood that every A/C unit in the region is on approaches 100 percent, which, in turn, causes an increase in electricity demand.[19] This phenomenon already contributes to power interruptions; in California, power outages are twice as likely and last 18 percent longer during heat waves.[20] This is well known by electricity grid stakeholders; for example, the California Independent System Operator (CAISO) issues Flex Alerts, which call "for voluntary conservation of electricity in the late afternoon and early evening."[21] Even without resource shortages, outages can occur as a result of equipment or distribution line malfunctions or failure caused by overloading or overheating during heat waves.[22] Adding more A/C units to buildings would increase the likelihood of power interruptions, especially if A/C installations occur quickly and do not provide utilities and system planner with appropriate time to plan for the increased demand. Because window units can be bought and installed within a few hours, this action might lead to sudden increases in demand that exceed the current plans for resource and infrastructure expansion. Thus, an important and immediate trade-off for policymakers to consider is how to lower indoor temperatures in a way that minimizes peak energy demand during heat waves.

Beyond the risk to the electric grid, there are other considerations. One of these considerations involves the longer-term goals of the state of California, as established in such laws as California Senate Bill 32, which sets a statewide goal to reduce greenhouse gas (GHG) emissions to a level that is 40 percent below the 1990 level by 2030.[23] Until California's electric grid fuel mix has fully decarbonized, any change in annual electricity demand will affect state GHG emissions. Therefore, any regulation concerning indoor temperature thresholds will affect these emissions goals. Other considerations include the equity goals of the state of California, such as the California Public Utilities Commission's guidance on energy justice.[24] Ideally, an indoor temperature threshold policy would be enacted in a way that minimizes both implementation costs (generally paid by landlords) and utility bills (which, although sometimes paid by landlords, are often paid by renters).[25]

A previous study examined some of these goals by evaluating 13 multifamily units in Los Angeles County, a variety of passive cooling (PC) and active cooling (AC) technologies, and two weather conditions (the 2018 heat wave and a hypothetical future heat wave in 2058).[26] The authors found a suite of PC strategies that can assist in reducing temperatures. They also note that during heat waves, PC is insufficient; AC (via A/C units or heat pumps) will be required. These calculations were done for El Monte, which is much cooler on average than other parts of the county (e.g., Pasadena or San Fernando). To our knowledge, no study has considered the 400,000-plus single-family rental homes in the county, about 30 percent of which currently lack any cooling devices.[27] Building geometry and materials differ greatly, and these differences allow for changes in AC performance and the possibility of installing different PC options. Stand-alone single-family units do not share walls, floors, or ceilings, so there is a difference in heat loss or gain, which typically leads to more energy consumption for cooling than occurs in multi-family units.[28] For this reason, it is important to consider single-family building types.

We see two gaps in the current research on cooling strategies. First, there is a need to understand how a temperature threshold policy within the

Abbreviations

°F	degrees Fahrenheit
A/C	air conditioning
AC	active cooling
CAISO	California Independent System Operator
CO_2e	carbon dioxide equivalent
EBC	Energy in Buildings and Communities
EER	energy efficiency ratio
EIA	U.S. Energy Information Administration
ft^2	square foot
GHG	greenhouse gas
HWY	heat wave year
IEA	International Energy Agency
kW	kilowatt
kWh	kilowatt-hour
LRMER	long-run marginal emissions rate
MW	megawatt
MWh	megawatt-hour
NREL	National Renewable Energy Laboratory
PC	passive cooling
SEER	seasonal energy efficiency ratio
SHGC	solar heat-gain coefficient
TMY	typical meteorological year

County of Los Angeles might be crafted to protect vulnerable populations renting single-family homes while minimizing power-grid strain during periods of extreme heat. Second, there is an underlying need to meet California state policies and priorities, including considerations of how cooling strategies affect GHG emissions and equity goals related to costs for both landlords and tenants.

Research Questions

Given this context, we consider the potential outcome of the adoption of an indoor maximum temperature threshold ordinance for unincorporated Los Angeles County, and we extend our analysis to gain an understanding of what would happen if all the incorporated parts of Los Angeles County joined this ordinance. Three research questions guide our study:

1. What are the types of AC and PC strategies that might be used to meet the ordinance in single-family detached homes in the County of Los Angeles?
2. How do these strategies perform under different weather conditions, including extreme heat conditions?
3. What aspects of the ordinance would make it more robust or otherwise better able to achieve its goals in a wide variety of futures?

> Our goal was to identify a robust strategy that is climate-resilient, sustainable, and affordable across a variety of future scenarios.

Methods

We first selected from the literature a menu of cooling measures and strategies that landlords can use to stay below a temperature threshold.[29] We then modeled one geometry of a residential building representing a single-family detached unit in EnergyPlus[30] to test these measures and strategies under various weather conditions and two thermostat temperature setpoints. Finally, we evaluated the performance of these measures and strategies across different metrics: maintaining safe indoor temperatures, minimizing power outage risk, minimizing annual energy use, and maximizing affordability to adopt and operate. Our goal was to identify a robust strategy that is climate-resilient, sustainable, and affordable across a variety of future scenarios.

Figure 1 outlines the details of our methodology and process. Our factorial sampling of various measures and weather conditions produced a total of 1,099 scenarios.[31] Details of each component will be discussed in the following sections.

For this study, we used high-fidelity building modeling, and we considered single-family detached rental homes in Los Angeles County that are without A/C. Note that we excluded existing units that are partially cooled, even when a strategy otherwise refers to cooling an entire unit. We also considered different weather conditions across the county, including both current and future scenarios. Other considerations include different combinations of AC and PC strategies and changes in thermostat setpoints.

Because of time, funding, and data constraints, other relevant considerations are outside this study's scope. For example, we did not consider other building types or building stock turnover. Our study includes seven distinct weather profiles that are applicable to different extreme heat waves and different parts of Los Angeles County. However, we applied each of those weather profiles uniformly across the whole region. When discussing the possibility of power interruptions, we did not consider distribution-level information of the electric grid. Although we discuss dangerous heat levels, we did not consider demographics or any specific or secondary health impacts. Furthermore, in this study, we did not consider enforcement or

FIGURE 1

Methodology

1. Define relevant factors and build scenarios

1,099 scenarios drawn from the following:
- 7 weather cases
- 8 AC measures
- 8 PC measures
- 2 thermostat setpoints (75°F and 82°F)
- + 203 extra cases including without AC

2. Calculate metrics for each scenario

U.S. Department of Energy's EnergyPlus output:
- Energy use (hourly)
- Indoor temperatures (hourly)

3. Evaluate robustness

Evaluate the performance across the following:
- Unsafe indoor temperature
  - Total hours above the threshold (82°F)
  - Maximum temperature
- GHG emissions[a]
- Power outage risk (peak cooling load)[b]
- Affordability (installation and operation)[c]

[a] National Renewable Energy Laboratory (NREL) annual levelized long-run marginal emissions rates (LRMERs) for California.

[b] NREL, "ResStock Public Datasets: End Use Savings Shapes."

[c] RSMeans, Quarter 1 of 2024, Los Angeles County (RSMeans Data Online); U.S. Energy Information Administration (EIA), "Average Retail Price of Electricity, Quarterly," respectively.

compliance models for the ordinance, even in situations when we expect that most good-faith efforts to meet indoor safety regulations will fail. We also did not consider any sort of behavioral response. For example, we did not include the effects of cell phone warnings about energy use, people moving to cooling centers, mechanical fans, or people opening windows to vent air.

Building Choice and Assumptions

Los Angeles County is the nation's largest county in terms of population, number of residential housing units, area, and many other features. According to census data, about 1.9 million homes in the county are occupied by renters.[32] If Los Angeles County adopts the temperature threshold ordinance that is under consideration as of early 2025, it will directly affect more than 100,000 rental homes within the county's unincorporated area. If every city in the county adopts the ordinance, the ordinance would apply to all of those 1.9 million homes (see Figure 2). Multifamily buildings in Los Angeles County have already been studied,[33] so we focused on single-family homes. There are more than 400,000 single-family rental homes in the county, about 30 percent of which currently lack any cooling devices. The rest have access to A/C for at least one room.[34] Another advantage of considering single-family homes is that the application of PC techniques is more straightforward than for multifamily homes.[35]

We modeled all single-family detached rental homes as a rectangular, 1,350-square-foot (ft^2), three-bedroom, two-bathroom unit with four windows, a door, and a sloped roof. More details on building geometry, materials, and input parameters are included in Appendix B.

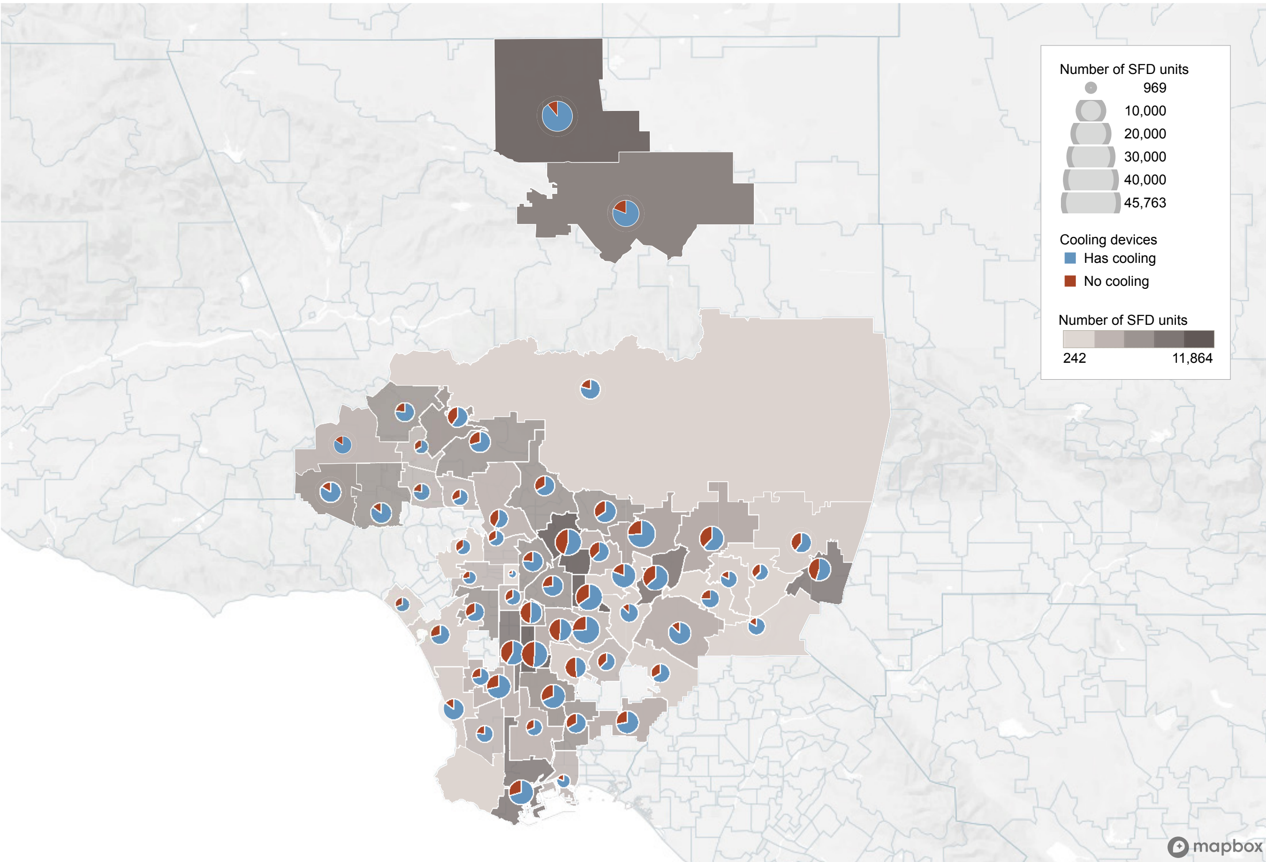
Active and Passive Cooling Measures and Strategies

We initially selected a set of AC and PC measures and strategies (see Figure 3). Most of the AC methods we considered were air conditioners; we considered different types and efficiencies of ACs, such as window units, central A/C, ductless mini-split systems, and heat pumps.[36] We also considered different potential cooling conditions and requirements, such as the option of cooling just one room instead of the entire house.

According to NREL's ResStock data,[37] central and room air conditioners are the most common methods for cooling homes in Los Angeles County, while heat pumps are used in a relatively small number of homes, and there are almost no ductless mini-split A/C systems. The lack of ductless mini-

FIGURE 2

Number of Single-Family Detached Rental Units and Proportion of Active Cooling Versus No Active Cooling in Los Angeles County



SOURCE: Features data from NREL's ResStock (NREL, "ResStock Public Datasets: End Use Savings Shapes").

NOTE: SFD = single-family detached units. The different gray shades and the size of the pie charts indicate the number of single-family detached rental units in each city boundary. (Darker shades and larger sizes reflect higher numbers.) The red slices of the pie charts represent the proportion of single-family detached rental homes without any A/C.

split systems could stem from higher initial costs and less familiarity among consumers. Given the small number of homes utilizing these cooling systems, we chose to model heat pumps and ductless mini-splits only at high-efficiency levels. Two efficiency ratings are used to assess how much energy an AC unit consumes to cool a home: Window units use the energy efficiency ratio (EER), while central A/C and heat pump systems use the seasonal energy efficiency ratio (SEER). The higher the SEER and EER ratings, the more energy-efficient the system. Details on sizing method, exact sizing, and efficiency ratings are included in Appendix B.

We modeled the following AC measures and a base case:

- one-room window A/C high efficiency (EER 12), regular sizing
- one-room window A/C high efficiency (EER 12), oversizing[38]
- one-room window A/C medium efficiency (EER 10)
- whole-unit window A/C high efficiency (EER 12)
- whole-unit window A/C medium efficiency (EER 10)
- central A/C high efficiency (SEER 20)
- central A/C medium efficiency (SEER 13)

FIGURE 3

Active and Passive Cooling Measures Used in This Study

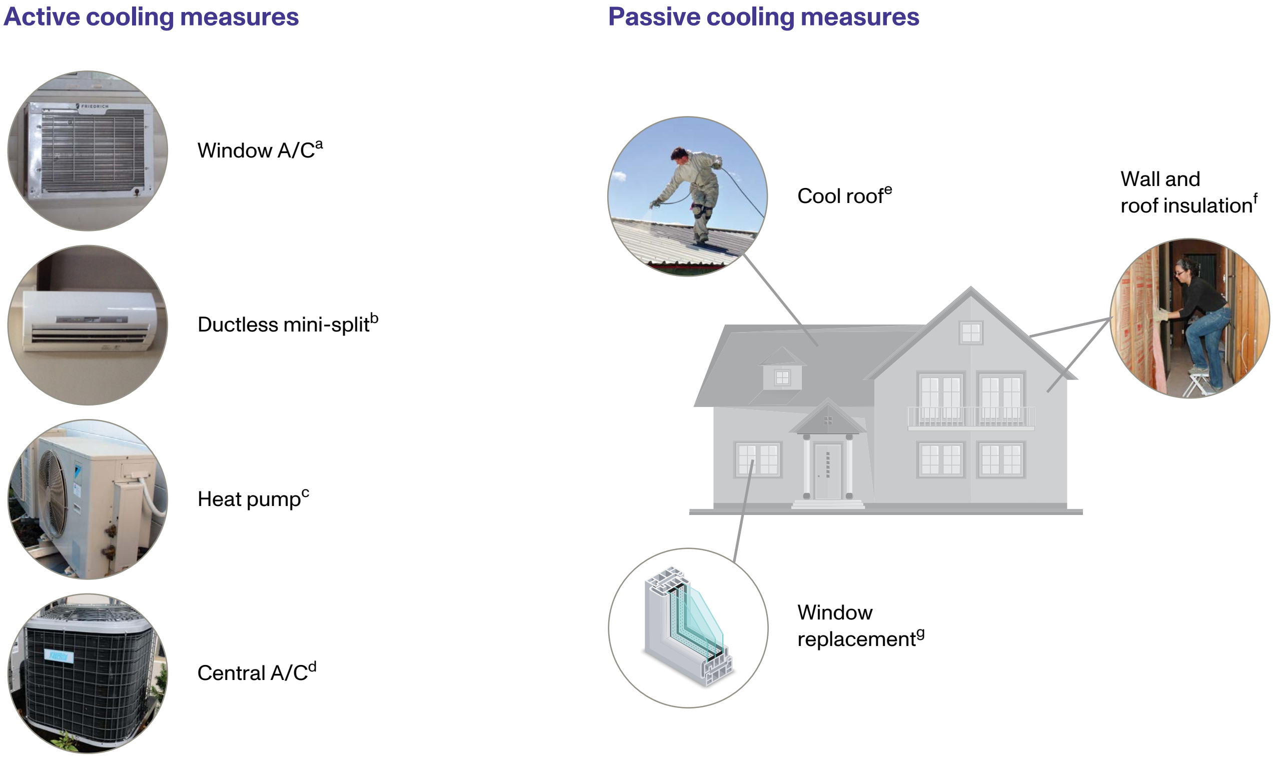


Image credits: [a] Infrogmation (CC BY-SA 4.0). [b] Sara Thompson (CC BY-SA 2.0). [c] WFIU Public Radio (CC BY-NC 2.0). [d] Raysonho (CC BY-SA 4.0). [e] Lakeview Images/Adobe Stock. [f] Nick Nguyen (CC BY-SA 2.0). [g] Macrovector/Freepik. House: Elegant Solution/Adobe Stock.

- ductless mini-split high efficiency (SEER 20)
- heat pump (variable-speed compressor) high efficiency (SEER 20)[39]
- no AC (base case).

PC includes modifying or designing a building with strategies such as better-insulated windows, reflective films on windows, or a reflective or well-insulated roof. Details on input parameters for each measure can be found in Appendix B. The PC and base-case measures we modeled are

- single-pane windows (base case)
- single-pane windows with a cool roof
- single-pane windows with a reflective film
- single-pane windows with a reflective film and a cool roof
- double-pane windows with a reflective film
- double-pane windows with a reflective film and a cool roof
- triple-pane windows
- triple-pane windows with a cool roof
- all PC: triple-pane windows with a cool roof, cool walls, and roof insulation.[40]

Each scenario is a combination of AC and PC methods that were tested for a weather condition. Therefore, the base case scenario involves no AC and single-pane windows.

EnergyPlus and OpenStudio-HPXML

The U.S. Department of Energy's EnergyPlus is an open-source program that simulates and evaluates energy consumption and efficiency in residential and commercial buildings. We used the OpenStudio-HPXML tool, which let us run EnergyPlus simulations using an HPXML file for the building description and could accommodate modifying a wide variety of building characteristics and technologies.

The tool allows for input parameters related to details about the building (see Appendix B), building use, and AC technologies. It reports various outputs at an hourly and annual resolution. We used hourly indoor temperatures for conditioned space and hourly cooling load for energy use to calculate performance metrics.

Weather Profiles

We used seven weather profiles from various public databases to ensure comprehensive coverage of Los Angeles County's diverse climate and of extreme heat wave conditions.[41] Table 1 summarizes the files, and Appendix C describes the relevant data cleaning. The weather cases include two primary categories of weather files: typical meteorological years (TMYs) and heat wave years (HWYs). The HWYs represent extreme conditions,[42] capturing the most intense, most severe, and most prolonged heat waves experienced during three reference periods. Table 1 and Figure 4 provide more detailed information and sources for the weather cases we modeled. Note that the Pasadena and San Fernando Valley TMYs are hotter than the HWYs for Los Angeles International Airport; it is likely that there will be even more heat waves in Pasadena and the San Fernando Valley than are described here. This means that studies that use temperature profiles in the area of Los Angeles International Airport,[43] even if those profiles are current or for future HWYs, are underestimating temperatures in Los Angeles County; a full understanding of a regulation's performance should consider the hotter temperature profiles.

Performance Metrics

We used different metrics to evaluate safe indoor temperature, power outage risk, climate impact, and affordability.

Safe Indoor Temperature

EnergyPlus outputs hourly temperature profiles for each of the 1,099 scenarios. Although there are many ways to evaluate safe indoor temperature, we used three metrics:

TABLE 1

Weather Data Information

Short Name	Type, Year	Location	Source
TMY	TMY, 2001–2020	Los Angeles International Airport	International Energy Agency (IEA) Energy in Buildings and Community (EBC) Annex 80[a]
Heat Wave Historical 2006	HWY (historical), 2006	Los Angeles International Airport	International Energy Agency (IEA) Energy in Buildings and Community (EBC) Annex 80[a]
Heat Wave Historical 2018	HWY (historical), 2018	Los Angeles International Airport	International Energy Agency (IEA) Energy in Buildings and Community (EBC) Annex 80[a]
Heat Wave Midterm 2056	HWY (forecasted), 2056	Los Angeles International Airport	International Energy Agency (IEA) Energy in Buildings and Community (EBC) Annex 80[a]
TMY Downtown LA	TMY, 2009–2023	Downtown LA/USC campus	Climate.OneBuilding.Org[b]
TMY Pasadena	TMY, unknown year	CEC Climate Zone 9	Climate.OneBuilding.Org[b]
TMY San Fernando Valley	TMY, 2007–2021	Whiteman Airport	EnergyPlus Weather[c]

NOTE: CEC = California Energy Commission; LA = Los Angeles; USC = University of Southern California.

[a] Machard et al., "IEA EBC Annex 80 'Typical and Extreme Weather Datasets for Studying the Resilience of Buildings to Climate Change' (Version 1.0)."

[b] Lawrie and Crawley, "Repository of Building Simulation Climate Data."

[c] EnergyPlus, "Weather Data."

- The **maximum indoor temperature** (°F) was determined by identifying the highest temperature recorded in the conditioned space during the summer months (May through October).
- The **total number of hours exceeding the threshold** was calculated by counting the hours during the summer months (May through October) when the temperature in the conditioned space surpasses 82°F. We used 82°F to align with guidance from officials in Los Angeles County involved with writing the ordinance.
- The **longest duration exceeding the threshold** was calculated by taking the highest number of consecutive hours that are above 82°F.

Power Outage Risk

Quantifying the risk of power outages is a complex task because of the numerous interrelated factors that can lead to various types of outages.[44] This risk is influenced by multiple variables, necessitating a dedicated analysis to accurately assess it. For our project, we operated under the assumption that the current grid is already vulnerable to extreme heat. We believe this to be a reasonable assumption because of multiple outage events in recent years and findings from the literature.[45] With this assumption, any additional load during peak times is expected to further strain the already stressed grid, thereby increasing the risk of failure. We did not have any local distribution-level data, so we were unable to calculate actual changes in power outage risk. Therefore, we focused on minimizing the additional peak cooling load, which is the output from EnergyPlus that we evaluated at an hourly resolution.

Climate Impact

In our analysis of GHG emissions that are associated with adopting new A/C systems, we used (1) a LRMER of 67.1 kg of carbon dioxide equivalent (CO_2e) emissions per megawatt-hour (MWh) and (2) the annual energy used for cooling (MWh), as reported by EnergyPlus.[46] The LRMER estimates the emissions that would be induced or avoided by a long-term change in electrical demand, extending over several years.

To determine the LRMER, we employed the NREL's Levelized LRMER worksheet,[47] which is designed to produce levelized LRMERs based on user inputs. We selected a 15-year timeline for levelization, reflecting the typical lifespan of A/C equipment, and we used the California mid-case scenario to project long-term structural changes in the electric grid.[48]

Although this approach might not capture hourly marginal emissions rates, it is particularly suited for our study, because it incorporates projected changes to the electric grid and considers the potential impact of incremental demand changes on the grid's structural evolution. This includes the construction and retirement of generation assets, providing a comprehensive view of the environmental impact over time.

Affordability (Installation and Operation)

In our affordability analysis, we assessed both the up-front cost of adoption (i.e., installation) and the long-term operational costs associated with new A/C systems.

To gauge the **installation costs** of AC measures, we relied on data from RSMeans for Quarter 1 of 2024 in Los Angeles County.[49] These data provided detailed cost estimates tailored to the specific region, as well as equipment and installation costs that landlords might be faced with to comply with the ordinance. Although RSMeans did not provide information on the cost of different-efficiency AC technologies, we found from a search of public commercial sellers of the AC technologies that, often, different efficiency systems (i.e., EER or SEER) did not have significantly different upfront costs. Other features, such as Wi-Fi connections, were often more correlated with up-front cost than mechanical efficiency.

Table 2 summarizes the average cost estimates for AC equipment installation by type and efficiency rating in Los Angeles County. Although the actual cost of installation will vary widely—because of such factors as installation location, specific brand, zonal control, thermostat installation, and additional

TABLE 2

Estimated Active Cooling Installation Costs in Los Angeles County

AC Type	Efficiency Ratings	Average Installation Cost Estimates[a]
One-room window A/C	Medium or high	$491
Whole-unit window A/C	Medium or high	$1,515
Mini-split	High	$4,000
Heat pump	High	$5,558
Central A/C	Medium	$4,767
	High	$5,170[b]

SOURCE: Features residential new construction data from RSMeans, Quarter 1 of 2024, Los Angeles County (RSMeans Data Online).

[a] These cost estimates include equipment costs, installation labor, and overhead and profit from the RSMeans database (RSMeans Data Online). These costs do not account for electrical work or panel upgrades, which might be necessary in some cases. Additionally, the cooling capacity is determined per the Air Conditioning Contractors of America manuals J and S (Air Conditioning Contractors of America, "Manual J—Residential Load Calculation"; Air Conditioning Contractors of America, "Manual S—Residential Equipment Selection") based on the cooling design load; if the space is larger, both the cooling capacity and the cost will increase.

[b] Because RSMeans (RSMeans Data Online) does not provide varying cost estimates for different efficiency ratings, we assumed a 10-percent increase in cost for central A/C units from SEER 13 to SEER 20.

features—the average cost estimates still provide valuable information into the relative costs of each AC measure. As shown in Table 2, the installation costs for other systems are 2.7 to 3.7 times higher than those of window A/C units, so it seems likely that window A/C units will be the preferred option to comply with the ordinance, in the absence of any financial support.

We were unable to accurately estimate the costs for PC measures, as such calculations depend on specifics of the building that do not scale in a straightforward manner. For example, the size, type, and style of the building; the complexity of the installation; and local jurisdictional building codes or homeowner association–related rules all affect the cost. In assessing the approximate cost implications of implementing all-PC measures for a representative single-family unit (geometry and size are further described in Appendix B), our analysis suggests an average expenditure exceeding $17,000. This estimate is based on aggregated data, detailed as follows: The cost of triple-pane windows varies from $400 to more than $3,000 per window, depending on size and materials.[50,51] Installing four windows might cost more than $5,000 (excluding the removal of existing windows), which is comparable to the cost of a central A/C unit or a heat pump. A solar-reflective cool roof is estimated to cost around $10,000 on average for the square footage of roof we modeled.[52] The roof insulation might cost between $1,500 and $4,500 for the entire project, depending on the materials and size of the roof, while blown-in wall insulation can cost between $975 and $2,200 on average.[53]

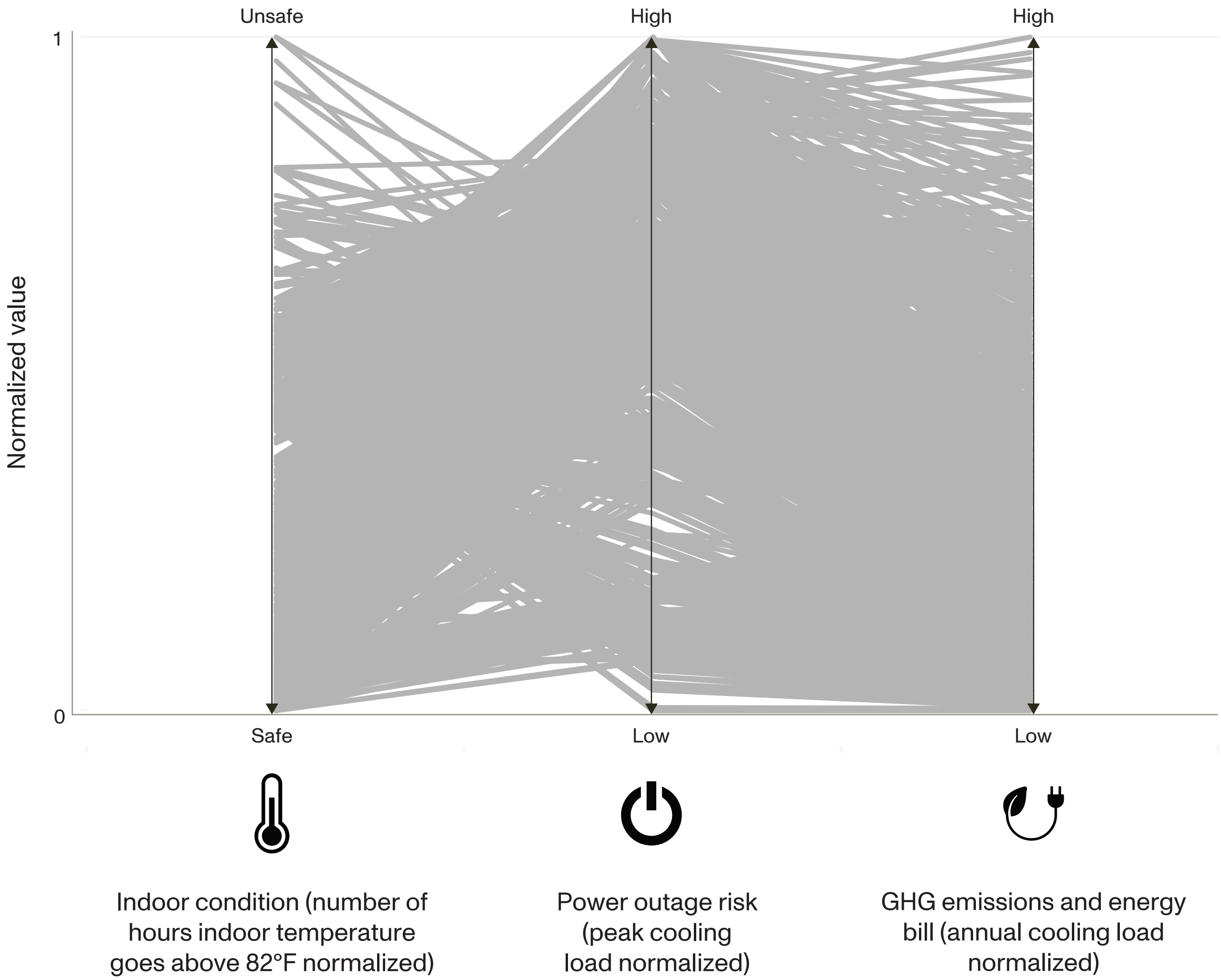
To evaluate the impact on **energy bills from the additional cooling load**, we used annual cooling energy consumption in kilowatt-hours (kWh) from EnergyPlus. These figures were then multiplied by the average residential retail electricity price for 2024 in California of 31.65 cents per kWh.[54] This calculation allowed us to estimate the ongoing operational costs, providing the financial implications for tenants.

Evaluating Robustness

We identify a robust cooling strategy as a climate-resilient, sustainable, and affordable one. A climate-resilient cooling strategy minimizes the risk of outages and maintains safe indoor temperature, even during prolonged and extreme heat conditions. A sustainable cooling strategy minimizes GHG emissions. An affordable cooling strategy should not be costly to adopt or operate.

FIGURE 4

Evaluating Three Metrics and Interpreting This Visualization



SOURCE: Figure created in EnergyPlus, using data described in the "Methods" section.
NOTE: This visualization includes all scenarios except those without AC methods.

Figure 4 shows the structure of a type of figure that is commonly used for presenting results from the formal Robust Decision Making (RDM) method. Each label on the horizontal axis represents key metrics for identifying a robust cooling strategy. The three metrics considered are the total number of hours exceeding the threshold (the second unsafe indoor temperature metric), the power outage risk, and the climate and energy bill impact (note that smaller values are more desirable for each metric). Each line represents one of the 1,099 analyzed scenarios, and the values for the three metrics are normalized between zero and one. In Figure 4, all scenarios (except those without AC) are shown in light gray. Despite the complexity of multiple cases, this visualization effectively compares options, highlights relative values, and illustrates trade-offs between metrics. More details can be found in Appendix A. In the "Findings" section, this visualization is repeated in Figures 5 to 10 and in Figure 13, where we highlight specific measures for discussion.

Findings

Regulation governing the maximum indoor temperature of rental properties in Los Angeles County could have different options for compliance. The interactions between these compliance options are complex and can have significant consequences. The annual electricity bill for tenants using AC can range from $238 to $970 per household. Furthermore, the additional peak cooling load may range from 43 to 275 megawatts (MW), and increased GHG emissions from cooling could range from 748 to 24,201 tons of CO_2e annually for Los Angeles County.[55]

As mentioned previously, we define a robust cooling strategy as one that is climate-resilient, sustainable, and affordable. To identify this strategy, we evaluated three performance metrics: the total number of hours exceeding the threshold, the power outage risk, and the climate and energy bill impact (note that smaller values are more desirable for each metric). This section presents nine major findings from the study.

Finding 1: Adding More Than 124,000 Window Air Conditioners in the Near Term Would Stress the Electric Grid

There are approximately 124,000 single-family detached homes that are not equipped with AC devices in Los Angeles County.[56] If we assume that all single-family detached homes without air conditioners were to install them and turn them on during heat waves, Table 3 summarizes the potential impact on peak cooling load as a function of AC type and across multiple weather conditions. Our analysis indicates that if all cities in the county join the ordinance, this additional peak load would range from 43 to 275 MW. These findings are significant because the adoption and use of AC in single-family detached homes alone could exceed the pace of grid hardening and expansion needed to accommodate such an increase.[57] Variations arise because of such factors as weather conditions, equipment types, equipment efficiency ratings, and the extent of PC measures. Notably, the different weather conditions, represented by various colors in Figure A.4 (in Appendix A), are not clustered together. Although weather might be beyond the county's control, the steps we take regarding AC and PC can help mitigate the impact on peak load.

Finding 2: When Window Units Are Used to Cool the Entire Home, the Temperature Threshold Might Still Be Exceeded, and Renters Might Encounter Higher Electricity Bills

We consider what might be a simple and seemingly cheap solution for landlords: installing window air conditioners for an entire home. Figure 5 shows the three normalized metrics (the total number of hours exceeding the threshold, power outage risk, and climate and energy bill impact) across all scenarios, focused on whole-unit window air conditioners. The high-efficiency window A/C (shown in red) performs better than the medium-efficiency window A/C (shown in pink) for power outage risk and climate impact, with minimal installation cost differences (shown in Table 2). Because the GHG emis-

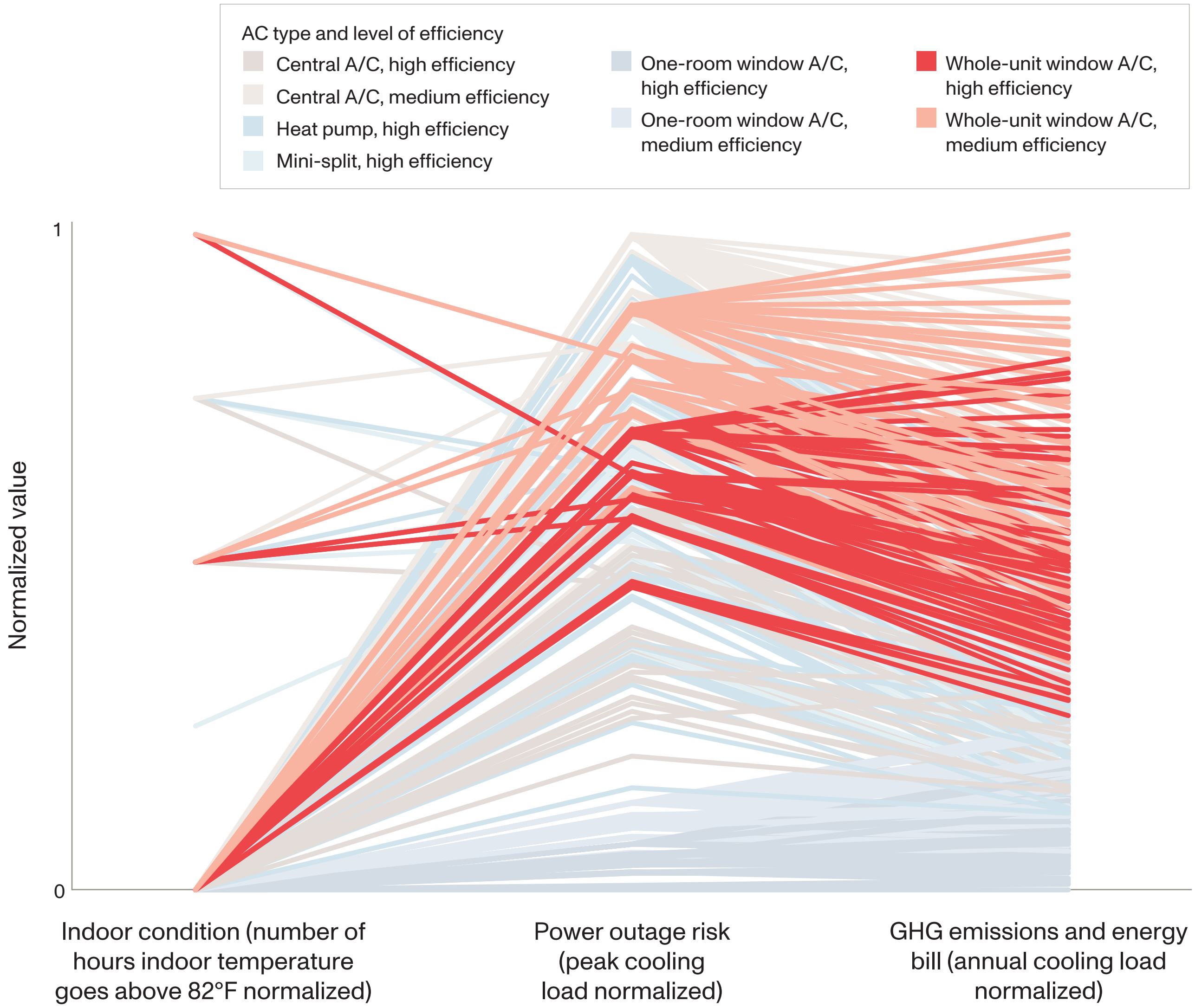
TABLE 3
Additional Peak Load Summary Table by Active Cooling Type

AC Type	Additional Peak Cooling Load (MW) Minimum	Median	Maximum
Whole-unit window A/C	91.5	163.2	250.7
Central A/C	44.3	143.8	275.4
Heat pump	43.4	147.9	266.9
Ductless mini-split	64.9	155.0	243.6

SOURCE: Features EnergyPlus output data, given input data described in the "Methods" section.

FIGURE 5

Normalized Metrics Across All Scenarios, Whole-Unit Window Air Conditioners



SOURCE: Figure created from EnergyPlus results, using input data described in the "Methods" section.
NOTE: High efficiency is EER 12, and medium efficiency is EER 10.

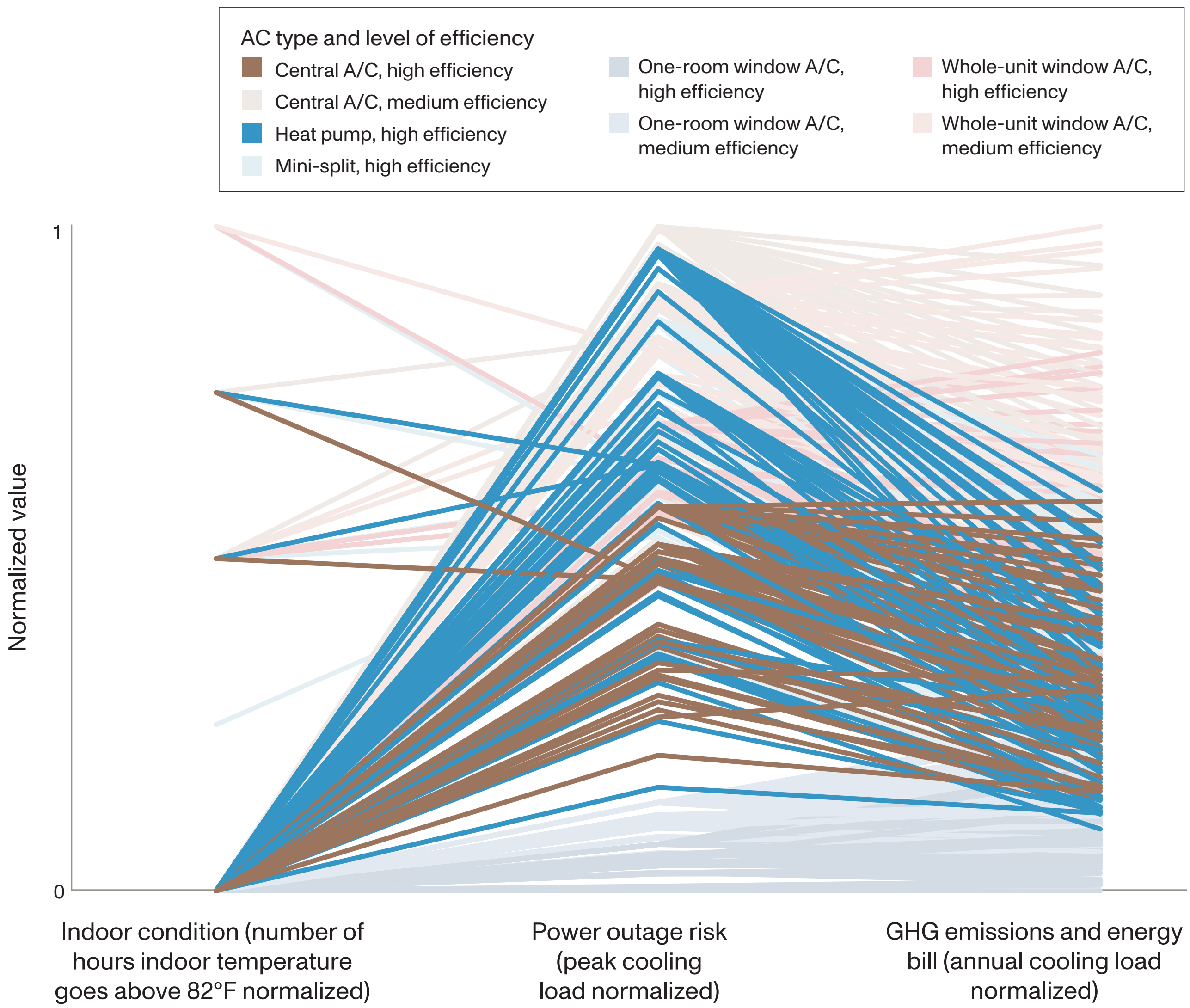
sions from additional electricity use correlate with renters' annual electricity bills, both the high- and medium-efficiency window units will result in higher electricity bills for renters than many of the other AC types we tested. Yet regardless of the efficiency, when window units are used to cool the entire home, they might not meet the indoor temperature threshold in some cases. These cases occur during severe and intense weather conditions in homes with low PC, such as single-pane windows, as shown on the left side of Figure 5 by the "unsafe indoor condition" lines that are higher than zero.

Finding 3: Efficiency Ratings and Compressor Systems Both Affect Peak Energy Use

The efficiency of AC systems is often described to customers by using an average over the entire cooling season via the SEER. However, this metric, evaluated for temperatures between 65°F and 104°F, does not fully capture how the system performs under very hot temperatures,[58] and it overlooks AC specifications that affect performance, such as the compressor motor type.[59] A previous study also noted that increasing the efficiency rating from SEER 16 to SEER 21 raised peak demand by as much as 2 percent.[60] Our study compares two types of compressors with the same SEER 20 efficiency rating: central A/C units with fixed-speed compressors, which cycle on and off, and heat pumps with variable-speed compressors, which adjust speed to meet cooling demands. Although variable-speed systems generally achieve higher SEER ratings (given the same cooling capacity and system), as a result of their efficient motors and ability to fine-tune temperature and humidity, focusing solely on SEER might overlook peak energy efficiency.[61] Figure 6 shows the three metrics for the central A/C units with fixed-speed compressors (shown as brown lines) and the heat pumps with variable-speed compressors (shown as blue lines). The two types of equipment performed

FIGURE 6

Normalized Metrics Across All Scenarios, Central Air Conditioners and Heat Pumps



SOURCE: Figure created from EnergyPlus results, using input data described in the "Methods" section.
NOTE: High efficiency represents SEER 20.

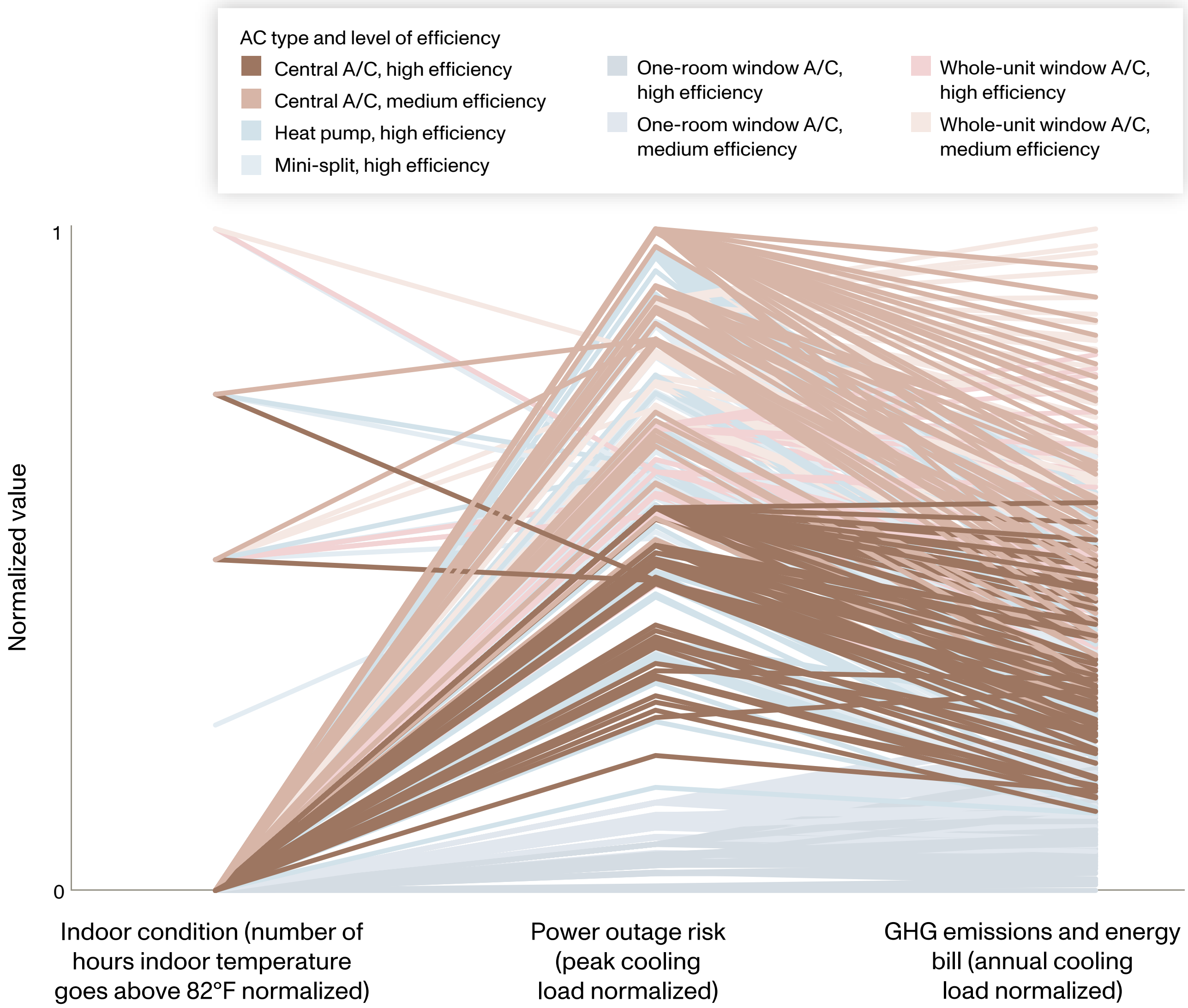
almost identically on the number of hours above 82°F and on the installation cost. The equipment also performed nearly identically on annual energy use (with heat pump systems having a wider range of bills than the central A/C units). However, there was a large difference in peak cooling load; in most cases, the central A/C units had half the peak cooling load of heat pumps. This highlights the importance of comprehensive energy assessments for (1) stress-testing cooling strategies for extreme heat conditions and (2) providing additional metrics or guidance beyond the total energy use that can communicate the risk of such events as surges and blackouts without overwhelming the landlord with technical complexities.

Finding 4: Higher-Efficiency Systems Lower Peak and Annual Energy Demand but Raise Installation Costs

Central A/C systems slightly outperformed window units in maintaining safe indoor temperatures, both in terms of the frequency and magnitude of tempera-

FIGURE 7

Normalized Metrics Across All Scenarios, Central Air Conditioners



SOURCE: Figure created from EnergyPlus results, using input data described in the "Methods" section.
NOTE: High efficiency represents SEER 20, and medium efficiency represents SEER 13.

ture exceeding the threshold (Figure 7). Although central systems are about three times more expensive to install, they also offer an advantage in annual energy use compared with other strategies, such as window units. Systems with higher efficiency ratings (SEER 20) reduced both peak and annual cooling loads by an average factor of 1.7, compared with those with medium efficiency ratings (SEER 13). Although our analysis did not include zonal control for central systems,[62] energy performance could be further enhanced by cooling only portions of the home (see Finding 7).

Finding 5: Passive Cooling Increases the Amount of Time the Maximum Indoor Temperature Stays Below the Threshold and Lowers Annual Energy Demand but Does Not Reduce Peak Load Unless Fully Implemented

Many of the PC strategies we consider act to insulate the building during times of extreme heat by slowing the speed at which heat from outside can make its way inside. This means that adding more types of PC generally reduces the highest maximum temperature that a building reaches, because the heat from the hottest part of the day does not have time to make it inside before it becomes cooler. Therefore, more PC, when coupled with AC, generally increases the amount of time the maximum indoor temperature stays below the temperature threshold and reduces the energy demand for AC strategies.

Figures 8, 9, and 10 show various combinations of PC measures. First, we consider performance during extreme heat waves. Single-pane windows (Figure 8), which we take as a "base case" representing no PC, often result in indoor temperatures exceeding the thresholds during extreme heat waves. That is, without any PC, the AC is working at full capacity (shown as very high peak energy demand) to attempt to achieve—and fail to meet—the thermostat setting. As a result, the indoor temperatures are so high that they exceed the temperature thresholds. When some PC is added (such as triple-pane windows, as shown in Figure 9), the AC continues to need to work at full or nearly full capacity during the most extreme heat waves to attempt to achieve the thermostat setting (resulting in very high peak energy demand). Although the thermostat setting might not be met, the maximum indoor temperatures are reduced compared with the base case, so the combination of AC and PC often results in lower indoor temperatures. When all PC measures—such as triple-pane windows, cool roofs, and wall and roof insulation (shown in Figure 10)—are implemented together, in most cases, we find that the combination is able to achieve the thermostat setting, which means that the peak energy demand is reduced.

When analyzing PC measures, we also consider the annual performance. We find that any PC measure helps reduce annual energy consumption (Figures 9 and 10), decreasing GHG emissions and benefiting tenants by reducing electricity bills.

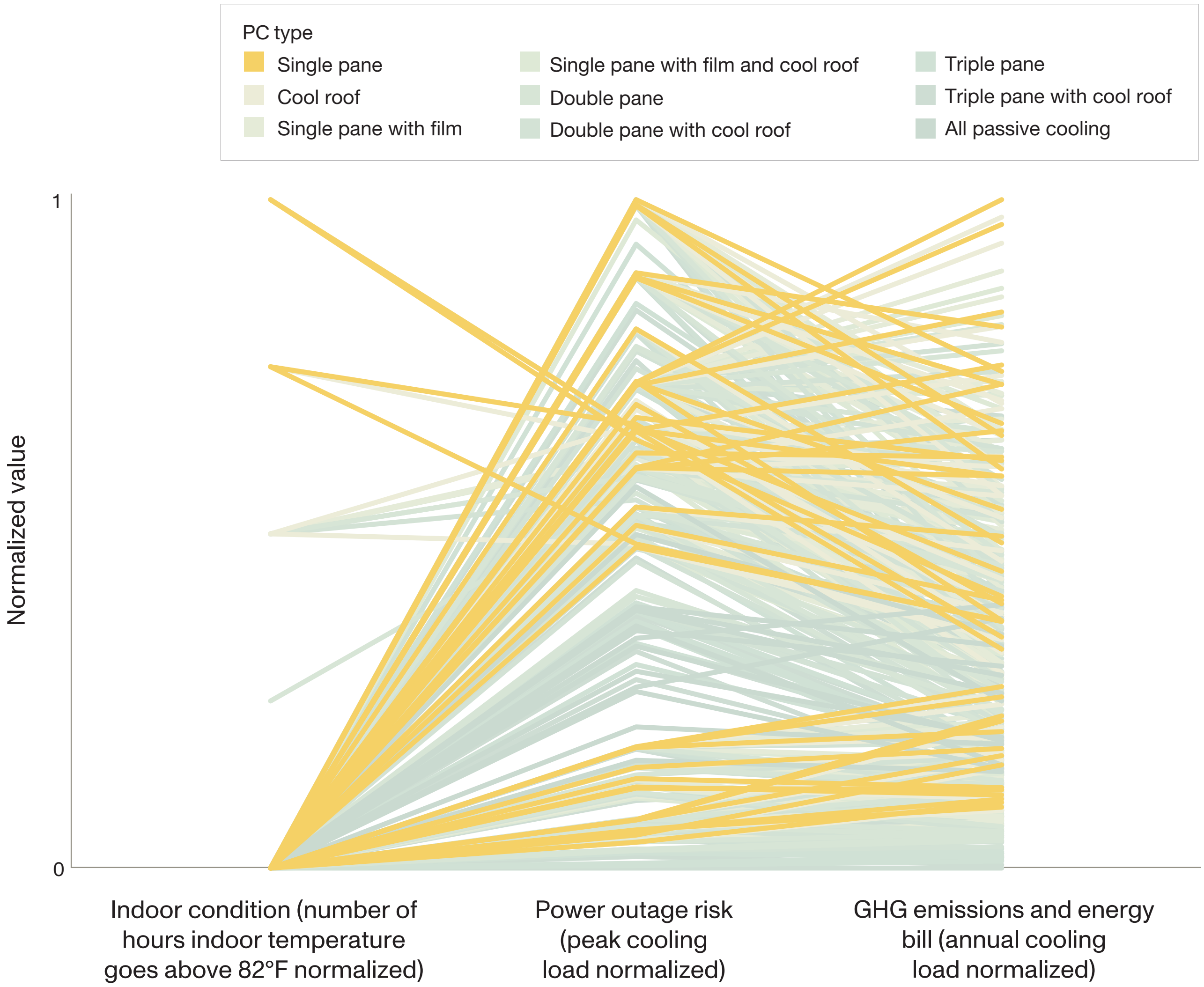
Finding 6: During a Power Interruption, There Is a Trade-Off Between the Intensity and Duration of Unsafe Indoor Temperatures When Looking at Passive Cooling Measures

We also modeled cases without AC. We found that PC alone cannot achieve the threshold, as even in the best-case scenario—using TMY weather with high levels of PC—indoor temperatures still exceed 91°F (Figure 11). These scenarios also provide valuable insight into the performance of PC during power outages.

Any type of PC works to reduce heat transfer between the indoors and outdoors. This means that when a heat wave occurs, the indoors will stay at the cooler temperatures for a longer period before equilibrating with the outdoors. This is the same phenomenon as using a cooler for soda at a barbecue; if the cans are left out on the table (no PC), they warm up quickly. If the cans are put in a frozen cooler, however, the cooler will begin to warm up, but the soda will still be cool throughout the barbecue. We find that this intuition holds in our analysis. That is, Figure 11 compares two different metrics for safe indoor temperatures for the cases without any AC: maximum indoor temperature (°F) versus the longest

FIGURE 8

Normalized Metrics Across All Scenarios, Single-Pane Window



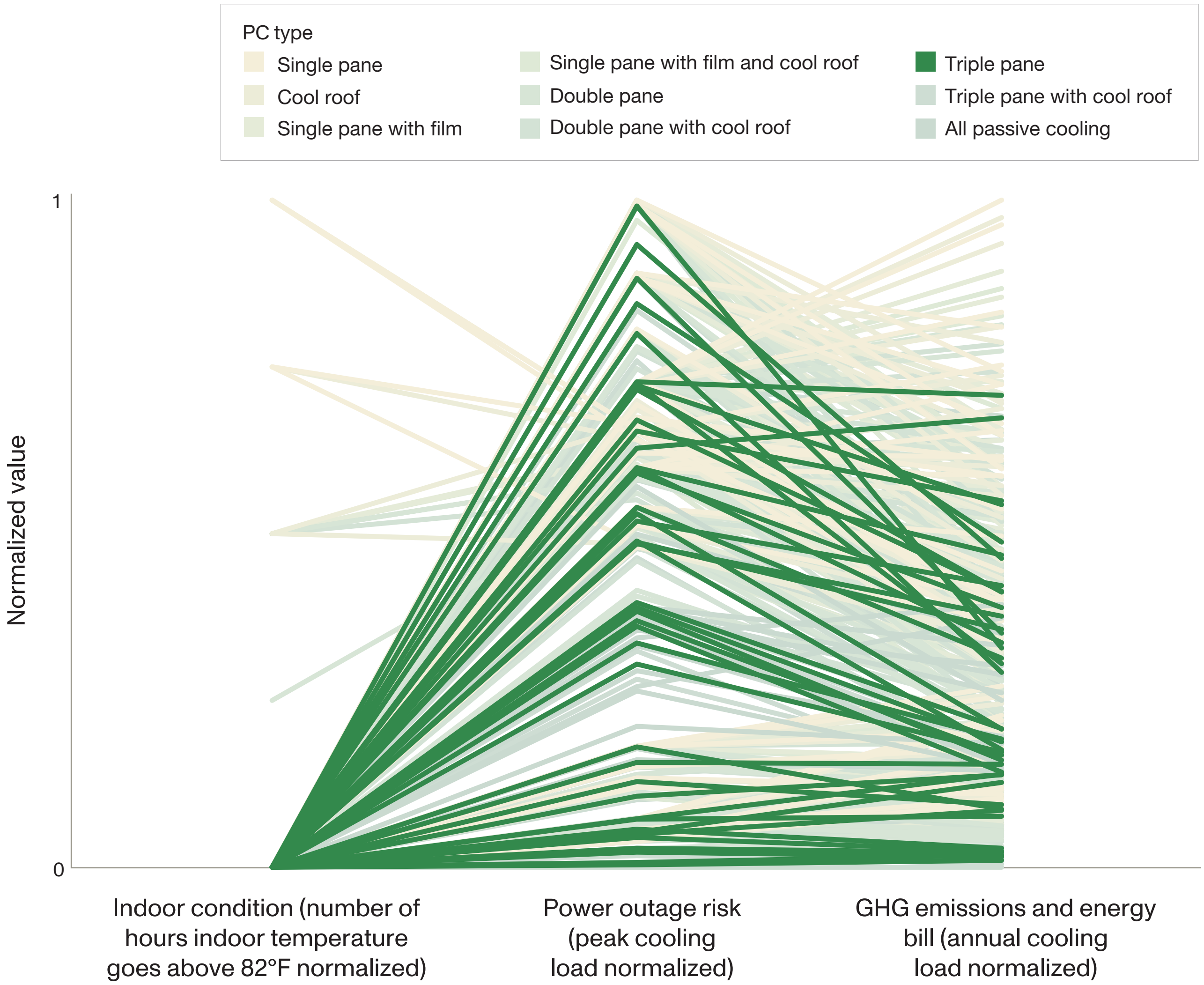
SOURCE: Figure created from EnergyPlus results, using input data described in the “Methods” section.
NOTE: Thermostat setpoint is 75°F, and these figures show all scenarios except those without any AC (i.e., no A/C units and no heat pumps).

consecutive hours above the threshold (number of hours). If there is a power interruption, AC systems will be off, and only the PC strategies will be working. In this case, just as during the barbecue, the buildings with the most PC strategies (e.g., the soda stored in a cooler) reach a lower maximum temperature than the buildings with fewer PC strategies (e.g., the soda left out on the table).

However, a heat wave does not just last one day; it can last several days. This is similar to leaving a cooler with drinks in it overnight and finding, the next day, that the soda inside is warm. This is because all the ice melted, the cooler got hot, and then—just like a soup thermos—the cooler is actually acting to keep the drinks warm. Similarly, we found that buildings with the most PC take longer to warm up but then stay at whatever temperature they reached for a longer period. That is, the buildings with the most PC experience the longest consecutive periods that exceed the temperature threshold, although the maximum temperature is lower.

FIGURE 9

Normalized Metrics Across All Scenarios, Triple-Pane Window

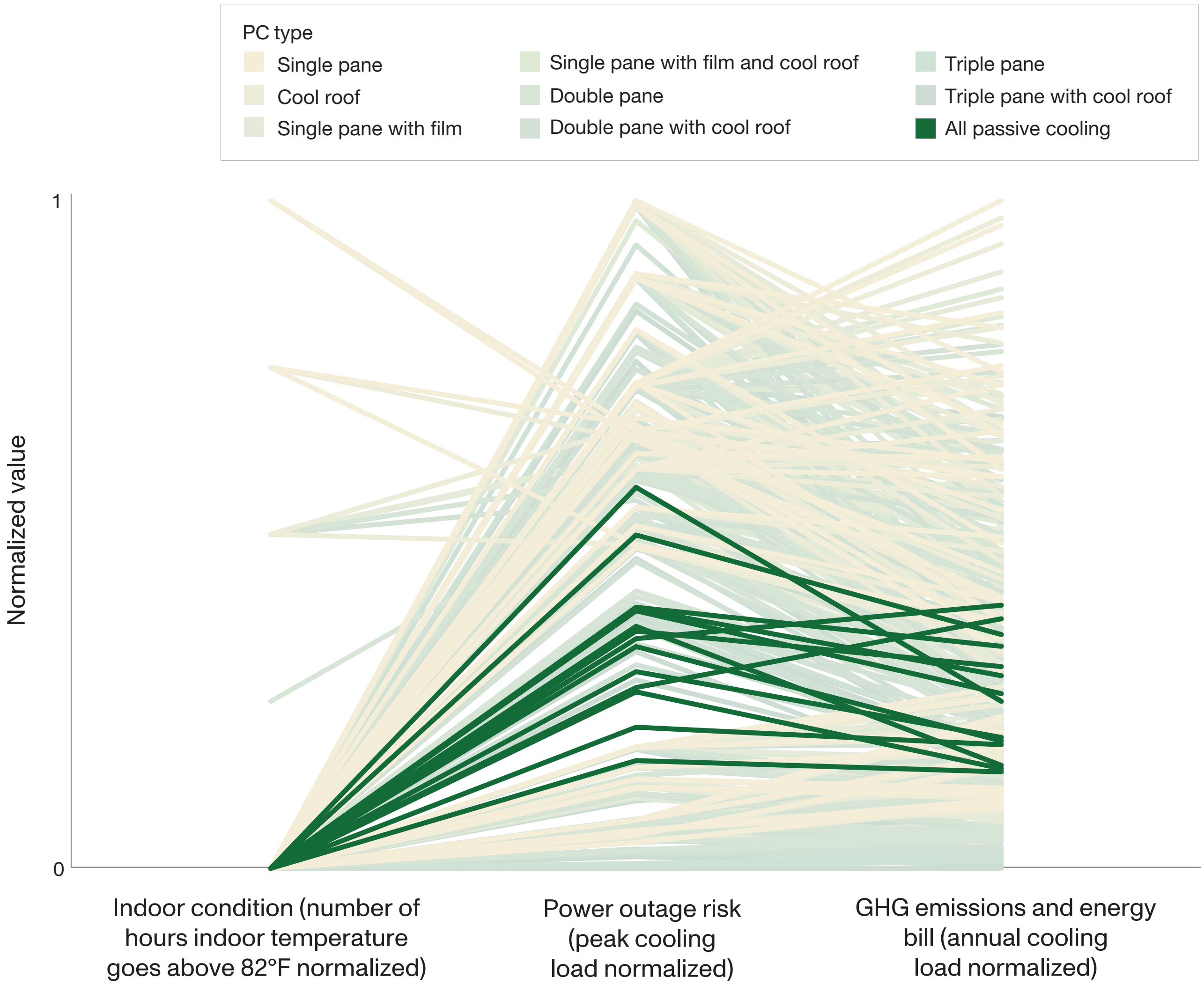


SOURCE: Figure created from EnergyPlus results, using input data described in the "Methods" section.
NOTE: Thermostat setpoint is 75°F, and these figures show all scenarios except those without any AC (i.e., no A/C units and no heat pumps).

This has two implications. First, it means that if there is a power outage, then homes with different levels of PC might be exposed to different types of indoor heat conditions. Buildings with less PC will experience shorter but more-severe heat exposure, whereas buildings with more PC will experience longer but more-mild heat exposure. Second, there is a time lag in the peak temperature, and the specific lag will vary based on the characteristics of the building in question. This means that when there is an outage, there will be differences in when emergency response will be needed. It also implies that if power is uninterrupted and AC systems are on, the peak demand on the energy grid for less-severe heat waves could be reduced because of varying lag times between outdoor peak temperatures and peak AC use.

FIGURE 10

Normalized Metrics Across All Scenarios, All Passive Cooling



SOURCE: Figure created from EnergyPlus results, using input data described in the “Methods” section.

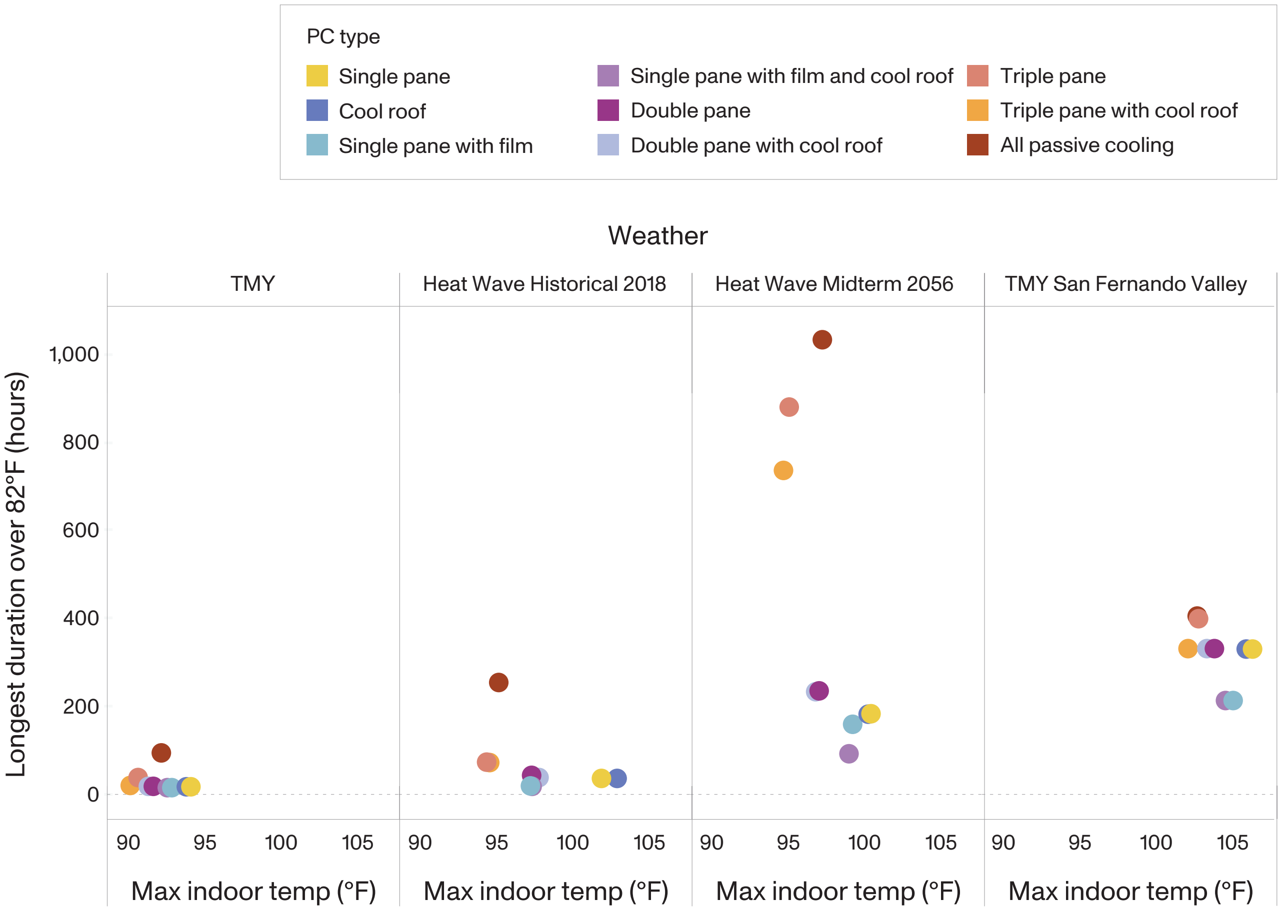
NOTE: Thermostat setpoint is 75°F, and these figures show all scenarios except those without any AC (i.e., no A/C units and no heat pumps).

Finding 7: Cooling Only One Room Reduces Peak Energy Use Across All Passive Cooling Levels and Weather Conditions Compared with Cooling an Entire Home

If a renter pays for their own utility bills, it is quite likely that they have already considered whether cooling one room will meet their needs. Figures 12 and 13 show the impact of cooling just one room—considered one-third of the entire home’s volume—instead of all habitable rooms on the peak energy demand (Figure 12) and three of the considered metrics (Figure 13). This strategy reduces both peak and annual energy use while maintaining temperatures below the threshold across all PC levels and weather conditions. Employing higher-efficiency units (EER 12) further decreases energy consumption and likely does not cost much more to install. Yet cooling one-third of a home does not require exactly one-third of the energy to cool the entire home. The magnitude depends on how much PC is implemented. This is because, when cooling a single room, some of

FIGURE 11

Maximum Indoor Temperature Versus Longest Duration of More Than 82°F for Various Passive Cooling Scenarios



SOURCE: Figure created from EnergyPlus results, using input data described in the "Methods" section.
NOTE: This figure is based on scenarios in which there is no AC.

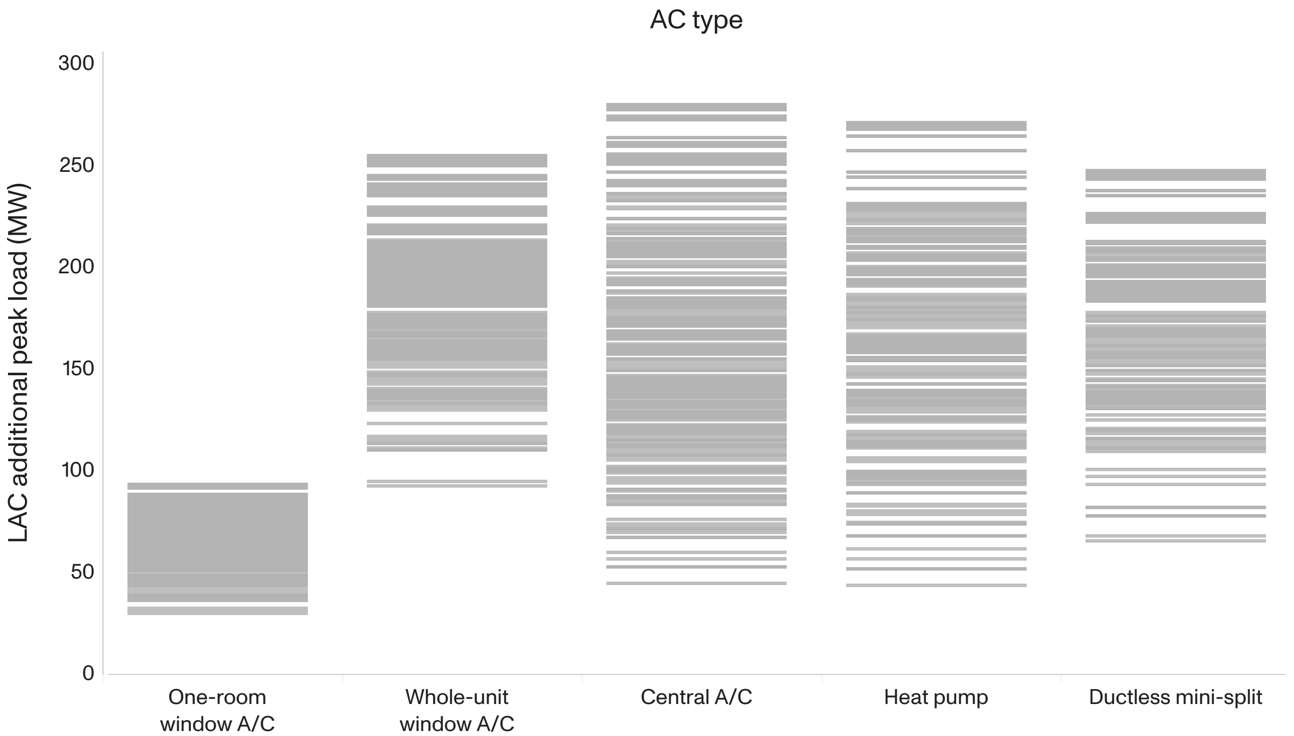
the walls of that room face other indoor spaces instead of the hotter outdoors. Adjacent spaces that do not face the exterior serve as insulation for a conditioned room, which could help maintain cooler indoor temperatures during extreme heat conditions. Thus, the amount of heat entering a single room is reduced compared with an entire home, making it easier to cool.

The ability of a cooling method to reduce indoor temperature and annual energy use increases as PC level increases. The flexibility to cool one room instead of a whole unit allows for safe temperatures for less-insulated homes, decreases the likelihood of power outages during a heat wave, and decreases the electricity bill burden.

Finding 8: A Higher Thermostat Setpoint, Such as 82°F, Reduces Annual Energy Use but Increases Unsafe Conditions and Does Not Always Reduce Peak Load When Compared with a 75°F Thermostat Setpoint

We tested two strategies: (1) increasing thermostat setpoints from 75°F (shown in orange in Figure 14) to 82°F (shown in blue) and (2) reducing the conditioned space from the entire unit to one room. Note that the most common thermostat settings in California range from 70°F to 76°F.[63] Additionally, we included the higher setpoint of 82°F to assess its

FIGURE 12
Additional Peak Load as a Function of Active Cooling Type



SOURCE: Figure created from EnergyPlus results using input data described in the "Methods" section.

NOTE: LAC = Los Angeles County. The one-room window A/C is modeled to cool 33 percent of the entire unit, whereas the other AC options are designed to cool 100 percent of the space.

impact on various performance metrics.[64] Figure 14 illustrates these strategies; thermostat setpoints are represented by different colors, and the reduced-space strategy is depicted in a separate column.

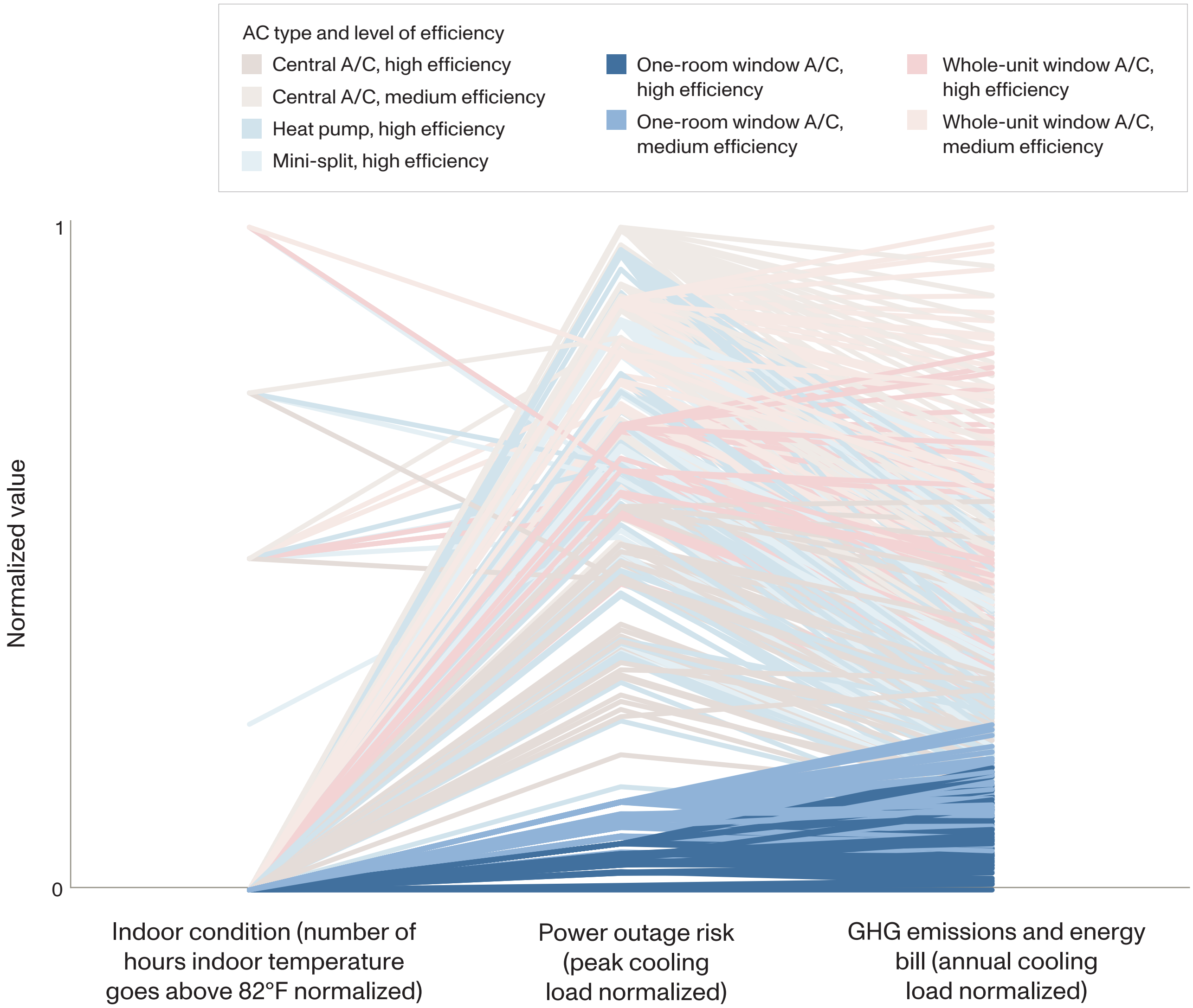
We find that a higher thermostat setpoint can moderately reduce peak cooling load while maintaining indoor temperatures below the threshold under typical weather conditions (as shown with the TMY weather case). However, during extreme heat conditions (as shown with the Heat Wave Historical 2018 case in the bottom half of Figure 14), a higher setpoint frequently results in extended periods of unsafe indoor temperatures because of delayed activation of the AC system. This issue is particularly pronounced when cooling the entire unit (as shown on the right side of Figure 14), with temperatures surpassing 91°F and accumulating 375 hours above the safe threshold, potentially resulting in adverse health effects. Although the higher setpoint effectively reduces annual cooling load across all scenarios if such a setpoint is maintained year-round (Figure A.3), it does not substantially reduce peak cooling load during extreme heat waves with low levels of PC because—in extreme cases without the assistance of PC strategies—the AC is already working at its capacity. Additionally, reducing the cooled space (see Finding 7) is more effective in keeping the home cool and reducing peak energy load than increasing the temperature setpoint.

Finding 9: All Whole-Home Active Cooling Methods Fail to Meet Safe Indoor Temperature Thresholds During the Worst Heat Waves When Combined with Some Passive Cooling Methods

For the weather condition that matches a heat wave experienced at Los Angeles International Airport in

FIGURE 13

Normalized Metrics Across All Scenarios, Focused on One-Room Air Conditioners



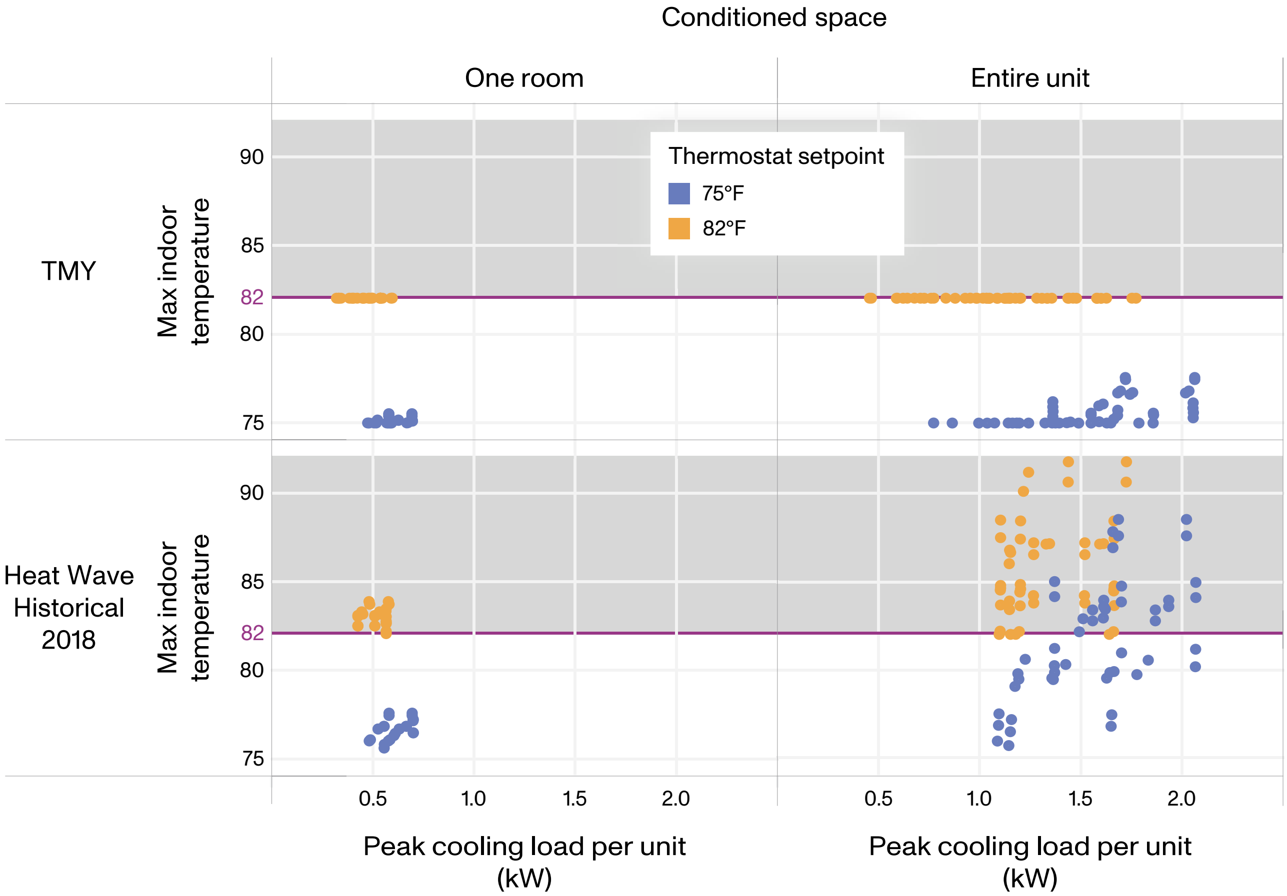
SOURCE: Figure created from EnergyPlus results, using input data described in the "Methods" section.
NOTE: Thermostat setpoint is 75°F, and this figure shows all scenarios except those without any AC (i.e., no A/C units and no heat pumps).

2018, every whole-home AC method that we tested exceeded the indoor safe temperature threshold of 82°F at least once when not paired with PC methods or when paired with just the cool-roof PC method. The ductless mini-split and window A/C methods failed even with double-pane windows. Additionally, even with more-typical weather conditions, the full suite of PC alone could not maintain indoor temperatures below a threshold of 82°F.

Although there were combinations of AC and PC methods that successfully met the temperature thresholds, many parts of Los Angeles County get hotter than the airport. Additionally, as heat waves in the region get worse, it is possible that a more severe heat wave could occur at Los Angeles International Airport. Given the failures we saw and the possibility of other heat waves, the expense and overcapacity required to ensure that any home will meet the indoor temperature threshold during every single possible heat wave might be too extreme to justify.

In this study, we did not evaluate methods to ensure compliance, but there are several ways that

FIGURE 14
Trade-Off Between Maximum Indoor Temperature and Peak Cooling Load for Two Different Thermostat Setpoints and Conditioned Spaces



SOURCE: Figure created from EnergyPlus results, using input data described in the "Methods" section.
NOTE: kW = kilowatt; max = maximum. This figure displays two weather conditions—TMY and Heat Wave Historical 2018—excluding those without A/C or heat pumps. The colors represent the thermostat setpoints (75°F versus 82°F), while the columns differentiate between cooling for a single room and the entire unit. The shaded area indicates cases that exceed the temperature threshold.

any regulation could prioritize safety for tenants while remaining realistic about how successful cooling methods can be. These include plans for opening and transporting people to cooling centers during the most extreme heat waves, recommendations for vulnerable community members to set their thermostat at much lower temperature during times when it will get much hotter, exemptions for compliance during certain types of heat waves or for a certain number of hours per year,[65] or adjustments to safety rules when it is particularly hot.[66] There is precedent for such adjusted rules; for example, in care facilities for the elderly in California, there is a maximum indoor temperature of 85°F or "30 degrees F less than the outside temperature."[67]

Summary

In this study, we investigated future scenarios that match the details of a maximum indoor temperature threshold for rental units in Los Angeles County across three performance metrics: the total number of hours exceeding the threshold, the power outage risk, and the climate and energy bill impact. We focused on one geometry and orientation of single-family homes, but the general findings apply more broadly. Because Los Angeles County is large and has regions that get much hotter than others, we tested seven weather conditions that represent different locations, typical years, and both historical and projected HWYs.

We identified nine major findings. Some of these are related to trade-offs between the different metrics considered. If every single-family rental unit suddenly received a means of AC—thereby satisfying the safety metric—the additional stress on the electric grid would increase the risk of blackouts. Using window units—the most affordable installation option—to cool the entire home without additional PC might lead to unsafe indoor conditions (especially for people vulnerable to heat) and could result in higher energy bills for tenants. PC can reduce annual energy bills for tenants and increase the time spent below the temperature thresholds but might not reduce the risk of blackouts during the worst heat waves unless many PC strategies are implemented together. Depending on particular building characteristics, these PC strategies might be very costly to adopt. Similarly, incentives to increase the thermostat setpoints on A/C units might reduce annual energy use, but these incentives will increase unsafe conditions and might not always reduce the risk of blackouts.

More-efficient strategies are not always obvious because of the numerous technical options available, such as different systems, compressor motor types, and varying efficiency ratings. Efficiency ratings alone do not reflect performance under extreme heat conditions, peak performance, or the impact of different compressor types, thereby complicating compliance choices. For the ordinance to achieve its policy objective of protecting vulnerable populations from extreme heat, the responsibility of navigating technical complexities and understanding the various trade-offs between energy use and the risk of power outages should not be left up to individuals. As an example of this complexity, power outages from a sudden increase in power demand can leave a community more vulnerable during extreme heat. There is a need for education, guidance, and support to help navigate these complexities and collectively prepare communities for the next record-breaking heat wave.

Other findings relate to the consequences of decisions on how to meet indoor temperature thresholds. For example, when there is a power interruption, different levels of PC strategies might lead to different types of heat exposure between the intensity and the duration of unsafe indoor temperatures. We also found that, despite the strategies used, very extreme heat waves might always result in a failure to meet safe indoor temperatures; this indicates that even stringent regulations would need plans beyond keeping homes cool to ensure that people remain safe.

Lastly, the only solution that consistently maintained safe indoor temperature across all tested weather conditions was reducing the cooled area to just one room instead of the entire home. This approach posed a lower risk of blackouts compared with other strategies and reduced GHG emissions and the impact on electricity bills, even without any PC measures. In order for this or other requests from the county to be implemented successfully, it is likely that an implementation or action plan would be needed to help renters understand this guidance.

Policy Recommendations and Next Steps

The nine findings suggest important implications for maximum indoor heat regulations:

- The Los Angeles County Board of Supervisors' ordinance to establish a maximum indoor temperature threshold should focus on safe temperatures for **at least one room** rather than the entire home.
- The ordinance, implementation plans, and incentives should **promote PC** to reduce overall GHG emissions and energy bills and combine passive and active strategies to ensure safe indoor temperatures.
- If higher levels of PC are costly and difficult to implement, it is crucial for the ordinance, implementation plans, and incentives to **prioritize higher efficiency ratings and zone control for A/C.**
- Implementation plans should include outreach that addresses different compliance options and their usage in a way that can promote safe indoor temperature and address electricity bill concerns. People who are especially vulnerable to heat should **consider prioritizing their health over public requests to reduce**

When is it best to ask people to turn off their AC and other appliances, and when is it best to encourage them to move from their homes to a cooling center (such as a library)?

energy demand and should not increase the thermostat temperature to conserve electricity or enroll in programs that give the utilities the ability to modify A/C thermostat settings during heat waves. Instead, efforts for those especially vulnerable to heat should focus on reducing the cooling space to maintain safe temperatures and lower energy consumption.

- Related implementation plans and incentive structures should **reduce barriers to adopting strategies** that minimize installation cost, grid impact, energy bill impact, and GHG emissions while ensuring safe indoor conditions.

In addition, we note that although this study focused on the specific weather conditions of Los Angeles County, the general findings should hold across multiple geographic locations. To help inform indoor temperature thresholds in other locations, we recommend several areas of future research.

First, across all findings, we recommend using a variety of local TMY and HWY files. During our analysis, we began by using the TMY and HWYs for Los Angeles International Airport. The HWYs are constructed to have longer, more-frequent, and more-extreme heat waves than the TMY. However, during the course of the analysis, we noticed that even the hottest of these years had fewer, shorter, and less-extreme heat waves than TMYs at other locations in the county, such as Pasadena or the San Fernando Valley.

Second, also across all findings, it is important to consider how people will respond. Our analysis calculates the changes in temperature, assuming that the people inside are keeping windows and doors closed. Future work could examine all types of behavioral responses. This work could look at the response rate: Will renters change the thermostat setpoint to the value suggested, voluntarily turn off their cooling if asked, or even just stay in the cooler room if only one room is cooled? Also, will renters choose to take additional actions that they perceive to be helpful, such as using fans or opening windows when it is colder outside than inside? There are additional considerations if the power goes out, such as whether renters will be willing to leave their homes to go to a cooling center. Future research could also investigate the trade-off (by using different groupings of PC measures) between intensity and duration of unsafe temperatures when the power is out and explore the interaction between this trade-off and behavioral change. For example, it might be that the indoor temperatures stay hot through the evening, even though a renter could open the window.

Next, just as cooling one room will reduce energy demand, asking people to voluntarily reduce demand can do the same. Future work could investigate a trade-off point: When is it best to ask people to turn off their AC and other appliances, and when is it best to encourage them to move from their homes to a cooling center (such as a library)?

Additionally, more-granular detail could affect some of our results. That is, by working with utilities, it might be possible to determine more specifically whether increased energy demand will have an effect on their operations. Likewise, we used just one building type to model all single-family detached rental units in the county; accounting for different building orientations, geometries, and construction materials could influence the magnitude of some of our results.

Finally, other areas for further research include more closely linking the indoor temperatures with changes in morbidity or mortality.

APPENDIX A

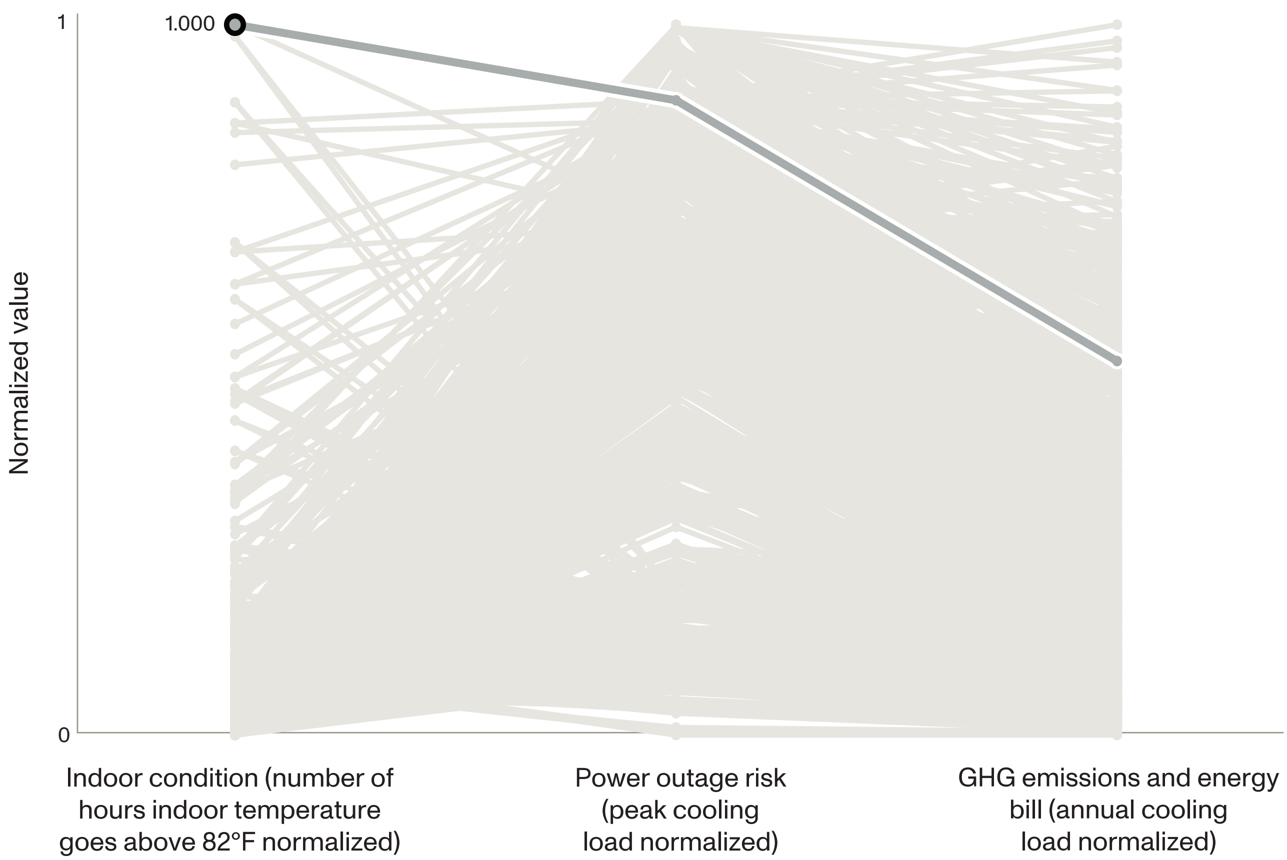
Additional Results and Interpreting the Figures Used in This Report

We used parallel coordinates plots to present our findings. Although the complexity of multiple cases can complicate interpretation, this visualization effectively compares different options and highlights the relative values for each case. It also illustrates the trade-offs between various metrics.

The x axis displays three normalized performance metrics: the total number of hours exceeding the threshold, power outage risk, and the climate and energy bill impact. For each metric, smaller values are more desirable. Each line on the plot represents a specific case, which consists of a combination of actions and uncertain conditions, including the type of AC measure, the type of PC measure, the weather scenario, and the thermostat setpoint. Figure A.1 illustrates a line and demonstrates the relative performance across the metrics we evaluated. The normalized value indicates its relative performance among other scenarios. The highlighted case in Figure A.1 exhibited the normalized value of 1 for the unsafe indoor condition metric, reaching the maximum number of hours above the unsafe temperature threshold out of all the scenarios. It also showed a relatively higher risk of power outages and a slightly above-average annual cooling load.

Figure A.2 highlights major findings with each performance metric when a whole-unit window A/C is adopted. Any value above zero indicates that the indoor temperature fails to meet the threshold, and

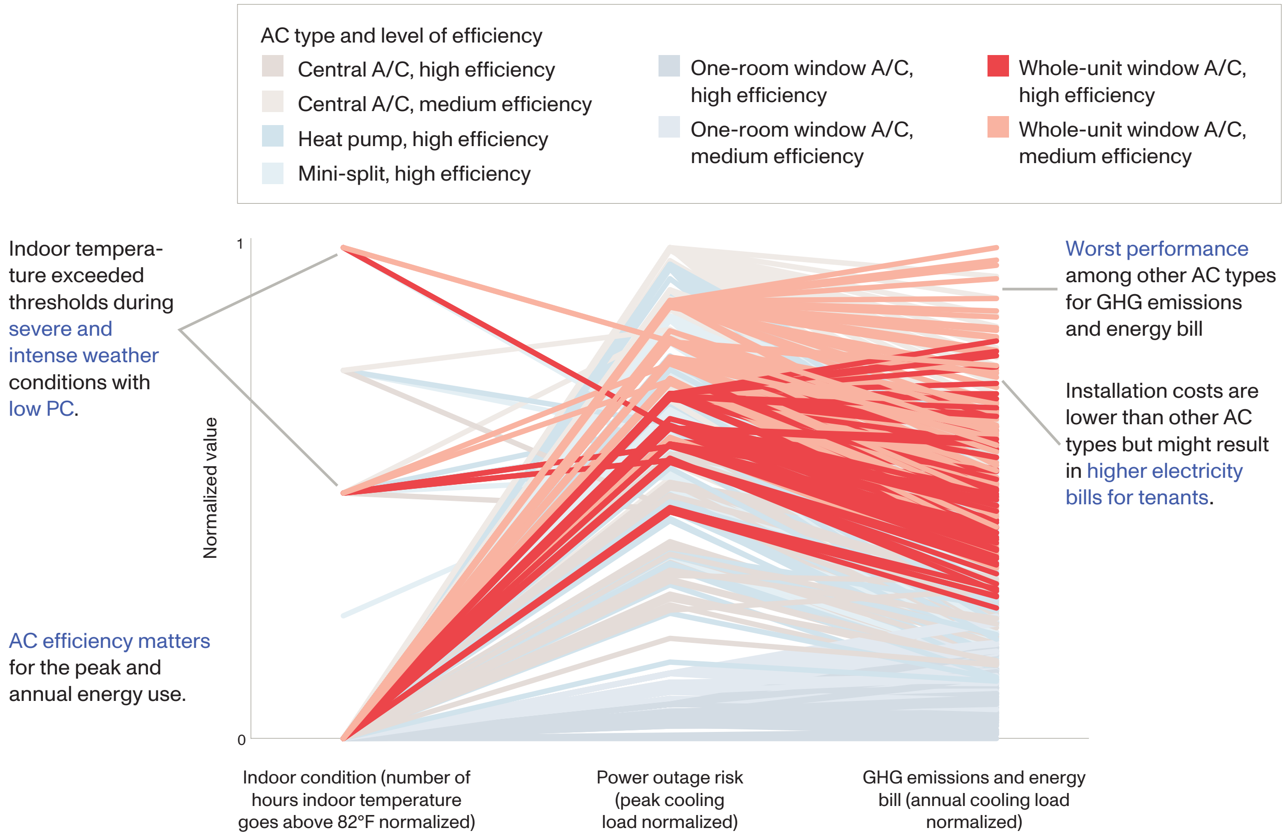
FIGURE A.1
One Scenario Represented on a Parallel Coordinates Plot



SOURCE: Figure created from EnergyPlus results, using input data described in the “Methods” section.
NOTE: The highlighted line represents a simulation run for the San Fernando Valley Weather case, using single-pane windows (base) with whole-unit window A/C (100roomac) at medium efficiency (EER 10) set to 82°F.

FIGURE A.2

Figure 5 with Findings Highlighted



SOURCE: Figure created from EnergyPlus results, using input data described in the "Methods" section.
NOTE: High efficiency is EER 12, while medium efficiency represents EER 10. Thermostat is set for 75°F.

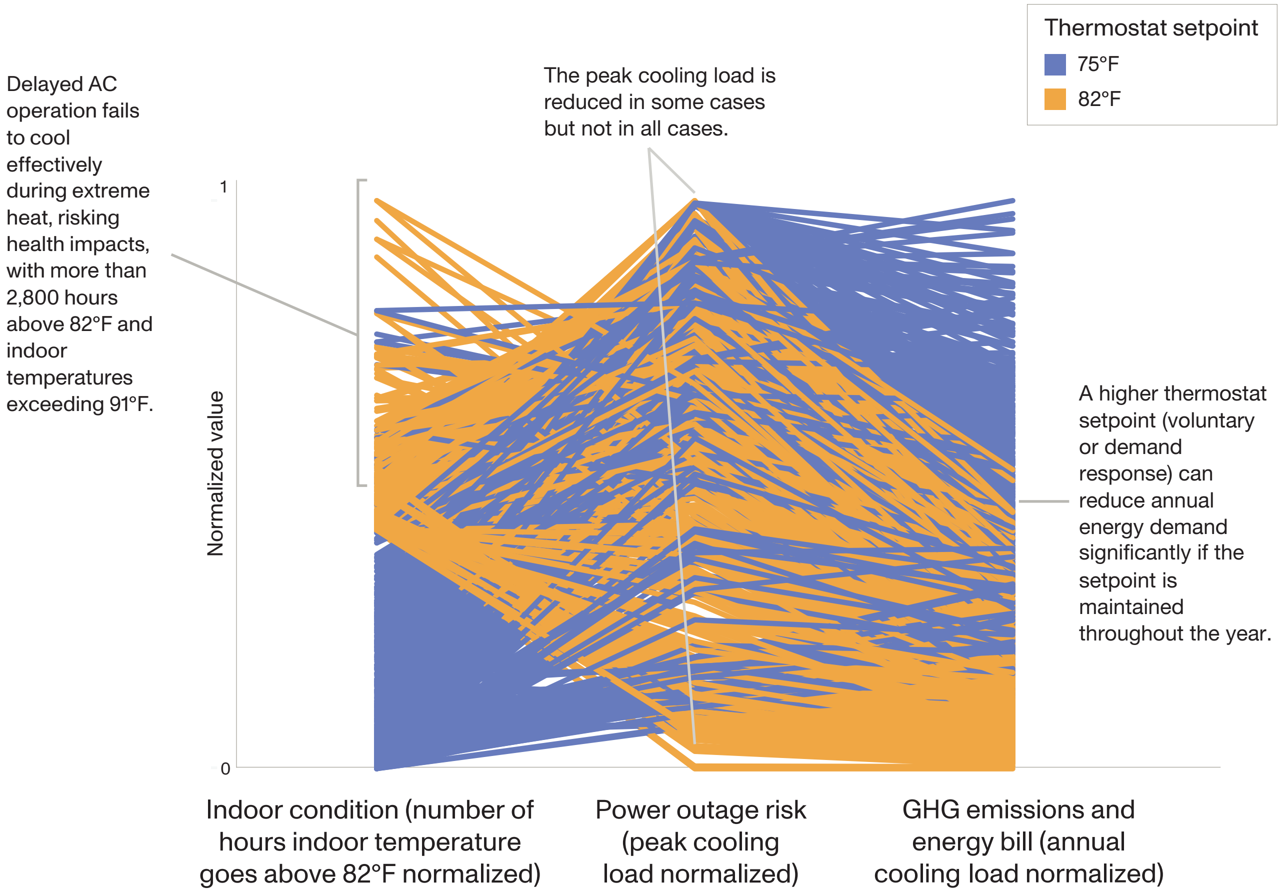
higher values signify longer periods of failure. We found that window A/C units, particularly during historically severe heat wave conditions and when paired with single- or double-pane windows, cause indoor temperatures to exceed the threshold. Additionally, window units are the least energy-efficient compared with other AC technologies, resulting in higher energy consumption, which translates to increased electricity bills for tenants and greater GHG emissions. Higher efficiency ratings (EER 12 versus EER 10) demonstrate improved performance in both peak and total energy use.

Figure A.3 compares two different thermostat setpoints across three metrics discussed above. We also highlight the key findings in the figure.

Figure A.4 illustrates the additional peak cooling load if all single-family detached homes in Los Angeles County without air conditioners were to install them.[68] This figure presents all cases summarized in Table 3, and the different colors represent various weather conditions. As noted in Finding 1, the lack of clustering among the same colors means that there are robust solutions that do not depend solely on the chosen weather condition.

FIGURE A.3

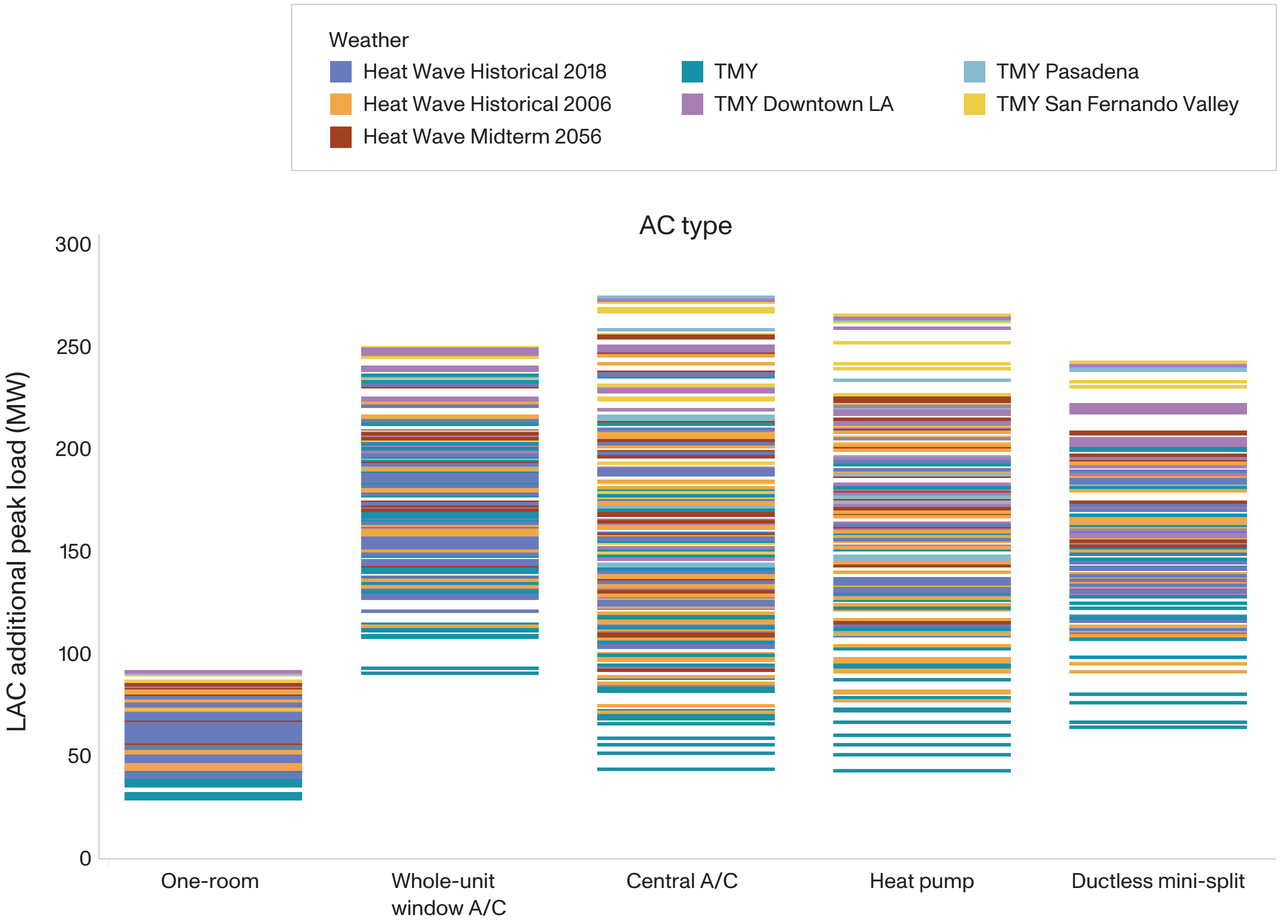
Normalized Metrics Across All Scenarios: Thermostat Setpoint of 75°F Versus 82°F



SOURCE: Figure created from EnergyPlus results, using input data described in the "Methods" section.

FIGURE A.4

Additional Peak Load for Los Angeles County as a Function of Active Cooling Type



SOURCE: Figure created from EnergyPlus results, using input data described in the “Methods” section.
NOTE: LA = Los Angeles; LAC = Los Angeles County.

APPENDIX B

Details of Building Geometry and Input Parameters Used in EnergyPlus

Building Geometry and Materials

We developed a model using a sample stand-alone single-family unit format provided by OpenStudio to represent typical homes in the county.[69] To reflect the house's components and materials, we used median values from NREL's ResStock data for Los Angeles County.[70] Table B.1 provides details on housing characteristics and systems.[71]

Table B.2 provides details on each modeled window. We excluded window overhangs and exterior shading. These values did not change across simulations. Variations in window materials and input parameters (as part of each PC measure) are listed in Table B.4.

We used default values from OpenStudio-HPXML for details that were not explicitly mentioned in Appendix B.[72] Default occupancy levels and schedules were applied to all simulations.[73] Input parameters that were modified for each run are described in the following sections.

Although we did not perform a formal sensitivity analysis of the parameters chosen, the size of the rooms, the size of the windows, and the direction of the windows will influence the effectiveness of PC techniques. In Los Angeles County in the summer, for example, the west-facing wall receives more than half the amount of sunlight as the north-facing wall.[74]

Input Parameters for Active Cooling Measures

We modeled various types of A/C systems with different efficiency ratings. EnergyPlus offers a feature that sizes cooling systems according to weather conditions (Table B.3). We applied this autosizing feature based on TMY conditions and kept the same sizing for simulations with different weather files.

Input Parameters for Passive Cooling Measures

Window Replacement

We varied a window's U-factor and solar heat-gain coefficient (SHGC) for respective PC measures. These values (listed in Table B.4) are default values used by the OpenStudio-HPXML software.[75] A win-

TABLE B.1

Building Geometry and Systems

Floor Size (ft^2)	Number of Bedrooms	Number of Bathrooms	Number of Windows	Roof Pitch	Heating System	Cooling System	Water Heating System
1,350	3	2	4	6.0/12 (26.57° slope)	Natural gas	Electricity	Electricity

SOURCE: Features data from Wilson et al., "End-Use Load Profiles for the U.S. Building Stock."

TABLE B.2

Window Characteristics

Name	Area (ft^2)	Orientation	Interior Summer Shading Coefficient[a]	Fraction Operable
Window 1	108	North	0.7	0.67
Window 2	72	East	0.7	0.67
Window 3	108	South	0.7	0.67
Window 4	72	West	0.7	0.67

[a] The shading coefficients range from 0 to 1, and 1 indicates no interior shading.

TABLE B.3

Active Cooling Measures

Conditioned Space	AC Type	AC Efficiency	Capacity (BTUh)[a]
No conditioned space (0%)	No A/C	N/A	N/A
One room (33%)	Window A/C	EER 10	6,000
One room (33%)	Window A/C	EER 12	6,000
Entire unit (100%)	Window A/C	EER 10	18,000
Entire unit (100%)	Window A/C	EER 12	18,000
One room (33%)	Window A/C	EER 12	8,000[b]
Entire unit (100%)	Central A/C	SEER 13	25,000
Entire unit (100%)	Central A/C	SEER 20	25,000
Entire unit (100%)	Heat pump	SEER 20	25,000
Entire unit (100%)	Mini-split	SEER 20	18,000

SOURCE: Features input data from an analysis conducted in EnergyPlus.

NOTE: BTUh = British Thermal Units per hour. N/A = not applicable.

[a] Autosized per Air Conditioning Contractors of America manuals J and S (Air Conditioning Contractors of America, “Manual J—Residential Load Calculation”; Air Conditioning Contractors of America, “Manual S—Residential Equipment Selection”) based on cooling design load, except for the oversized unit.

[b] Oversizing factor of 1.5 applied to the regular sizing.

TABLE B.4

Window Types and Input Parameters

Passive Cooling Type	Frame Type	Glass Type	U-Factor	SHGC
Single pane	Fiberglass, vinyl, wood	Clear, reflective	0.89	0.64
Single pane with film	Fiberglass, vinyl, wood	Tinted, reflective	0.89	0.54
Double pane	Fiberglass, vinyl, wood	Tinted, reflective	0.51	0.46
Triple pane	Fiberglass, vinyl, wood	Low-e	0.27	0.31

SOURCE: Features data from OpenStudio-HPXML, “Workflow Inputs: HPXML Enclosure.”

NOTE: Low-e glass = low-emissivity glass.

dow’s U-factor is a measure of how well it insulates. The lower the U-factor, the better the window insulation. The SHGC measures how much of the sun’s heat comes through the window. The lower the SHGC, the less solar heat the window lets in. Table B.4 includes details on the values we used.

Roof

A cool roof reflects more sunlight and absorbs less solar energy than a conventional roof, lowering the building’s temperature. We assigned a solar absorptance factor of 0.5 for reflective and cool roofs (Table B.5).[76]

Insulation

Based on NREL ResStock,[77] most single-family detached homes are not well insulated in Los Angeles County. Assembly effective R-values are modified to reflect a well-insulated home (Table B.6).[78]

TABLE B.5

Roof Types and Input Parameters

Passive Cooling Type	Roof Type	Roof Color	Solar Absorptance
Baseline	Shingles (baseline)	Medium dark	0.89
Cool roof	Cool roof (upgrade)	Reflective	0.5

SOURCE: Features data from OpenStudio-HPXML, "Workflow Inputs: HPXML Enclosure."

TABLE B.6

Insulation and Input Parameters

PC Name	Component Name	Assembly Effective R-Value	Component Name	Assembly Effective R-Value
Baseline	Exterior wall	4	Roof	2.3
All PC[a]	Exterior wall	19	Roof	40

SOURCE: Features data from OpenStudio-HPXML, "Workflow Inputs: HPXML Enclosure."

[a] The all-PC cases include wall and roof insulation, in addition to triple-pane windows and a cool roof.

APPENDIX C

Data Cleaning

We identified unusual cooling-load behavior from IEA's four weather files when simulating building energy use under extreme and normal weather conditions in Los Angeles and when considering various building characteristics and cooling systems. The four weather files we used are as follows:

- 3B_LosAngeles_HW_Historical_Longest_2006.epw (2006)
- 3B_LosAngeles_HW_Historical_MostIntense_MostSevere_2018.epw (2018)
- 3B_LosAngeles_HW_Midterm_Longest_2056.epw (2056)
- 3B_LosAngeles_TMY_2001-2020.epw (TMY)

These files were downloaded directly from the metadata for IEA EBC Annex 80.[79] In the 2018 weather file, we observed a spike in the cooling load at 5 a.m. on August 18 when the dry bulb temperature was fairly mild and constant (i.e., 67–70°F).

A similar issue occurred with all other weather files from the IEA at different times of the day. Table C.1 shows the timing of abnormal peaks and the outdoor temperature at that time. Figure C.1 displays an unusual spike in cooling energy consumption for a heat pump (SEER 20) in a well-insulated single family home in August simulated with the Heat Wave Historical 2018 weather case, alongside the hourly air temperature data. We noticed unusual peak cooling loads under mild temperature conditions in all IEA weather cases, when simulated with a higher level of insulation. The rest of the weather cases from other sources described in Table 1 did not show the unusual peak during non-hot days, and the cooling load increased with rising outdoor temperatures.

As we continued to investigate the weather files, we noticed that the diffuse solar radiation spiked on the days described in Table C.1, while direct solar radiation dropped significantly. There appears to be an interaction between diffuse solar radiation and cooling load, causing spikes on non-hot days.

To correct for these data issues, each IEA weather file presented a unique instance of these spikes, occurring on different days and at different times. The following steps outline our approach to correcting the data:

Step 1 (identification of spikes): We reviewed the hourly cooling energy-load data for each weather file to identify instances of anomalous spikes. This involved examining the data for sudden, unexplained increases in energy load that deviated significantly from the expected pattern. We confirmed that this was happening only for the four IEA weather data files.

Step 2 (verification of anomalies): Once potential spikes were identified, we verified these anomalies by comparing other scenarios with the same weather file. This step ensured that the identified spikes were indeed errors and not genuine fluctuations caused by specific weather conditions.

Step 3 (replacement of data): For each identified spike, we selected the corresponding hourly cooling energy-load data from the previous day as a replacement. This choice was based on the assumption that the previous day's data would provide a reliable baseline, given similar weather conditions and operational parameters. We implemented the data correction for all scenarios using the IEA weather data.

The weather files used in this report are listed in Table 1 and shown graphically in Figure C.2.

TABLE C.1

Identified Timing of Anomalies

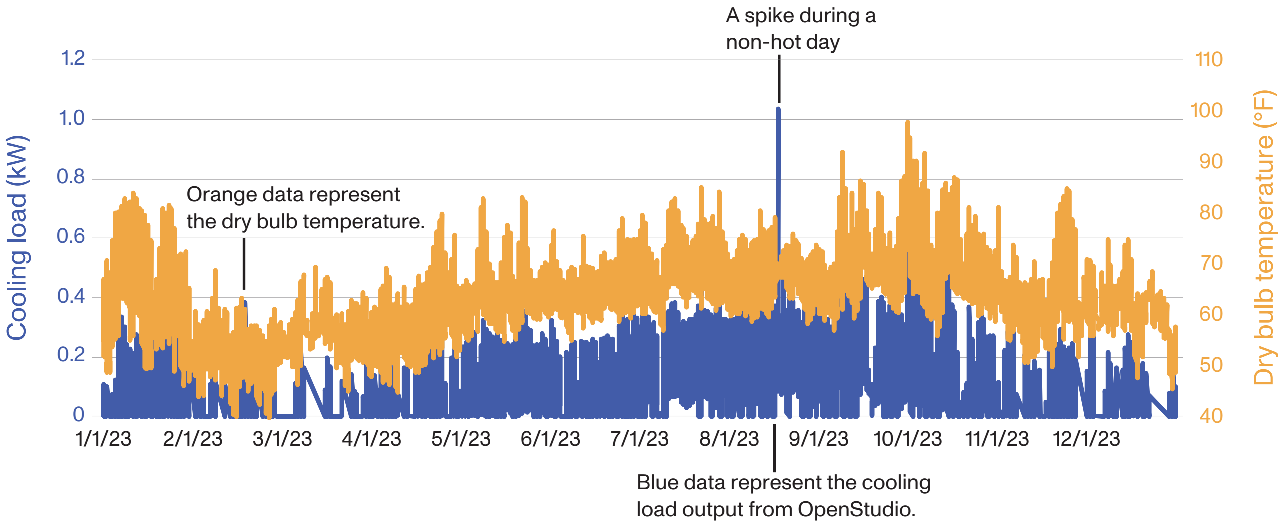
Weather Case	Date (Day/Month/Year) and Time of Abnormal Peak[a]	Dry Bulb Temperature (°F)[b]
TMY	2/16/2023, 5:00:00 p.m.	58.3
Heat Wave Historical 2006	4/20/2023, 5:00:00 a.m.	58.1
Heat Wave Historical 2018	8/18/2023, 6:00:00 a.m.	67.8
Heat Wave Midterm 2056	9/29/2023, 5:00:00 p.m.	72.5

[a] Hourly output from EnergyPlus, using input data described in the "Methods" section.

[b] Machard et al., "IEA EBC Annex 80 'Typical and Extreme Weather Datasets for Studying the Resilience of Buildings to Climate Change' (Version 1.0)."

FIGURE C.1

Hourly Simulation Results for Cooling Load and Outdoor Temperature Data

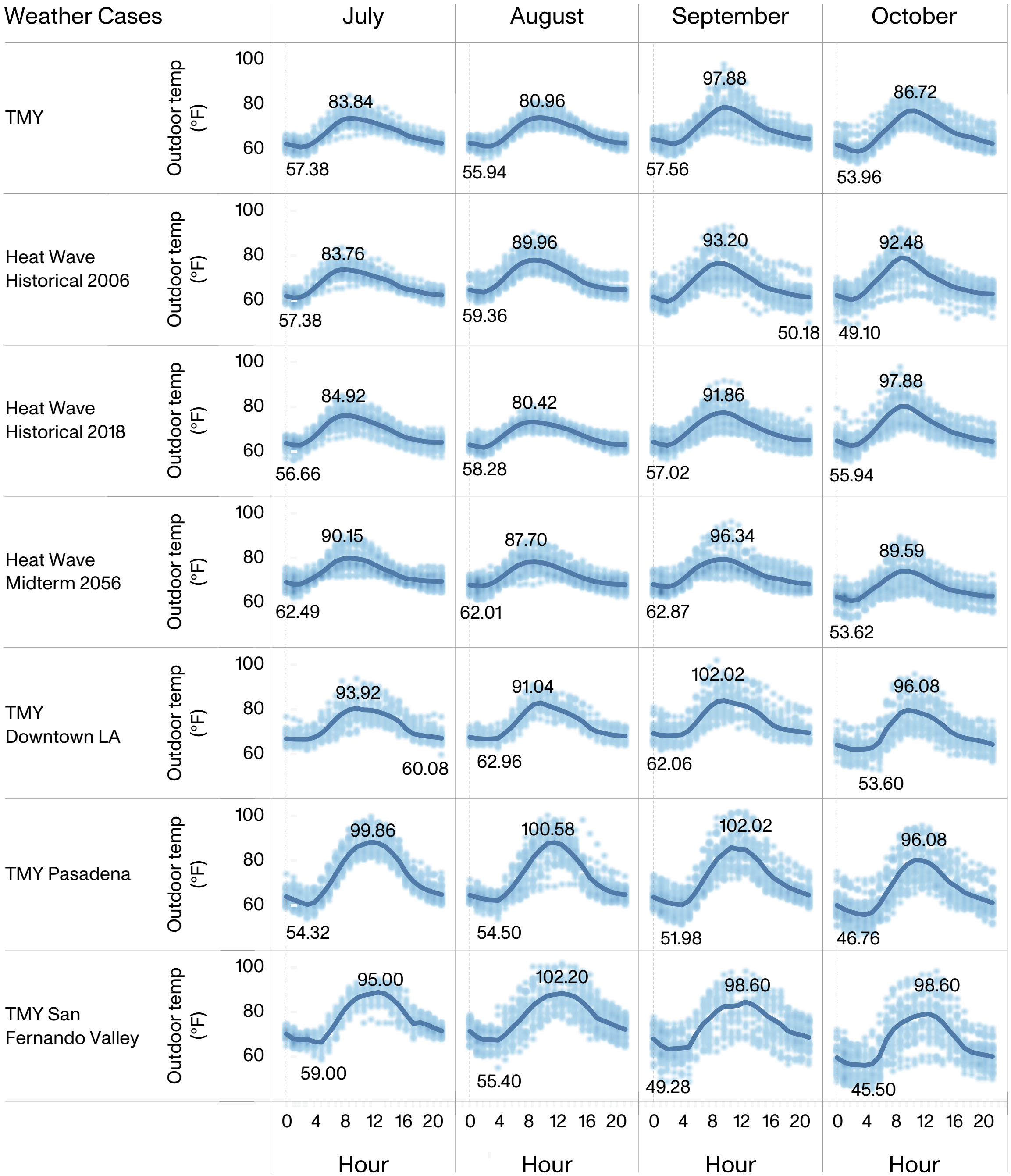


SOURCES: Orange line features data from Machard et al., "IEA EBC Annex 80 'Typical and Extreme Weather Datasets for Studying the Resilience of Buildings to Climate Change' (Version 1.0)"; blue line created from EnergyPlus results, using the weather data from Machard et al., "IEA EBC Annex 80 'Typical and Extreme Weather Datasets for Studying the Resilience of Buildings to Climate Change' (Version 1.0)."

NOTE: This visualization represents the hourly cooling load (left y axis) and outdoor temperature (right y axis) in a well-insulated single-family home with a heat pump (SEER 20). The y axis displays hourly data for day/month/year at 0:00 (i.e., 12 a.m.).

FIGURE C.2

Weather Profiles Used in This Study



SOURCE: Features a visualization of data from EnergyPlus, "Weather Data"; Lawrie and Crawley, "Repository of Building Simulation Climate Data"; and Machard et al., "IEA EBC Annex 80 'Typical and Extreme Weather Datasets for Studying the Resilience of Buildings to Climate Change' (Version 1.0)."

NOTE: LA = Los Angeles; temp = temperature. Outdoor temperatures (°F) for seven weather cases are visualized by hour for the months of July through October. The line indicates the average outdoor temperature for each hour for that month, with minimum and maximum temperatures (°F) labeled for each month. "Heat Wave Historical 2006" and "Heat Wave Midterm 2056" represent the longest heat waves, while "Heat Wave Historical 2018" denotes the most intense and severe heat wave characteristics defined by IEA EBC Annex 80.

Notes

[1] Allan et al., "Intergovernmental Panel on Climate Change (IPCC). Summary for Policymakers."

[2] Åström, Bertil, and Joacim, "Heat Wave Impact on Morbidity and Mortality in the Elderly Population: A Review of Recent Studies"; Marx, Haunschild, and Bornmann, "Heat Waves: A Hot Topic in Climate Change Research"; Xu et al., "The Impact of Heat Waves on Children's Health: A Systematic Review."

[3] Bradford et al., "A Heat Vulnerability Index and Adaptation Solutions for Pittsburgh, Pennsylvania"; Prosdocimi and Klima, "Health Effects of Heat Vulnerability in Rio de Janeiro: A Validation Model for Policy Applications."

[4] National Centers for Environmental Information, "U.S. Climate Normals Quick Access."

[5] National Centers for Environmental Information, "Summary of Monthly Normals: 1991–2020."

[6] Plantmaps.com, "ZIP Code 91365 Hardiness Zones and Climate Data."

[7] Lindsey, "Extreme Overnight Heat in California and the Great Basin in July 2018"; Lindsey and Collins, "Heat Wave in Southern California and the Southwest in Early September 2024," respectively.

[8] Sturm, Baker, and Krovetz, *Health and Social Services During Heat Events: Demand for Services in Los Angeles County.*

[9] Centers for Disease Control and Prevention, "Extreme Heat: A Prevention Guide to Promote Your Personal Health and Safety."

[10] Wilson et al., "End-Use Load Profiles for the U.S. Building Stock."

[11] U.S. Census Bureau, "QuickFacts: Los Angeles County, California."

[12] Office of Environmental Justice and Climate Health, "Establishing a Safe Maximum Temperature Threshold for Rental Housing Units"; Solis and Horvath, "Establishing a Safe Maximum Temperature Threshold for Residential Units."

[13] Solis and Horvath, "Establishing a Safe Maximum Temperature Threshold for Residential Units," p. 6.

[14] Office of Environmental Justice and Climate Health, "Maximum Indoor Residential Temperature Threshold Ordinance."

[15] Los Angeles Code of Ordinances, Title 11, Part 1.

[16] In 2022, Assembly Bill 209 was passed, which requires the California Department of Housing and Community Development to recommend a policy to ensure safe maximum indoor air temperatures for residential dwellings (California State Assembly, Energy and Climate Change).

[17] Burillo et al., "Forecasting Peak Electricity Demand for Los Angeles Considering Higher Air Temperatures Due to Climate Change."

[18] Burillo et al., "Forecasting Peak Electricity Demand for Los Angeles Considering Higher Air Temperatures Due to Climate Change."

[19] Burillo et al., "Forecasting Peak Electricity Demand for Los Angeles Considering Higher Air Temperatures Due to Climate Change."

[20] Loa, *Ovens and Tinderboxes in the Golden State: A Mixed-Methods Exploratory Analysis of Joint Heatwave Power Outage Events.*

[21] Wian, "CAISO Warns Excessive Heat Will Stress Power Grid."

[22] EPRI, "READi Insights: Extreme Heat Events and Impacts to the Electric System"; Los Angeles Department of Water & Power, "Beating the Heat: LADWP Power Reliability."

[23] California State Senate, California Global Warming Solutions Act of 2006: Emissions Limit.

[24] See, for example, California Public Utilities Commission, "Environmental & Social Justice Action Plan."

[25] Note that there is a well-known incentive problem when landlords pay for the building and equipment, and the renters pay for the utilities. Given that the ordinance focuses on all rental units in unincorporated areas (regardless of who pays the utility bills), we do not discuss this split incentive further.

[26] Lee et al., "Assessment of Energy and Thermal Resilience Performance to Inform Climate Mitigation of Multifamily Buildings in Disadvantaged Communities."

[27] Wilson et al., "End-Use Load Profiles for the U.S. Building Stock."

[28] Jonathan Rose Companies, "Location Efficiency and Housing Type."

[29] Burillo et al., "Climate Change in Los Angeles County: Grid Vulnerability to Extreme Heat"; California Strategic Growth Council, "Cal-THRIVES: Air Conditioning Systems"; Energy in Building and Communities Programme, "Resilient Cooling of Buildings: Technology Profiles Report (Annex 80)"; U.S. Department of Energy, "Energy Saver 101: Everything You Need to Know About Home Cooling."

[30] Woods et al., "EnergyPlus™ v.23.2.0 2023 [SWR-17-23]."

[31] We used factorial sampling with seven weather cases, eight AC measures, two thermostat setpoints, and eight PC measures. Additionally, we included 203 extra cases, including scenarios without A/C.

[32] U.S. Census Bureau, "QuickFacts: Los Angeles County, California."

[33] Lee et al., "Assessment of Energy and Thermal Resilience Performance to Inform Climate Mitigation of Multifamily Buildings in Disadvantaged Communities."

[34] Wilson et al., "End-Use Load Profiles for the U.S. Building Stock."

[35] As recommended by Lee et al., "Assessment of Energy and Thermal Resilience Performance to Inform Climate Mitigation of Multifamily Buildings in Disadvantaged Communities."

[36] A heat pump is not exactly the same as an air conditioner because although both can cool a home, a heat pump can also reverse its process to heat a home, whereas an air conditioner

only cools. We used AC to represent all cooling measures, including heat pumps.

[37] Wilson et al., "End-Use Load Profiles for the U.S. Building Stock."

[38] Regular sizing is per the Air Conditioning Contractors of America manuals J and S (Air Conditioning Contractors of America, "Manual J—Residential Load Calculation"; Air Conditioning Contractors of America, "Manual S—Residential Equipment Selection"), based on the cooling design load and using the TMY weather condition, and 150 percent of the regular size is used to model an oversized unit.

[39] Heat pumps are modeled with a variable-speed compressor, while all other AC units are modeled with a single-speed system. Single-speed systems are basic cooling systems that operate at full capacity, cooling until the indoor temperature is reached before shutting off completely. Variable-speed systems are more advanced; they adjust their output based on indoor and outdoor temperatures and humidity levels to reach the desired temperature.

[40] The all-PC option is specifically tested for high-efficiency central air conditioners and heat pumps, because significant improvements to the building envelope are most logical when paired with advanced A/C technology.

[41] These data were fully compatible with the EnergyPlus model.

[42] Machard et al., "IEA EBC Annex 80 'Typical and Extreme Weather Datasets for Studying the Resilience of Buildings to Climate Change' (Version 1.0)."

[43] Lee et al., "Assessment of Energy and Thermal Resilience Performance to Inform Climate Mitigation of Multifamily Buildings in Disadvantaged Communities."

[44] EPRI, "READi Insights: Extreme Heat Events and Impacts to the Electric System."

[45] For information about these outage events, see California ISO, *Summer Market Performance Report*; City News Service, "Utilities Work to Restore Power to SoCal Customers Amid Heatwave"; and LADWP News, "LADWP Heat Storm Update: 2PM Saturday, September 7." As an example of the relevant literature, see Loa, *Ovens and Tinderboxes in the Golden State: A Mixed-Methods Exploratory Analysis of Joint Heatwave Power Outage Events*.

[46] Gagnon, Hale, and Cole, "Long-Run Marginal Emission Rates for Electricity—Workbooks for 2021 Cambium Data."

[47] Gagnon, Hale, and Cole, "Long-Run Marginal Emission Rates for Electricity—Workbooks for 2021 Cambium Data."

[48] The mid-case scenario refers to central estimates for such inputs as technology costs, fuel prices, and demand growth, excluding nascent technologies. This scenario considers electric sector policies as they were in September 2022, with the assumption that the Inflation Reduction Act's Production Tax Credit and Investment Tax Credit will not phase out (Gagnon et al., *Cambium Documentation: Version 2021*).

[49] RSMeans Data Online.

[50] West Shore Home, "Evaluating the Cost of Triple-Pane Windows."

[51] Minasian-Koncewicz, "How Much Do Triple-Pane Windows Cost? (2025)."

[52] Fixr.com, "How Much Does It Cost to Install a Cool Roof?"

[53] Simms, "How Much Does Insulation Installation Cost? [2025 Data]."

[54] U.S. Energy Information Administration, "California: State Profile and Energy Estimates."

[55] These estimates assume that all cities in the county join the ordinance.

[56] Wilson et al., "End-Use Load Profiles for the U.S. Building Stock."

Additionally, more than 68,000 single-family detached homes in Los Angeles County have partially conditioned spaces, but we did not consider the possibility of these homes adding extra cooling devices to comply with the ordinance scope of "all habitable rooms" (Los Angeles Code of Ordinances, Title 11, Part 1).

[57] According to the EIA-860M data (October 2024), approximately 321 MW of battery storage, natural gas–fired combined cycle units, and small-to-medium-scale solar generation units (1–19 MW) are scheduled to come online, while more than 1 gigawatt of natural gas steam turbine units at AES Alamitos are set to retire by 2026 in the Los Angeles region (U.S. Energy Information Administration, "Inventory of Operating Generators as of October 2024"). It is important to recognize that nameplate capacity (i.e., theoretical maximum output rating, which is measured in MW) cannot be directly compared with additional peak load (MW) because of the intermittency of solar resources and the limited energy available from battery storage. Additionally, extreme heat conditions affect the generation and discharge output from thermal, solar, and battery storage sources.

[58] Burillo et al., "Forecasting Peak Electricity Demand for Los Angeles Considering Higher Air Temperatures Due to Climate Change."

[59] Faramarzi et al., "Performance Evaluation of Rooftop Air Conditioning Units at High Ambient Temperatures."

[60] Burillo et al., "Forecasting Peak Electricity Demand for Los Angeles Considering Higher Air Temperatures Due to Climate Change."

[61] Chretien et al., "System Solution to Improve Energy Efficiency of HVAC Systems."

[62] Adding a zonal control system costs extra, depending on the number of zones and the thermostat type; two zones average $1,700 to $2,000. For cost estimates, see Sparks, "How Much Does an HVAC Zoning System Cost? [2025 Data]."

[63] Palmgren et al., "2019 California Residential Appliance Saturation Study (RASS)."

[64] Utilities commonly use this strategy during heat waves to reduce energy consumption. Power Savers (Los Angeles Department of Water & Power, "Power Savers") and the Smart Energy Program (Southern California Edison, "Smart Energy Program") are two programs that allow utilities to temporarily raise a home's thermostat setting by up to four degrees, limiting A/C usage in exchange for a bill credit.

[65] Under the 2018 historical heat wave condition, the whole-home AC methods we tested (without the use of any PC methods) failed to meet the indoor temperature thresholds for four hours or less when the thermostat was set to 75°F.

[66] When the thermostat was set to 75°F, the indoor temperature never rose above 89°F for scenarios that aimed to cool the whole unit and used one of the four AC methods.

[67] California Code of Regulations, Title 22, Section 87303.

[68] This scenario includes both incorporated and unincorporated Los Angeles County.

[69] OpenStudio-HPXML, "Sample_Files."

[70] Wilson et al., "End-Use Load Profiles for the U.S. Building Stock."

[71] Note that changing the assumption of using the median value will likely affect results. For example, if the square footage was decreased to a smaller value (e.g., 750 ft^2), the AC would need to cool a smaller volume. All other things being equal, this would mean that the AC would need less power to cool the volume. Or, if there were more windows (especially single-pane windows), there would be more heat transfer with the exterior, and the AC would need more power to cool the volume. Although these types of changes are predictable for this building type, large changes in the building type or structure run the possibility of causing different interaction. Thus, it is important to consider these results for just the type of building we modeled: a small, detached, single-family home. The analysis would need to be redone for a different building type. Indeed, this is part of the reason why, in this study, we chose to focus on a different building type than in previously published studies.

[72] For descriptions of default values, equations, and logic, see OpenStudio-HPXML, "Workflow Inputs: Input Defaults."

[73] Occupant-driven end uses (e.g., plug loads, appliances, hot water) are calculated based on the number of bedrooms (OpenStudio-HPXML, "Workflow Inputs: HPXML Building Occupancy"). Default schedules are typically smooth, averaged schedules. To review these default schedules, see OpenStudio-HPXML, "Workflow Inputs: Default Schedules."

[74] Rosado and Levinson, "Appendix A: Simulated HVAC Energy Savings in an Isolated Building (Task 2.1 Report)."

[75] OpenStudio-HPXML, "Workflow Inputs: UFactor/SHGC Lookup."

[76] The solar absorptance factor for a roof indicates how much sunlight a roof absorbs, ranging from 0 to 1; a higher number means that a greater amount of solar energy is absorbed by the roof material. For a discussion of the different values for solar absorptance, see OpenStudio-HPXML, "Workflow Inputs: HPXML Roofs."

[77] Wilson et al., "End-Use Load Profiles for the U.S. Building Stock."

[78] Assembly effective R-value includes insulation performance from all material layers and interior and exterior air films (Residential Energy Services Network, "2022 ANSI/RESNET/ICC 301 Standard for the Calculation and Labeling of the Energy Performance of Dwelling and Sleeping Units Using an Energy Rating Index.")

[79] Machard et al., "IEA EBC Annex 80 'Typical and Extreme Weather Datasets for Studying the Resilience of Buildings to Climate Change' (Version 1.0)."

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About This Report

In 2024, the Los Angeles County Board of Supervisors began working to develop an ordinance that would establish a maximum indoor temperature threshold for rental units. Officially, this ordinance would affect only renters living in the unincorporated parts of the county, and a simple way to comply might be for a landlord to provide some form of air conditioning. To gain a more holistic understanding of what would happen if the incorporated areas joined the ordinance, RAND researchers conducted a county-wide analysis of how different ways to meet the indoor temperature threshold for single-family rental houses might lead to differences in energy use, greenhouse gas emissions, the burden on the electric grid, and affordability for landlords and tenants. This study may be of interest to County of Los Angeles technical and academic stakeholders who are interested in learning details about the study's analysis of the proposed indoor temperature threshold ordinance. Additionally, the findings in this report are applicable to a broader variety of stakeholders in any region that is considering maximum indoor temperature threshold regulations. For a related video that presents these topics from a higher level, see Hye Min Park, Kelly Klima, and Sophia Charan, "Keeping Los Angeles Renters Cool," RAND Corporation, RB-A3563-1, 2025.

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