Title

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Publication Date

2026-09-09

UCLA Luskin Center for Innovation

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STUDENT REPORT

Green Schools and Hot Playgrounds

ASSESSING THE OUTCOMES OF GREENING THRESHOLDS ON ELEMENTARY SCHOOL CAMPUSES IN LOS ANGELES, CALIFORNIA

BY KATHRINE WALL

AUGUST 2026

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JUNE 2026
MASTER'S THESIS

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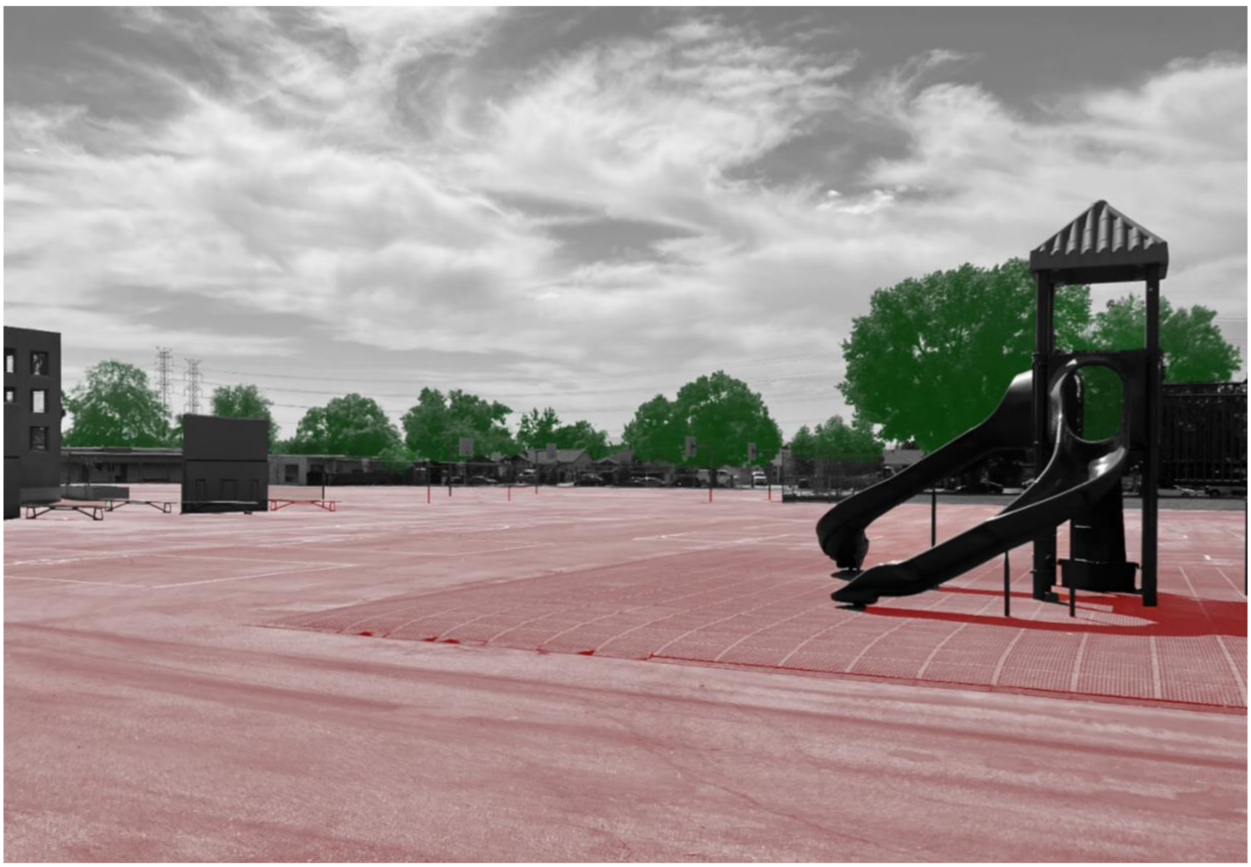

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Green Schools and Hot Playgrounds:

Assessing the outcomes of greening thresholds on elementary school campuses in Los Angeles, California

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Acknowledgements

I would like to thank the professors at the Luskin School of Public Affairs for supporting my education and development over the course of my master's degree. Specifically, I want to thank Professor Kelly Turner for consistently providing me with research opportunities, supporting me throughout the development of this thesis, and inspiring me to study the topics I love. I would also love to thank Professor Minjee Kim for her ongoing support of this thesis and of my own professional development, and for always encouraging me to put my best self in my work.

Thank you also to my parents, friends, and family, who, by association with me, are now all very well versed in the world of microclimates and urban heat. Especially, I want to thank Allie, who read my graduate school applications dozens of times, has spent a collective 1,000+ hours on the phone with me throughout my degree, and has always been my very best role model.

Lastly, thank you to Carlos for being an unwavering cheerleader through the entirety of my degree and research. I will never be able to put into words how grateful I am for your creativity, humor, and constant encouragement.

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Abstract

The urban heat island effect is a well-studied and well-documented phenomenon describing the tendency of cities to be hotter than their surrounding suburban and rural environments. Within cities, differences in land use regimes, the built environment, and proximity to vegetation and water create systems of microclimates. Intraurban temperature variation and increased likelihood of climate-change induced heatwaves have highlighted the need for heat-conscious micro-scale urban design. This is especially true on school campuses, where common building materials and site design can create unsafe conditions for children, who already experience heightened vulnerability to heat. Greening thresholds represent a potential policy instrument to address heat dangers on campuses, but their effectiveness and limitations are understudied. This research addresses this gap using the Los Angeles Unified School District's Green Schools for All Goal- which calls for 30% greening across all campuses- as a case study. Four elementary school campuses are compared: two that have met the threshold and two that have not. Using the SOLWEIG environmental model, this study simulates both existing conditions and a refined policy scenario in which greening is narrowly defined as tree canopy cover. The study examines usable space on the playground in each scenario in order to assess whether greening thresholds are meaningful indicators of thermal safety and whether a more refined design strategy improves cooling potential. The results demonstrate that baseline climatic conditions are widely determinant in greening's success in increasing usable space, even in cases where 'greening' is narrowly defined as tree canopy. This research supports the growing consensus that heat mitigative design should be site specific to best ensure that the interventions are effective and equitable.

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INTRODUCTION

The urban heat island effect is a well-studied and well-documented phenomenon describing the tendency of cities to be hotter than their surrounding suburban and rural environments. This is due primarily to the replacement of natural water, permeable surfaces, and vegetation with heat-absorbing building materials, impervious surfaces, waste heat from vehicles and buildings, and urban geometries that trap and re-radiate heat energy. As climate change worsens heat waves around the globe, more and more cities are experiencing an exaggerated heat island effect, which poses a threat to residents' physical safety and mental health. The equity implications of urban heat are also well studied and documented, with the hottest areas of cities around the globe disproportionately overlapping with low income and marginalized communities.

Children, compared to adults, experience heightened vulnerability during heat events. Their high metabolic rate and high surface area-to-body ratio make their bodies less efficient at regulating temperature, increasing their likelihood of experiencing negative physical and mental impacts as a result of outdoor heat exposure. As such, schools, which serve as primary sites of physical and mental development- and are also where children are required to spend most of their daytime hours- have an increased responsibility to provide heat-safe learning environments.

Despite this, common American schoolyard design utilizes economic yet heat-dangerous design. Open play fields offer little shade, and common materials like asphalt and steel increase surface and radiative heat. With existing campus design posing an increasing climatic threat to one of society's most vulnerable groups, school districts across the United States face an urgent need for cooler campuses but have little direction on how to get there. School-based heat mitigating policies are relatively new and understudied, preventing their widescale acceptance and applicability. This research addresses a critical gap in the literature assessing on-the-ground implications of one schoolyard heat policy: greening thresholds. Through analyzing the limitations and successes of thresholds as a heat safety measure, this research seeks to improve existing heat mitigation while also contributing to a small but increasingly important body of literature informing best practices.

To do so, this research examines Los Angeles Unified School District's (LAUSD) Green Schools for All goal as a case study. LAUSD considers itself a pioneer in schoolyard heat safety, and as such has set an objective target of 30% greening across all campuses. Through modeling the thermal conditions of schools within the existing policy guidelines as well as a refined policy prioritizing canopy, this research seeks to answer the question: are school greening thresholds meaningful indicators of thermal safety, and does shifting the design strategy change the cooling potential? Utilizing four LAUSD elementary schools as study sites, this research calls into question the equity of uniform numerical targets and examines the extent to which 'greening' can reliably increase a playground's usability.

LITERATURE REVIEW

Urban Form and Microclimate

It is well understood that urban areas are hotter than surrounding rural areas due to factors including dense construction, use of heat absorbing materials like asphalt, and lack of greenspace (Heaviside, 2017; Joshi et al., 2024; Kim, 1992; Li et al., 2020). This urban heat effect increases cities' vulnerability to extreme heat events, exacerbating individuals' heat-related health risks (Heaviside 2017; Joshi et al., 2024). However, research increasingly suggests that observing urban heat at a regional or city scale obscures substantial intra-urban temperature variation. While cities' regional context, topography, and land use regime influence air temperature, humidity, and wind speed, small-scale urban morphology, materiality, and use patterns produce a series of microclimates which influence localized heat exposure (Holst & Mayer, 2011; Johansson, 2006).

Microclimates largely dictate an individual's thermal comfort, which is a "condition of mind that expresses satisfaction with the thermal environment, assessed by subjective evaluation" (ASHRAE, 2023). About half of an individuals' thermal comfort is attributed to their environment, with the additional half depending on individual factors such as age, fitness, acclimation, and preference (Middel, n.d.). Environmental factors influencing one's thermal comfort include air temperature, wind speed, humidity, and radiant temperature. Radiation refers to the exchange between a body and all surfaces in a given environment, including those that have a warming effect (such as sunlight or black asphalt) and those that have a cooling effect (such as shade). Radiant temperature captures the influence of the built form, shading, and vegetation. It is heavily influenced by building morphology and the local physical environment (Vanos, 2015).

The impact of urban form on heat is well studied at the city scale (Brown et al., 2001; Johannson, 2006; Joshi, 2024; Ka-Lun Lau et al., 2021; Wong, 2016). Microclimates within cities are influenced by the presence of water, vegetation, topography, and the built form which result in differing patterns of ventilation, shade, and radiation (Brown et al., 2001; Johannson, 2006; Joshi, 2024; Ka-Lun Lau et al., 2021; Wong, 2016). However, examining urban heat at the site scale, rather than the city scale, allows planners to consider the thermal experience of individuals as they live and move through a discrete space (Vanos, 2015).

At the site scale, urban heat can be mitigated by intercepting solar radiation, manipulating airflow, and reducing surface radiation by preventing absorption (Antoniadis, 2020; Brown, 2011). More recently, efforts have been made to quantify and assess causative factors and understand how individual design elements, including building orientation, building height, density, use, geography, and more impact microclimate variation within a city (Joshi, 2024; Middel et al., 2020). Take, for example, an open sports field or a dense urban canyon. An open sports field has a sky view factor (SVF) of about 0.95, while a densely designed street with high rises has an SVF of 0.2-0.4 (SVF refers to the ratio of radiation received by a planar surface to radiation received from the entire hemispheric radiating environment). Despite a lack of green space and a high concentration of impervious surfaces, researchers found the dense street to be cooler than the grass field, since high rises create shade that cools the streets below (Johansson, 2006; Vanos, 2015).

Indeed, research surrounding shade consistently finds it to be the most effective means by which to reduce outdoor heat due to its ability to intercept shortwave radiation, regardless of its source (Johanson, 2006; Joshi, 2024; Vanos, 2015; Vanos, 2017). Shade is also relatively easy to create by manipulating site layouts or adding structures or trees to existing sites (Vecellio et al., 2022). However, densely situated structures can reduce ventilation and trap longwave radiation, reducing radiative cooling (Li, 2020; Vanos, 2015). Disagreement over the success of individual design elements emphasizes the need to study each intervention within the context in which it will be implemented.

At the site scale, air temperature, humidity, and wind speed vary little, and differences in radiant temperature are the most prominent drivers of heat gain (Vanos, 2017). Given this, urban planners can look to site design to reduce heat waves' impact on individuals (Brown, 2011; Brown, 2015; Vanos, 2015). While a growing body of literature describes the means by which to utilize design to reduce thermal stress, a much smaller body of literature measures these interventions within the context of a real landscape (Brown, 2015; Vanos, 2015). Furthermore, different interventions behave differently across various climates, urban forms, seasonality, and uses, highlighting the importance of assessing context when considering site design (Brown, 2015). Understanding how theoretically helpful design interventions behave in an actual urban site can inform best practices and provide guidelines that will make urban settings safer and more comfortable. This study seeks to address this gap directly.

Heat and Vulnerable Populations

Intra-urban variability also poses an equity concern: across the globe, poorer neighborhoods tend to bear higher heat exposure within cities (Chakraborty et al., 2019). In the United States, heat disproportionately affects lower income areas, marginalized communities, and communities of color due to, for example, lack of air conditioning, lack of greenspace, and lack of shade (Heaviside, 2017; Johnson, 2009; Wolf et al., 2013). Furthermore, heat mitigating interventions tend to favor high income residents, with researchers finding disparities in the effectiveness of strategies based on race, income, and age (Vargo et al., 2016). Even more direct interventions, like cooling centers, tend to have limited accessibility by heat vulnerable groups who lack access to cars, offering yet another social disparity in heat safety (Nayak et al., 2019).

Existing research has also demonstrated that children are more vulnerable than adults to heat, primarily due to a high metabolic rate (meaning they produce more heat per body mass) and high surface area-to-body ratio (Antoniadis, 2020;, Cheng, 2020; Vanos, 2015). Children have a different physical makeup than adults, resulting in unique thermal regulations and responses (Cheng, 2020). Even so, most studies examining heat health impacts focus only on adult thermal comfort (Antoniadis, 2020). Recent research has begun to focus on children, identifying children-centric spaces such as park playgrounds as study areas or tweaking existing thermal comfort models to better reflect children's energy budgets (Vanos, 2015; Vanos, 2017). Still, this area of research is relatively understudied considering its importance.

Combining social and physical vulnerability, children in low-income and minority populations are more vulnerable to negative heat-related health impacts including asthma, heat stroke, and heat exhaustion (Patel et al., n.d.; Vanos, 2015). In low-income areas, children are less likely to return home to air conditioning, leading to continued heat exposure and increased vulnerability for heat health impacts (Lala et al., 2023). Together, this literature highlights the need to make schools, where children spend the majority of their daylight hours, heat safe.

Schoolyards: Equity, Design, and Thermal Exposure

Installing air conditioning is the fastest and most effective means to address unsafe thermal conditions in schools (Lala et al., 2023, Park and Goodman, 2020). However, limited funding opportunities, energy costs, and maintenance capacity limits school districts' ability to depend on air conditioning (Lala et al., 2023). Additionally, air conditioning only supports indoor environments. Outdoor areas should be prioritized too, as they serve numerous purposes such as supporting children's play, creativity, socialization, and health while providing breaks for teachers (Antoniadis, 2020).

Typical schoolyard design increases the risk of heat-related health impacts due to lack of shade and extensive use of heat-absorbing materials, which together result in an increased radiative heat load and surface temperatures (Antoniadis, 2020; Vanos, 2015). Large areas of urban schoolyards often have sky view factors greater than .70, indicating a near total absence of shade (Antoniadis, 2015). Schoolyards are primarily covered by turf/grass and impervious surfaces (Schulman, 2007), many of which reach extremely high surface and radiant temperatures under direct sunlight. Asphalt, an economic and durable ground surface commonly used in schoolyards, has an extremely high heat capacity and readily absorbs and retains heat. Even on a day with air temperatures of 68°F, asphalt in direct sunlight can reach 120°F (Patel et al., n.d.). Other frequently used playground materials, including rubber, steel, aluminum, artificial turf, pea gravel, sand, and woodchips, can reach surface temperatures high enough to cause burn injuries upon contact (Antoniadis, 2020; Vanos, 2016; Patel et al., n.d.).

Outdoor areas of school yards have a long history with inequities. The provision of public space for children to play in is a relatively new element of American urban settings, beginning only in the late 19th century. As part of the reform movement, which sought to improve public education, public health, and living conditions for the urban poor (among other things), American cities began establishing public play facilities near schools (Hendricks, 2011, ch. 12). After the first world war, the purpose of playgrounds shifted to focus on supporting low-income children' s physical development, in part to support future national defense efforts (Hendricks, 2011, ch. 12). From their inception, American playgrounds at school have reflected broader urban inequities, evolving from the need to mitigate the health impacts of industrialization to spaces embedded within systems linking poverty with militarization.

Today, disparities exist in access to recess across neighborhoods, with schools in lower-income areas tending to offer shorter recesses and less effective playgrounds than schools in more affluent areas (Anderson et al., 2022; Thompson et al., 2023). Thermal safety presents a crucial access barrier to recess and productive play in low-income schools, which tend to be hotter and offer less shade and vegetation. Thermal comfort strongly influences the duration and intensity of children's physical activity, with extreme heat discouraging play (Cheng & Brown, 2020; Gaitani, 2007; Vanos, 2015). Increasing the thermal safety of playgrounds presents an opportunity to close the recess equity gap and provide more effective, safer recesses for all students.

In addition to preventing safe outdoor play, heat also impedes learning by impairing cognitive function and academic performance (Roach, 2022; Park & Goodman 2020; Park et al., 2020, Patel et al., n.d.). Even within the same school, students who took the same standardized test on a day following a heat spell scored lower than students who took the same test following a cooler period (Park, 2020). What's more, hot temperatures impact students attending school in low income or disadvantaged neighborhoods more than those in non-disadvantaged schools: one study found that each week above 80°F reduced learning for Black and Hispanic students by an amount equivalent to reducing teacher quality by as much as 6% of a standard deviation (Park, 2020). Another study based on PSAT scores found that weekend and summer temperatures have negligible impact on test scores, but as average school year temperatures increase, each additional degree Fahrenheit hotter is associated with a 1% reduction in student learning (Park and Goodman, 2020).

Playground heat exposure is also related to additional adverse health outcomes, including impacts on asthma, obesity, and poor mental health (Anderson et al., 2022; Vanos, 2015). Because urban heat burdens are disproportionately higher in low-income communities of color, these conditions further undermine the safety and effectiveness of outdoor play in already underserved environments. Despite their potential for danger and the increased academic vulnerability of their users, schoolyard design standards around the world make little to no mention of thermal safety (Vecellio et al., 2022). Other priorities, such as physical hazards, preventing blunt force injuries, preventing vandalism, and maintenance costs take precedent over heat safety in schoolyard design (Schulman, 2007; Vecellio et al., 2022).

Recess is crucial to all children, but its availability and quality varies widely across communities. Addressing disparities in thermal safety, and therefore, access to recess, represents a necessary step toward advancing urban climate equity. Continued urbanization and climate change will undoubtedly worsen this issue, making campuses hotter and reducing learning. If hotter campuses reduce learning capacity and limit future capital development, then hot campuses reinforce an existing equity disparity.

This Research

The usability and safety of playgrounds is currently threatened by existing design and climate change-related heat events, an issue exacerbated by the natural heightened vulnerability of children. Existing literature suggests that site-scale design interventions like shade can improve the thermal conditions of a space. This research tests the extent to which site scale variation limits or enhances the success of heat mitigative design interventions, including greening and canopy coverage. It seeks to tie existing research into reality by observing how commonly cited heat mitigators may actually improve the heat safety and usability of a schoolyard and, therefore, the effectiveness of recess.

CONTEXT

LAUSD Building History

Established in 1872, Los Angeles Unified School District (LAUSD) oversees nearly 800 campuses across 700 sq. miles and over 520,000 students, making it the second largest public school system in the country. In the last 150 years, LAUSD has commissioned and designed hundreds of campuses, buildings, and outdoor play areas, positioning it as one of the longest-running and most powerful influencers of building design in the Los Angeles Region. Understanding the context of campus design and outdoor play spaces requires a consideration of LAUSD building history.

Los Angeles grew rapidly in the late 1800s with the transcontinental railroad's arrival which connected the city to the rest of the country. At that time, land purchase, development, and population exploded. Administrative bodies and government entities were formed quickly in response to growing needs, including the LA Unified school district. In the earliest years of its functioning, LAUSD campuses were quickly constructed, wood framed, and vaguely resembled the Late Victorian style without any established play areas (LAUSD OEHS, 2014).

In the early 1900s, the progressive movement inspired more thoughtful school campuses, with individual buildings housing unique facilities and separate classrooms by grade (LAUSD OEHS, 2014). This era also brought about the first established play areas. The progressive movement's prioritization of public schools inspired Southern California's leading architects to design and construct dozens of school campuses, each in a characteristic Southern California style. Campuses became wider and more spread out. Schools came to be considered as community spaces, and their designs reflected it: new builds included auditoriums that could co-function as local meeting halls, outdoor spaces that could function as parks outside of school hours, and public rooms designed to function as gathering areas (LAUSD OEHS, 2014). This era of design also reflected the contemporaneous emphasis on health and the need for 'fresh air'. In Los Angeles, architects looked to the outdoors to provide heating and ventilation. Architect Alfred D. Hamlin wrote in a 1910 guide for designing school houses, "let it be clearly understood and always remembered that no artificial heating and ventilation can ever take the place of fresh outdoor air and sunshine" (LAUSD OEHS, 2014, pp. 35). Architect John Donovan, who authored guidelines for school architects, wrote for California schools: "Elevating the building and spreading its area over more ground brought forth many interesting developments in plan of single units and groups of units...Thus it is that the school architecture of California has found a permanent spot in the sun" (Donnovan, 1921 pp. 48).

The 1933 Long Beach earthquake ushered in another era of context-responsive design for LAUSD. Many campuses were rebuilt- and new campuses were built- with updated building safety codes. Stylistic elements from the early 20th century were traded in for more efficient, sturdy, and modern styles. Design in this era reflected functionality and educational efficiency. Buildings were angled to maximize natural light filtering through the windows, and in elementary schools, classrooms were often constructed so that they had doors connecting the classroom to the outdoor play area (LAUSD OEHS, 2014).

Figure 1. Emerson Middle School, 1937. Source: Julius Schulman Archives, Getty Research Inst.

This trend continued following WWII, when campuses grew larger, offering larger areas for physical activity, and continued to streamline functionality and educational efficiency. Architects in this era took advantage of Southern California’s climate, encouraging indoor-outdoor movement and prioritizing ventilation over shade. Schools were built low-mass, intending to be child friendly, and rarely stretched beyond two stories high (LAUSD OEHS, 2014).

Figure 2. Fern Drive School in 1956. Source: Julius Schulman Archives, Getty Research Inst.

LAUSD's buildings were primarily constructed in an era that emphasized indoor-outdoor design and ventilation. Southern California style, combined with a desire to make spaces child-friendly, meant that most structures on elementary school campuses were a single story. Today in California, as many as 20% of schools have no air conditioning at all, and an even higher proportion of individual buildings lack air conditioning. Furthermore, schools in low-income areas are less likely overall to have working air conditioning systems (Patel et al., n.d.). In LAUSD, each campus has at least one air conditioner. However, at least 50,000 need to be replaced, even more need to be installed to ensure coverage in every classroom, and many calls for repairs go unheeded due to high demand and limited financial resources (Reyes-Velarde, 2024). Combined with a design history focused on maximizing sunlight, outdoor play, and ventilation without significant consideration for shade or heat safety, Southern California Schools now need to find solutions to campus heating.

How is Heat Currently Managed in LAUSD?

In LAUSD, administrators and teachers are instructed to keep children off asphalt, turf, and concrete on heat days (LAUSD, 2022 b), indicating an awareness of these design materials' heat dangers. Other current mitigation efforts include encouraging students to drink water, establishing a "cool room" and sending students there when they begin to show signs of heat stress, and reporting HVAC malfunctions (LAUSD, 2022 b). Perhaps most significantly, on very hot days, administrators are encouraged to exercise judgement and cut the school day short to the minimum number of minutes required to log an instructional day (Dale and Brenneman, 2024). This poses significant equity concerns, as hotter schools in hotter neighborhoods- which typically experience additional social vulnerabilities- experience fewer instructional hours than cooler campuses. Additionally, students in disadvantaged neighborhoods are less likely to have air conditioning at home, so cutting a school day short means little in terms of individual heat safety.

LAUSD acknowledges that heat threatens students' health and learning ability (LAUSD, 2022 b; LAUSD, 2025). However, limited funding and multitudinous additional priorities often result in limited action towards heat safety. For example, replacing and repairing existing HVAC systems across the District will cost at least $9 billion, likely more when considering new unit installation (Reyes-Velarde, 2024). Over the past two decades, the district has invested $1 billion in HVAC systems, only a fraction of what is needed now (LAUSD, 2022 b).

LAUSD self-identifies as "a leader on heat mitigation at schools" (LAUSD, 2022 b). However, heat is not mentioned directly in the entirety of the LAUSD 2022-2026 strategic plan (LAUSD, 2021). The closest mention is nested within Pillar 2: Joy and Wellness, in which one goal is to create welcome learning environments. A strategy listed within this goal is to "Develop safe and sustainable green spaces, outdoor learning environments, and shaded areas at each school" (LAUSD, 2021), without direct mention of heat.

The Green Schools for All Goal

In September of 2022, the Los Angeles Board of Education voted unanimously in favor of a resolution calling for all LAUSD campuses to have a minimum of 30% of their campus devoted to greenspace. At that time, only 16% of campuses met the goal (LAUSD, 2022 a).

A September heatwave that had brought on-campus temperatures above 100°F inspired this resolution, which was primarily created to address campus overheating. The resolution also acknowledged that students attending schools in socially vulnerable neighborhoods were more likely to experience worse heat and less likely to have green space accessible to them (LAUSD, 2022 a), directly agreeing with urban heat literature (Heaviside, 2017; Johnson, 2009; Wolf et al., 2013). In response, the resolution states that all funding and planning should first prioritize campuses in DACs and campuses with a schoolyard that is less than 10% green/natural (Los Angeles Unified School District Board of Education, 2022).

'Schoolyards' are defined as the 'exterior areas of the school site to which students have general, unrestricted, and secure access within the school fence line, including open space between permanent buildings wider than 20 feet", not including lunch shelters, bleachers, parking areas, buildings, frontages, or walkways (LAUSD, 2024). 'Green' or 'natural' areas are defined as "In-ground planting/trees, grass/lawn/natural turf/other turf materials, dirt/mulch, decomposed granite (DG), permeable pavers" (LAUSD, 2024).

This rather expansive definition of greening raises some red flags regarding the ability of this resolution to provide the cooling effect it intends to. Literature demonstrates that shade is the most effective means by which to improve thermal comfort (Johanson, 2006; Joshi, 2024; Vanos, 2015; Vanos, 2017), yet only one example of schoolyard greening includes shade (installation of trees). At a scale as small as a school campus, reducing individual heat exposure through shading is more impactful than modest reductions in surface temperature afforded by replacing asphalt or bare earth with lawn, native plants, or gardens (Johanson, 2006; Vanos, 2017). While all greening offers co-benefits of varied value- including education, pollution reduction, aesthetics, and more- their ability to substantially alter thermal exposure is limited in comparison with tree canopy.

Thus, without further refining where, how, and to what extent greening should take place, the Green Schools for All initiative risks overlooking site-specific nuance that may challenge the effectiveness of the policy.

METHODOLOGY

Research Design

This research utilizes LAUSD's Green Schools for All goal as a case study to test if greening thresholds are a meaningful indicator of thermal safety, and furthermore, if prioritizing tree canopy produces more reliable outcomes.

Site Selection

Studying this topic first required selecting study sites. Four school sites were selected to represent a range of geography, progress toward the Green Schools for All threshold, and physical schoolyard conditions within Los Angeles.

Younger children are amongst the most vulnerable to heat stress (Cheng, 2020; Vanos, 2015). Young students are also more likely to engage in and benefit from outdoor play, as it is critical for physical, mental, and social development (Anderson et al., 2022, Gustat et al., 2023). As such, I filtered sites to highlight elementary schools. I began with a polygon GIS data layer of all 1,152 school campuses in LAUSD. I filtered for active public elementary schools, excluding other grade levels, closed campuses, and charter schools. 414 campuses remained.

Due to the demonstrated heightened risk within disadvantaged communities (Chakraborty et al., 2019; Heaviside, 2017; Johnson, 2009; Wolf et al., 2013), I filtered for sites all located within disadvantaged communities (DACs) as designated by CalEPA for the purposes of SB535. An area qualifies as a DAC is it is disproportionately affected by negative environmental externalities or if it includes high concentrations of people experiencing unemployment, high rent burdens, low incomes, and low educational attainment (CalEPA, 2022). The CalEPA DAC designations are often used for funding designations and are widely regarded as authoritative. After filtering out schools in non-DAC neighborhoods, 284 campuses remained.

Vast differences in urban geography, heat exposure, and built form comprise LAUSD. To best capture this variation with four study sites, I considered the school locations along with the following layers:

a) Buildings: Using the ArcPro 'Summarize Within' tool, I calculated the percent of campus area made up of buildings. This value represents lot coverage per campus.

b) Existing vegetation: The normalized Difference Vegetation Index (NDVI) indicates vegetation density and health using red and infrared satellite bands from LANDSAT 8. Values of -1 to 0 represent a total absence of green vegetation, while values closer to 1 indicate healthier, denser vegetation. I used LANDSAT 8 satellite imagery to calculate NDVI in QGIS. Using the ArcPro 'Summarize Within' tool, I calculated the average NDVI for each campus, within school boundaries, as a proxy for vegetation prevalence, health, and density.

Next, I categorized each school into low, medium, and high categories for each criterion (building density and vegetation density) to create binned indices. Using a rule-based typology, I grouped each school into discrete categories reflecting its varied form. Using the following grid to ensure variation in campus design, I selected 4 representative sites:

Table 1. Case Study School Site Selection Matrix.

Low Lot Coverage High NDVI **Rosa Parks Learning Center** (has reached Green Schools for All goal) See Figure 4	High Lot Coverage Low NDVI **Ninth Street Elementary School** (has not reached Green Schools for All goal) See Figure 5
Low Lot Coverage Low NDVI **Halldale Elementary** (has not reached Green Schools for All goal) See Figure 6	High Lot Coverage High NDVI **Danny J. Bakewell, Sr. Primary Center** (has reached Green Schools for All goal) See Figure 7

Importantly, site selection also considered geography of the school within LAUSD to best reflect the highly varied geography, climate zones, and urbanization levels of the School District. Campuses' geographic locations are seen in Figure 3.

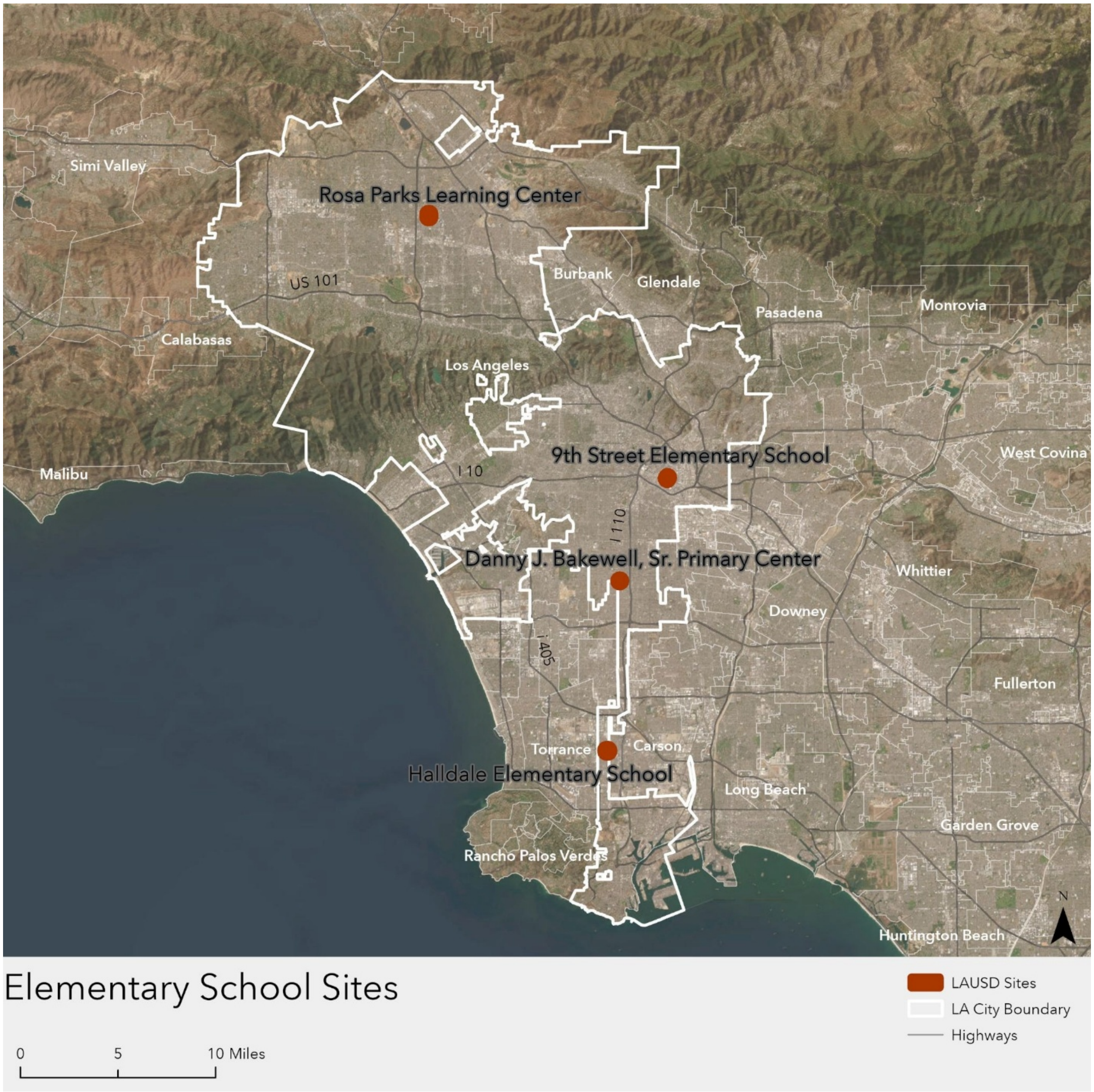

Figure 3. Geographic locations of elementary school case study sites

These sites best serve the central question since they allow comparison across geographies, vegetation prevalence, built form, and whether the Green Schools for All goal has been reached.

Table 2. Case Study Site Characteristics

Campus	Category	Location	Cal-Enviro-Screen Percent-age	Area	Lot Coverage	Mean NDVI	Enrolled	LAUSD Region	Year Built
Halldale Elementary Figure 6	Low lot coverage, low NDVI	Torrance	8 5.4	27,070.1 sq. m	17.30%	0.03	446 students	South	1947
Ninth Street Elementary School Figure 5	High lot coverage, low NDVI	Downtown Los Angeles	99.7	12,435.0 sq. m	62%	0.03	300 students	East	1890, recon-structed in 2010-2013
Rosa Parks Learning Center Figure 4	Low lot coverage, high NDVI	North Hills	93.6	27,228.5 sq. m	16.60%	0.18	518 students	North	2005
Danny J. Bakewell, Sr. Primary Center Figure 7	High lot coverage, high NDVI	South Los Angeles	95.3	6,099.7 sq. m	40.70%	0.1	173 students	South	2005

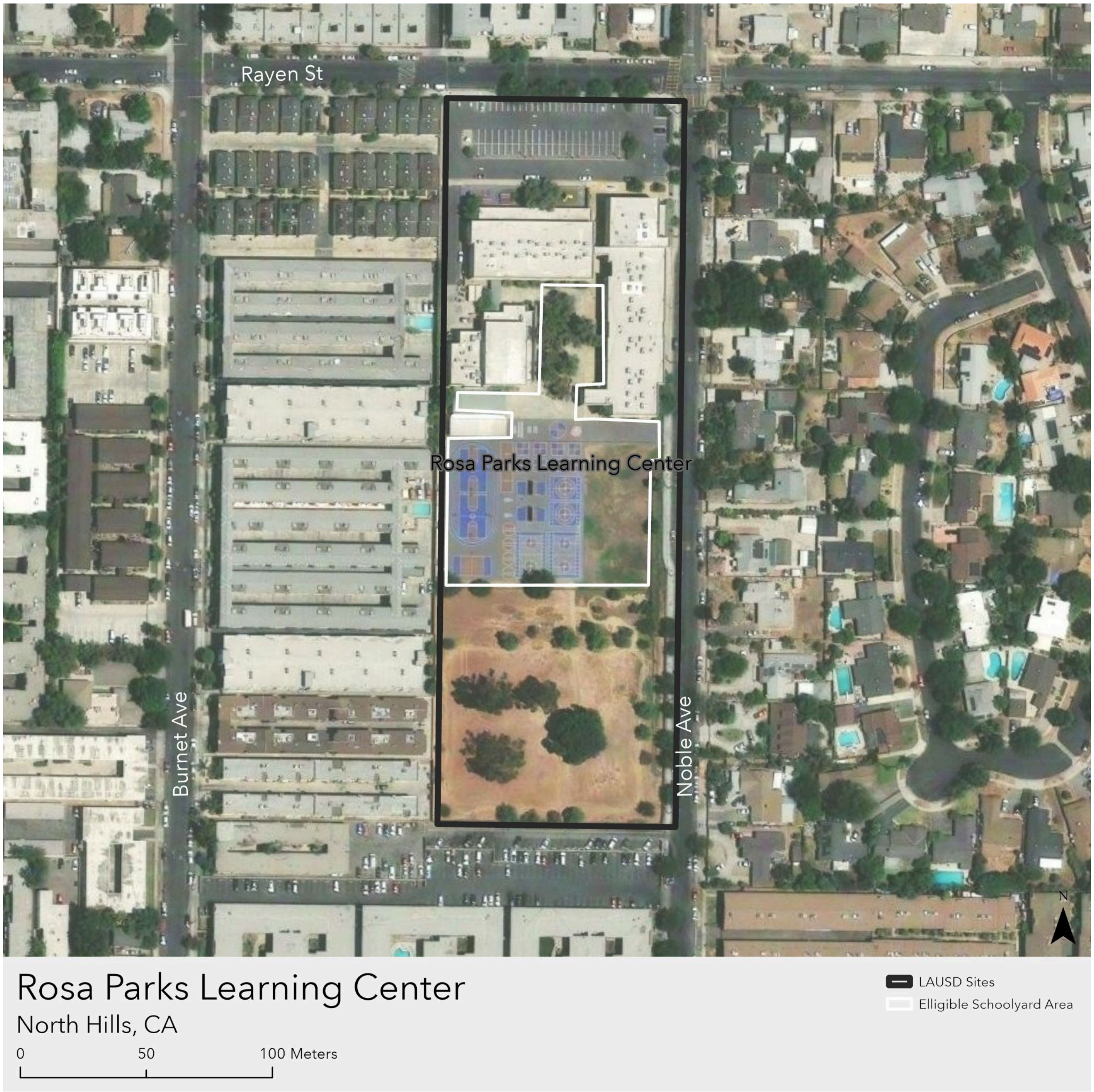

Figure 4. Rosa Parks Learning Center context map.

Figure 5. Ninth Street Elementary context map.

Figure 6. Halldale Elementary context map.

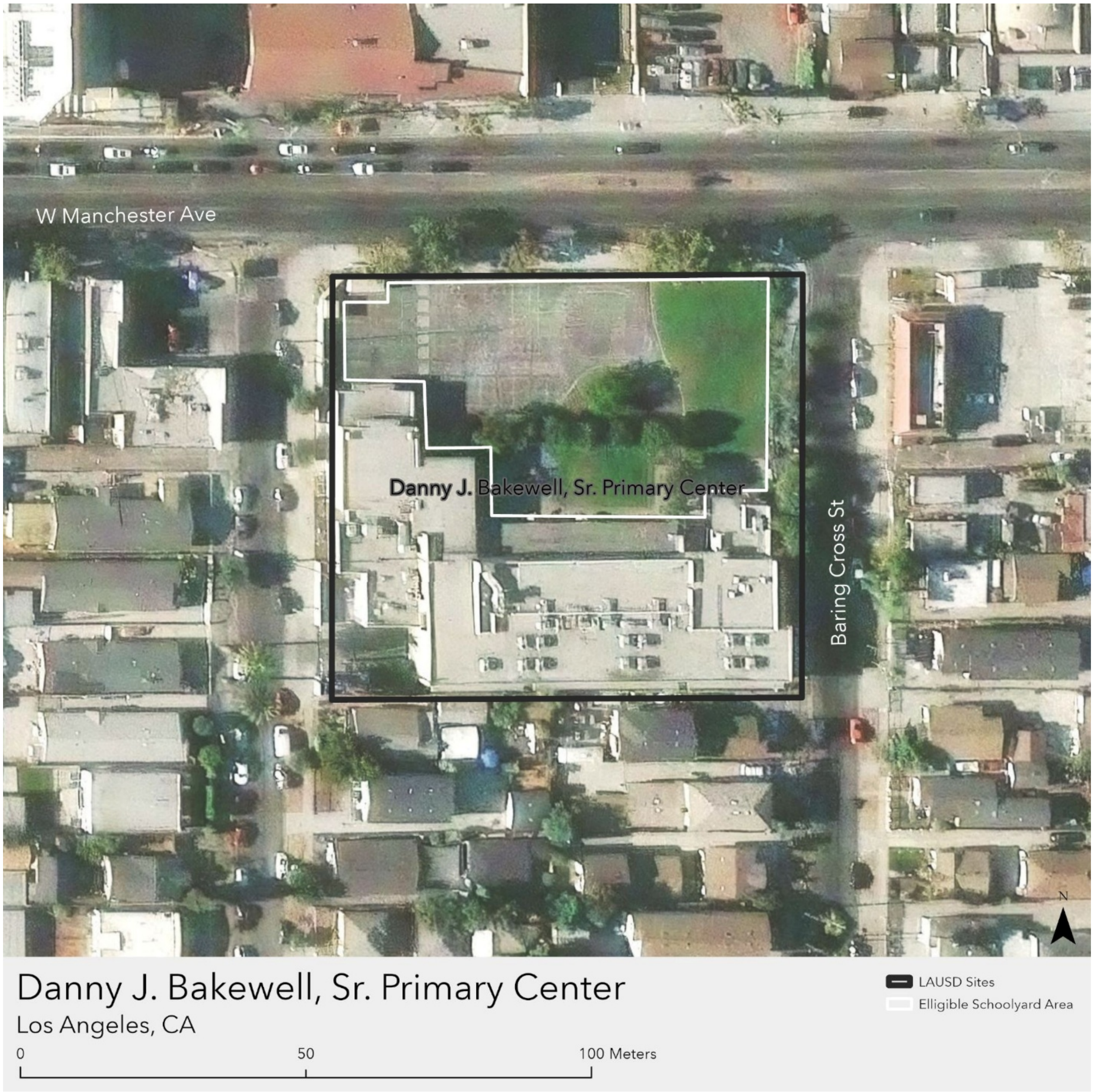

Figure 7. Danny J. Bakewell, Sr. Primary Center context map.

Analysis

Following the site selection, I first analyzed the existing conditions of each site to quantify greenspace as defined by the Green Schools for All goal. This provided a baseline understanding of where each campus sat relative to the Goal, which defined 'greening' quite broadly.

Building the results from the existing conditions analysis, I modeled the existing thermal conditions on the hottest day of the 2025-2026 school year using the SOLWEIG environmental model. This phase allowed for a comparison between campuses that had reached the goal versus those that had not, providing insight into whether reaching the goal was a reliable indicator of thermal safety.

The final phase of this study examines the potential impacts to on-campus heat if *Green Schools for All*'s definition of greening was narrowed to just tree canopy, refining the goal to require playgrounds to have at least 30% canopy coverage. Shade is widely accepted to be the most effective design intervention against heat (Middel et al., 2021). Shade on schoolyards in particular increases physical activity and safety, protecting children from heat exposure and dangerous UV rays (Antoniadis, 2020). Schools are often designed to have large areas with a SVF of greater than .7, indicating a general lack of built shade on playgrounds (Anatoniadis, 2020). Shade sails or trees can be installed on a playground post-construction to provide shade. However, shade from trees produces additional benefits including shelter, moisture, outdoor education, ecosystem services, support for fauna and insect species, and air filtration (Anatoniadis, 2020, Gamson, 2010). As such, I modeled the existing campus conditions, with added trees to bring each campus up to 30% canopy coverage. Trees were placed in the hottest parts of campus (based on the existing conditions model simulation), avoiding playground equipment and ball courts, to represent a best case scenario hypothetical.

After attaining both the existing conditions and canopy scenario model results, I converted the values into the Universal Thermal Climate Index (UTCI), which provided a 'feels like' temperature reading throughout campus. UTCI temperatures are grouped by heat stress, which can be used to indicate if a space is 'usable' (no to moderate heat stress) or 'not usable' (strong, very strong, and severe heat stress). Using UTCI, I assessed how much of each schoolyard was usable to children in the existing conditions scenario and the canopy scenario.

Taken together, these analysis steps directly answer the question regarding Green Schools for All's effectiveness and provide insight into the policy's limitations and potential improvements. See subsequent sections for technical methodology.

Key Terms and Metrics

Measuring Heat

Air temperature alone is insufficient at capturing outdoor thermal comfort as experienced by humans (Holst and Mayer, 2011). Instead, a human's experience in heat is a conglomeration of air temperature, radiation fluxes, humidity, wind speed, and personal factors (Antoniadis, 2020). These factors are reflected in many indices for human comfort which weigh parameters and provide a value measuring thermal stress reflecting the urban environment (Holst and Mayer, 2011). This study utilizes the Universal Thermal Climate Index (UTCI), a widely used index of human thermal stress (Antoniadis, 2020). UTCI requires the inputs air temperature, relative humidity, wind speed, and mean radiant temperature. These variables are entered into a 6th degree polynomial regression accounting for physiological effects such as metabolic heat production, sweat evaporation, skin blood flow, convective heat loss (for example, due to wind), respiration, and radiation with surroundings. The result is a numeric value measured in degrees Celsius which represents "the air temperature (Ta) of the reference condition causing the same model response as actual conditions" (Błażejczyk et al., 2013). In other words, air temperature could be 30°C, but with consideration of one's physical surroundings, the physiological experience of heat, and additional meteorological factors, it could actually feel much higher.

UTCI requires meteorological variables collected at weather stations as well as mean radiant temperature. The ISO defines Mean Radiant Temperature (Tmrt) as "the uniform temperature of an imaginary enclosure in which radiant heat transfer from the human body is equal to the radiant heat transfer in the actual non-uniform enclosure" (International Organization for Standardization, 1998), or the average temperature of everything around a person that is giving off heat, including the sun, pavement, walls, and buildings. Tmrt is a critical determinant of outdoor heat exposure highly sensitive to urban design and built form. Tmrt reflects how heat is enhanced or mitigated by one's surroundings and captures micro-scale variations in sky view factor, shortwave radiation from the sun and reflected from surrounding surfaces, longwave radiation emitted from surfaces, proximity to water, and the evapotranspirative effect of vegetation.

Tmrt is a critical input of UTCI. As such, this study first employs environmental modeling to calculate Tmrt across school sites, then combines these outputs with meteorological parameters to calculate UTCI across school sites.

Modeling Heat with SOLWEIG

I used the environmental model Solar Longwave Environmental Irradiance Geometry (SOLWEIG) to conduct environmental simulations. SOLWEIG is a climate modeling tool designed to assess Tmrt in an urban setting. It simulates complex urban environments and the resulting fluxes in radiation by modeling long and shortwave radiation in six directions: upwards, downwards, and from the four cardinal points (Lindberg et al., 2008). The model requires spatial inputs, including a high resolution digital elevation model, landcover raster, and digital surface model showcasing urban form. The model also requires meteorological inputs including direct, diffuse, and shortwave radiation, air temperature, relative humidity, and wind speed (Antoniadis et al., 2020; Lindberg et al., 2008). SOLWEIG is an opensource model based in QGIS, allowing for many iterations. In addition to being opensource, SOLWEIG is effective: when compared with other models, SOLWEIG performs satisfactorily and can calculate Tmrt across an area, showing how it varies across a given space (Chen et al., 2014; Ka-Lun Lau et al., 2021). SOLWEIG results were processed and measured in GIS, which has been a useful tool for assessing spatial distribution of heat and social parameters for decades (Schulman and Peters 2007; Vescovi et al., 2005).

Data Collection

SOLWEIG requires spatial data representing urban form and geography. This data must be precise: all layers must have the exact same dimensions, cell sizes (I chose to use 3 US survey feet x 3 US survey feet), and projection. All units must be meters. This required a period of data collection and cleaning. The following layers were collected and altered for use in the following ways:

- Digital Elevation Models (DEMs) from NOAA Landsat Collection: I collected all digital elevation data within a 200 M buffer to ensure that neighborhood dynamics and surrounding form were reflected in the model. SOLWEIG requires DEMs to be in M above sea level. I mosaiced the relevant tiles together and ran a raster calculation to convert the DEM from feet to meters (values were already representative of elevation above sea level).
- Digital Surface Models (DSMs) from USGS Landsat California 1 B23: I exported all DSMs within a 200 M buffer. SOLWEIG requires the canopy DSM (CDSM) to be measured in M above ground level. To create the CDSM, I extracted DSM values within the boundaries of LA County's Authoritative tree canopy boundary layer and subtracted the DEM values from the cells. To create the building and ground DSM (BGDSM), I extracted DSM values within building footprints and applied these values to the ground DEM.

- Land Cover Rasters: Using Google Earth Imagery, I digitized each land cover type by hand according to SOLWEIG's land cover schema (1 = paved, 2 = buildings, 5 = grass/lawn, 6 = bare soil, and 7 = water). I then converted the resulting polygons to raster data.
- Wall Aspect and Wall Height were calculated within UMEP's preprocessor for all sites using the BGDSM.
- Sky View Factor was calculated within UMEP's preprocessor for all sites using the building and ground surface model and the canopy surface model.

Meteorological data for each site is also required. This data must include date and time of day (to assume the angle of the sun), precipitation, solar radiation, vapor, air temperature, relative humidity, dew point, wind speed, and soil temperature. Because Los Angeles' geography is highly varied, I gathered meteorological data from the National Oceanic and Atmospheric Administration National Weather Service (NOAA-NWS) weather stations closest to each campus, then converted it into units suitable for SOLWEIG (Fahrenheit to Celsius, wind mph to m/s). The values are shown in Table 3. Meteorological Parameters Input to SOLWEIG for each site (based on NOAA weather stations). The stations utilized are as follows:

- For Rosa Parks Learning Center (North Hills, CA), I used NOAA-NWS's Van Nuys Airport Weather Station (34.21250 °N, 118.49083°W).
- For Ninth Street Elementary School (Downtown Los Angeles, CA), I used NOAA-NWS's Downtown LA Weather Station (34.06778°N, 118.24167°W).
- For Halldale Elementary (Torrance, CA), I used NOAA-NWS's Torrance Zamperrini Airfield Weather Station (33.80°N, 118.33°W).
- For Danny J. Bakewell, Sr. Primary Center (South Los Angeles, CA), I used NOAA-NWS's LAX Weather Station (33.94°N, 118.38889°W).

Due to data access constraints, NOAA data was used for air temperature, wind speed, and relative humidity. Additional meteorological inputs, including global radiation, direct radiation, diffuse radiation, and wind sensor height, are unavailable for public access and therefore could not be included. Instead, these metrics were held at SOLWEIG's default value to minimize inaccuracies across campuses.

Table 3. Meteorological Parameters Input to SOLWEIG for each site (based on NOAA weather stations).

Campus	Time of Day	Air Temperature (°C)	Wind Speed (m/s)	Relative Humidity (%)
Halldale Elementary	8 AM	22.7	1.3	69.0
	2 PM	32.2	5.4	32.0
Ninth Street Elementary	8 AM	25.0	0.4	71.0
	2 PM	35.0	1.8	31.0
Rosa Parks Learning Center	8 AM	26.1	0.0	51.0
	2 PM	38.9	4.5	20.0
Danny J. Bakewell, Sr. Primary Center	8 AM	23.8	2.2	6.0
	2 PM	27.8	4.0	58.0

Data Analysis

Modeling Baseline Conditions

Next, I assessed the existing area considered ‘green’ according to the Green Schools for All Plan to understand current heat exposure on an extreme heat day on each campus to measure if the Green Schools for All greening threshold is a meaningful indicator of thermal safety. First, I digitized the area of eligible schoolyard for each campus. Eligible schoolyard according to the Green Schools for All Plan include “the exterior areas of the school site to which students have general, unrestricted, and secure access within the school fence line, including open space between permanent buildings wider than 20 feet” and does not include building footprints, narrow walkways between buildings, lunch shelters, fenced off areas, parking areas, nor frontages (LAUSD, 2024). Next, I digitized the area of existing greenspace compliant with the Green Schools for All Plan, which includes in-ground planting/trees, grass, dirt, decomposed granite, and permeable pavers (LAUSD, 2024). I then calculated the area for canopy greenspace, non-canopy greenspace, and combined total. In cases where canopy overlaid the lawn, I merged it into one to prevent overrepresenting the ‘green’ area.

With an understanding of existing greenspace and eligible schoolyard area, I ran SOLWEIG for all school sites. All simulations were run for August 22, 2025, the hottest day of the 2025-2026 school year. I ran each campus and simulation at two times: 8 AM and 2 PM, representing approximately the lowest and highest reported air temperatures across the sites on August 22, 2025.

I then used the Tmrt results from SOLWEIG to calculate UTCI using the pythermalcomfort python module (Tatarini, 2020). This operation required meteorological data and Tmrt rasters to output a raster of UTCI values portraying the variation in 'feels like' temperature across the sites.

In GIS, I analyzed the Tmrt and UTCI values for each site. I used the zonal statistics feature to calculate statistics for Tmrt per school site, capturing mean, median, range, and percentile values. I then analyzed the usable space for each site at 2 PM (the hottest part of the day) using UTCI as a proxy for usable space. I categorized each 3 ft x 3 ft cell in the UTCI rasters to reflect UTCI thresholds to then calculate the percent area per schoolyard within each UTCI category (Błażejczyk, 2010; Krüger, 2022):

1. UTCI Category 1 (no heat stress): <26°C
2. UTCI Category 2 (moderate heat stress): 26-32°C
3. UTCI Category 3 (strong heat stress): 32-38°C
4. UTCI Category 4 (very strong heat stress): 38-46°C
5. UTCI Category 5 (extreme heat stress): >46°C

For the purposes of this analysis, I considered space 'usable' if it was within UTCI category 1 or 2, indicating no or moderate heat stress. If a cell fell into the strong, very strong, or extreme heat stress categories, it is assumed that the thermal conditions are dangerous and the space represented by that cell is not usable for schoolyard activity.

UTCI values closely reflect Tmrt values. Tmrt reflects the combined radiation of all surfaces, essentially capturing the influence of the built form on thermal exposure. These spatial patterns are apparent even after converting Tmrt to UTCI. As such, usable cells appeared in clusters large enough to accommodate one or more children at play. There were no instances of scatter or of individual error cells. As such, no further steps were needed to ensure that each usable area was large enough to accommodate a child at play.

Modeling Scenario: Does prioritizing tree canopy produce more reliable outcomes?

To understand how narrowing the policy's broad definition of greening to just tree canopy coverage would serve children' s heat safety on the playground, I brought each campus to 30% canopy coverage and simulated the same heat day.

To determine the amount of canopy coverage needed to reach 30%, I calculated the area of existing canopy and existing percent coverage. Next, I determined the number of trees needed to bring each campus to 30%. Each simulated tree had a radius of 3 meters (therefore, a canopy coverage area of 305 square feet) and a height of 5 meters, representing a mature tree. I used the following formula, the results of which are shown in Table 4. Existing schoolyard and canopy and simulated canopy:

Let:

A = Eligible area of schoolyard (sq ft)

E = Existing canopy (sq ft)

For:

$$N = ((A \times 0.30) - E) \div 305$$

Table 4. Existing schoolyard and canopy and simulated canopy

Campus	Eligible Area of schoolyard (sq ft)	Existing Canopy (sq ft)	Existing Canopy %	Trees Added	New Canopy Added (sq ft)	Simulated Canopy %
Halldale Elementary	142,019.7	517.7	0.4%	138	42,090	30%
Ninth Street Elementary	57,489.4	2,689.8	4.7%	47	14,335	29.6%
Rosa Parks Learning Center	71,122.9	7,397	10.4%	46	14,030	30%
Danny J. Bakewell, Sr. Primary Center	26,942	2,302.5	8.5%	19	5,795	30%

With the formula results, I placed tree planting point locations on each playground. Plantings were placed on the hottest areas from the existing conditions study without blocking equipment, sports fields, or structures. This is in alignment with the Green School for All Plan, which states that greening- particularly shading- shall occur in areas where students are most active, particularly surrounding game courts (LAUSD, 2024). The resulting locations represented idealistic plantings in possible locations that would not hinder playground use. I buffered the point locations with a 3 m radius to create canopy, assigned a height value of 5 meters to the new simulated trees, and converted the polygons to raster. Existing green spaces and simulated canopy locations can be seen in Figure 8. Existing green space as defined by the Green Schools for All Goal and simulated canopy on each campus.I added the new raster to the existing CDSM, since the simulation *adds trees* to reach 30% canopy coverage. Finally, I reran SOLWEIG for each school, for 8 AM and 2 PM on August 22, 2025, with the new CDSM. All other data were held constant.

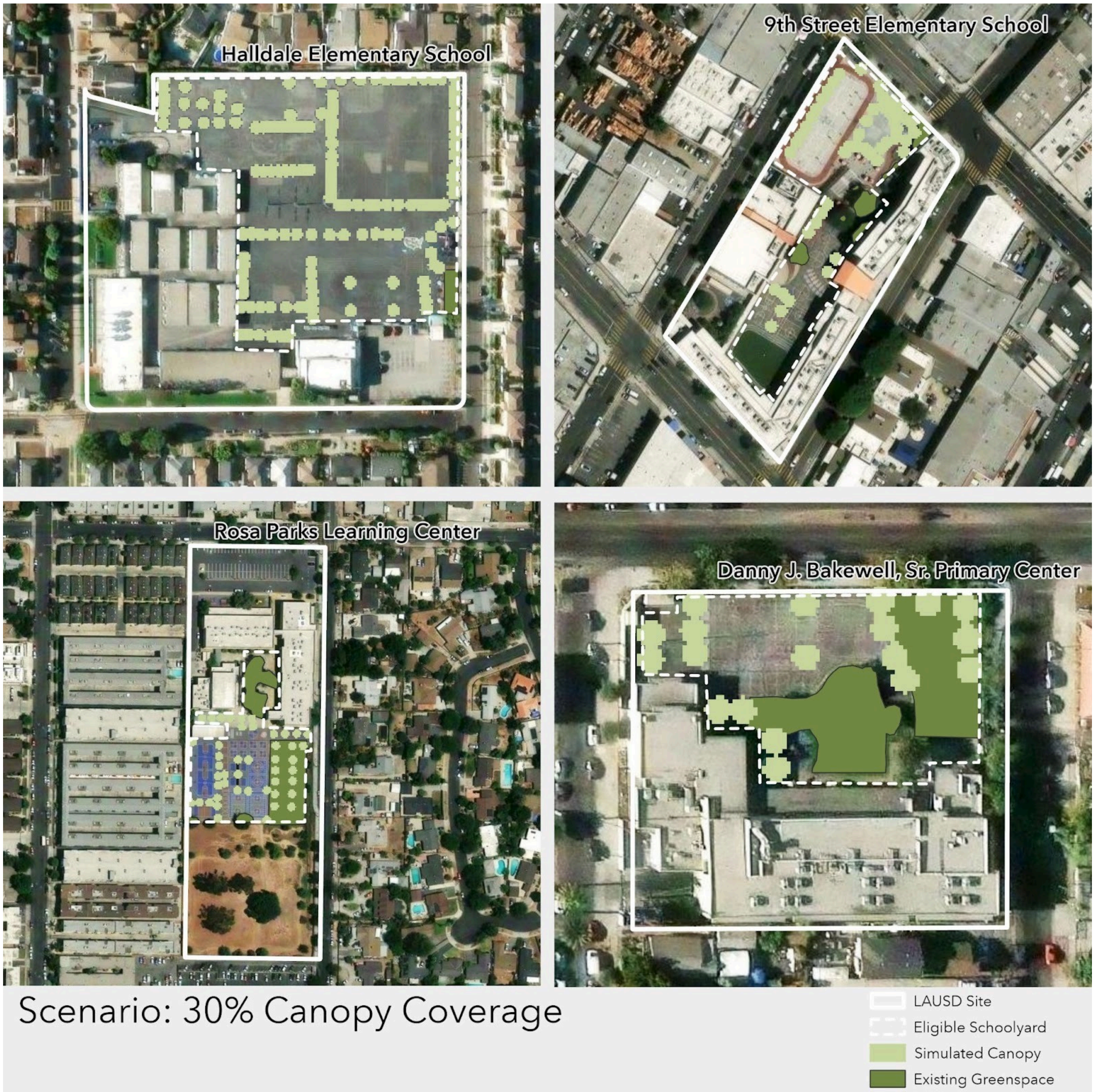

Figure 8. Existing green space as defined by the Green Schools for All Goal and simulated canopy on each campus.

I then replicated the steps I used in the existing conditions study to convert Tmrt to UTCI, calculate statistics for Tmrt and UTCI results, and calculate UTCI category areas.

RESULTS

Summary

Across the existing conditions simulations and canopy scenario simulations, Ninth Street Elementary (has not reached Green Schools for All Goal) and Rosa Parks Learning Center (has reached Green Schools for All Goal) tended to endure the hottest conditions, while Danny J. Bakewell, Sr. Primary Center (has reached Green Schools for All Goal) and Halldale Elementary (has not reached Green Schools for All Goal) tended to stay cooler. All schools experienced an increase in Tmrt and UTCI between 8 and 2 PM, although these diurnal increases varied widely across campuses. The subsequent sections outline the results of the individual analyses.

Existing Conditions: Greenspace, Canopy, and Schoolyard Area

The existing conditions analysis quantified each campus's progress towards the Green Schools for All Goal, as shown in Table 5.Existing greenspace and canopy per campus. Rosa Parks Learning Center and Danny J. Bakewell, Sr. Primary Center had over 30% 'green' space, demonstrating that both campuses have already reached the Green Schools for All Goal. Across all campuses, the majority of greenery was non-canopy and was instead primarily made up of lawn. None of the campuses had xeriscaping or decomposed granite, although these would have counted as 'green' under the Green Schools for All guidelines.

33.1% of Rosa Parks Learning Center's school yard is devoted to greenspace as defined by the Green Schools for All Plan documentation, and Danny J. Bakewell, Sr. Primary Center has 39.9%. In contrast, Ninth Street Elementary and Halldale Elementary did not reach the goal, having 6.0% and 1.0% green space respectively. Rosa Parks Learning Center had the highest canopy coverage at 10.4%, followed by Danny J. Bakewell, Sr. Primary Center (8.5%), Ninth Street Elementary (4.7%), and Halldale Elementary (0.4%).

Table 5.Existing greenspace and canopy per campus

Campus	Eligible Schoolyard Area	Existing eligible Greenspace Area (pct)	Has reached Green Schools for All Goal	Existing Non-Canopy Greenspace Area (pct)	Existing Canopy Area (pct)
Halldale Elementary	142,019.68 Sq ft or 3.26 Ac	1,452.8 Sq ft (1.0%)	No	1,450.6 Sq ft (1.0%)	517.7 Sq ft (0.4%)
Ninth Street Elementary	57,489.4 Sq ft or 1.32 Ac	3,423.4 Sq ft (6.0%)	No	1,191.1 Sq ft (2.1%)	2,689.8 Sq ft (4.7%)

Rosa Parks Learning Center	71,122.9 Sq ft or 1.63 Ac	23,530.4 Sq ft (33.1%)	Yes	16,133.4 Sq ft (22.7%)	7,397.0 Sq ft (10.4%)
Danny J. Bakewell. Sr. Primary Center	26,942.0 Sq ft or 0.62 Ac	10,738.7 Sq ft (39.9%)	Yes	10,323.4 Sq ft (38.3%)	2,302.5 Sq ft (8.5%)

Existing Conditions: Radiant Temperature, UTCI, and Useable Space

The 8 AM existing conditions model demonstrated Tmrt across campuses at the coolest daytime hour on the hottest day of the year. Early in the morning, we see relatively little variation between campuses. For the 8 AM existing conditions model, Danny J. Bakewell had the lowest average schoolyard Tmrt at 53.5°C, followed by Halldale Elementary at 57.1°C, then Ninth Street Elementary at 59.0°C and Rosa Parks Learning Center at 59.1°C. These results are seen in Table 6. Existing Conditions: Tmrt at 8 AM on August 22, 2025. All measurements are in degrees Celsius.

By 2 PM, the hottest time of day on the hottest day of the school year, we begin to see variation, with diurnal increases in Tmrt differing sharply across campuses. As seen in Table 6. Existing Conditions: Tmrt at 8 AM on August 22, 2025. All measurements are in degrees Celsius., Danny J. Bakewell, Sr. Primary Center again had the lowest average schoolyard Tmrt at 57.2°C, a 6.4°C increase from 8AM. Halldale Elementary had an average 2 PM schoolyard Tmrt of 65.5°C, an increase of 8.7°C. Rosa Parks Learning Center had an average schoolyard Tmrt of 65.9°C, representing an increase of 11.9°C. Finally, Ninth Street Elementary had an average schoolyard Tmrt of 67.4°C, a 15.5°C increase from 8 AM. The diurnal increases in average and median Tmrt can be seen in Table 8. Existing Conditions: Summary of increase in Average TMRT from 8 Am to 2 PM. All measurements are in degrees Celsius. and Table 9. Existing Conditions: Summary of increase in Median TMRT from 8 Am to 2 PM. All measurements are in degrees Celsius., respectively.

UTCI calculations for 2 PM demonstrate the ‘feels like’ temperature at the hottest time of the day. None of the campuses had any area that fell into the ‘no heat stress’ category, which is to be expected on the hottest day of the school year. However, over a third of Danny J. Bakewell, Sr. Primary Center was still usable, with 39.31% of its area in the ‘moderate heat stress’ category and the rest of the schoolyard falling into the ‘strong heat stress’ category. Halldale Elementary’s schoolyard was almost entirely (99.69%) in the ‘strong heat stress’ category. Both Ninth Street Elementary (95.79%) and Rosa Parks Learning Center (99.99%) were almost entirely in the ‘very strong heat stress’ category. UTCI results are in Table 10. Existing Conditions: UTCI categories at 2 PM on August 22, 2025..

Table 6. Existing Conditions: Tmrt at 8 AM on August 22, 2025. All measurements are in degrees Celsius.

Campus	Min - max Tmrt (range)	Median	Mean	Standard deviation	25th percentile	75th percentile
Halldale Elementary	24.6° - 58.9° (34.3°)	57.1°	56.8°	2.9°	57.07°	57.07°
Ninth Street Elementary	24.8° - 61.5° (36.7°)	59.0°	51.9°	2.9°	58.1°	59.1°
Rosa Parks Learning Center	25.8° - 61.2° (35.4°)	59.1°	54.0°	10.4°	55.8°	59.2°
Danny J. Bakewell, Sr. Primary Center	21.6° - 59.1° (37.4°)	53.5°	50.8°	8.4°	51.6°	54.9°

Table 7. Existing Conditions: Tmrt at 2 PM on August 22, 2025. All measurements are in degrees Celsius.

Campus	Min - max Tmrt (range)	Median	Mean	Standard deviation	25th percentile	75th percentile
Halldale Elementary	39.5° - 69.0° (29.5°)	65.6°	65.5°	1.3°	65.6°	65.6°
Ninth Street Elementary	36.8° - 73.4° (36.5°)	68.3°	67.4°	5.2°	68.1°	68.3°
Rosa Parks Learning Center	40.3° - 75.7° (35.4°)	70.4°	65.9°	7.9°	62.4°	70.5°
Danny J. Bakewell, Sr. Primary Center	32.2° - 64.8° (32.7°)	56.5°	57.2°	7.5°	55.0°	63.1°

Table 8. Existing Conditions: Summary of increase in Average TMRT from 8 Am to 2 PM. All measurements are in degrees Celsius.

Campus	8 AM	2 PM	Jump
Halldale Elementary	56.8°	65.5°	+8.7°
Ninth Street Elementary	51.9°	67.4°	+15.5°
Rosa Parks Center	54.0°	65.9°	+11.9°

Danny J. Bakewell, Sr. Primary Center	50.8°	57.2°	+6.4°

Table 9. Existing Conditions: Summary of increase in Median TMRT from 8 Am to 2 PM. All measurements are in degrees Celsius.

Campus	8 AM	2 PM	Jump
Halldale Elementary	57.1°	65.6°	+8.5°
Ninth Street Elementary	59.0°	68.3°	+9.3°
Rosa Parks Learning Center	59.1°	70.4°	+11.3°
Danny J. Bakewell, Sr. Primary Center	53.5°	56.5°	+3.1°

Table 10. Existing Conditions: UTCI categories at 2 PM on August 22, 2025.

Campus	UTCI -1 (No stress)	UTCI -2 (moderate stress)	UTCI -3 (strong heat stress)	UTCI -4 (very strong heat stress)	UTCI -5 (extreme heat stress)
Halldale Elementary	0.00%	0.31%	99.69%	0.00%	0.00%
Ninth Street Elementary	0.00%	0.00%	4.21%	95.79%	0.00%
Rosa Parks Learning Center	0.00%	0.00%	0.00%	99.99%	0.01%
Danny J. Bakewell, Sr. Primary Center	0.00%	39.31%	60.69%	0.00%	0.00%

Canopy Simulations: Mean Radiant Temperature, UTCI, and Useable Space

The results from the canopy simulation models indicate that while canopy can increase usable space, its success still varies widely across campuses.

Similar to the existing conditions analysis, the 8 AM canopy simulation models demonstrate little variation across campuses at the coolest time of day. Danny J. Bakewell, Sr. Primary Center had the lowest average schoolyard Tmrt at 44.4° C, followed by Ninth Street Elementary and Rosa Parks Elementary at 44.7°C, then Halldale Elementary at 47.5°C. These results are in Table 11. Canopy Simulation: Tmrt at 8 AM on August 22, 2025. All measurements are in degrees Celsius.

Despite bringing all campuses to the same level of canopy coverage, the 2PM canopy scenario models, captured in Table 12. Canopy Simulation: Tmrt at 2 PM on August

22, 2025. All measurements are in degrees Celsius., still demonstrated sharp variations in Tmrt and diurnal Tmrt variations. The diurnal increases in average and median Tmrt for the canopy simulation model can be seen in Table 13. Canopy Simulation: Summary of increase in Average TMRT from 8 AM to 2 PM. All measurements are in degrees Celsius. and Table 14. Canopy Simulation: Summary of increase in Median TMRT from 8 Am to 2 PM. All measurements are in degrees Celsius., respectively. Danny J. Bakewell, Sr. Primary Center again had the lowest average schoolyard Tmrt at 53.2°C, an 8.8°C increase from 8AM. Halldale Elementary had an average 2 PM schoolyard Tmrt of 60.0°C, an increase of 12.5°C. Ninth Street Elementary had an average schoolyard Tmrt of 62.0°C, representing an increase of 17.3°C. Finally, Rosa Parks Elementary had an average schoolyard Tmrt of 62.1°C, a 17.4°C increase from 8 AM.

Between the existing conditions and canopy simulation models, average schoolyard Tmrt decreased on all campuses. Between the 2 PM existing conditions and canopy scenario simulations, Halldale Elementary's average schoolyard Tmrt decreased by 5.5°C, Ninth Street Elementary's by 5.4°C, Rosa Parks by 3.8°C, and Danny J Bakewell by 4.0°C, as captured in Table 15. Average Tmrt at 2 PM on August 22,2025: Existing conditions vs. Canopy Simulation. All measurements are in degrees Celsius..

Converting the canopy simulation values into UTCI further emphasizes the varied results canopy had on the campus' thermal conditions, as shown in Table 17. Canopy Simulation: UTCI categories at 2PM on August 22, 2025.. Despite increasing canopy coverage across all campuses, still none of the campuses had any area that fell into the 'no heat stress' category. However, usable space increased in some cases. Danny J. Bakewell Sr. Primary Center's area in the 'moderate heat stress' category increased to 48.62%, leaving an additional 51.38% in the 'strong heat stress' category. Halldale Elementary's area in the 'moderate heat stress' category increased to 22.95%. Improvements in UTCI occurred at Ninth Street Elementary as well; however, conditions on this campus were so severe that the improvements still did not result in an increase of usable space: the area in the 'strong heat stress' category increased to 24.86%, with the remaining area remaining in the 'very strong heat stress' category. Finally, Rosa Parks Elementary saw a very slight increase in area in the extreme heat category, making it the only campus to experience an increase in UTCI category between existing conditions and canopy simulations. Change in UTCI Category between Existing Conditions vs. Canopy Simulation can be seen in Table 18. Change in UTCI Category between Existing Conditions vs. Canopy Simulation..

Table 11. Canopy Simulation: Tmrt at 8 AM on August 22, 2025. All measurements are in degrees Celsius.

Campus	Min - max Mrt (range)	Median	Mean	Standard deviation	25th percentile	75th percentile

Halldale Elementary	24.4° - 59.5° (35.1°)	56.9°	47.5°	14.1°	27.9°	57.1°
Ninth Street Elementary	24.8° - 61.6° (36.8°)	58.2°	44.7°	15.7°	28.0°	59.1°
Rosa Parks Learning Center	25.8° - 62.3° (36.4°)	56.0°	44.7°	15.7°	29.9°	59.1°
Danny J. Bakewell, Sr. Primary Center	21.5° - 59.9° (38.4°)	52.1°	44.4°	13.5°	28.0°	55.0°

Table 12. Canopy Simulation: Tmrt at 2 PM on August 22, 2025. All measurements are in degrees Celsius.

Campus	Min - max Tmrt (range)	Median	Mean	Standard deviation	25th percentile	75th percentile
Halldale Elementary	34.9° - 71.1° (36.2°)	65.3°	60.0°	10.5°	64.4°	65.7°
Ninth Street Elementary	36.7° - 74.3° (37.6°)	68.3°	62.0°	12.1°	66.6°	68.8°
Rosa Parks Learning Center	41.1° - 76.6° (35.5°)	69.5°	62.1°	10.8°	62.4°	70.5°
Danny J. Bakewell, Sr. Primary Center	32.5° - 66.4° (34.0°)	55.5°	53.2°	10.9°	39.0°	62.6°

Table 13. Canopy Simulation: Summary of increase in Average TMRT from 8 AM to 2 PM. All measurements are in degrees Celsius.

Campus	8 AM	2 PM	Jump
Halldale Elementary	47.5°	60.0°	+12.5°
Ninth Street Elementary	44.7°	62.0°	+17.3°
Rosa Parks Learning Center	44.7°	62.1°	+17.4°
Danny J. Bakewell, Sr. Primary Center	44.4°	53.2°	+8.8°

Table 14. Canopy Simulation: Summary of increase in Median TMRT from 8 Am to 2 PM. All measurements are in degrees Celsius.

Campus	8 AM	2 PM	Jump
Halldale Elementary	56.9°	65.3°	+8.4°
Ninth Street Elementary	58.2°	68.3°	+10.1°
Rosa Parks Learning Center	56.0°	69.5°	+13.5°
Danny J. Bakewell, Sr. Primary Center	52.1°	55.5°	+3.4°

Table 15. Average Tmrt at 2 PM on August 22,2025: Existing conditions vs. Canopy Simulation. All measurements are in degrees Celsius.

Campus	Existing Mean	Simulated Mean	Reduction
Halldale Elementary	65.5°	60.0°	−5.5°
Ninth Street Elementary	67.4°	62.0	−5.4°
Rosa Parks Learning Center	65.9°	62.1°	−3.8°
Danny J. Bakewell, Sr. Primary Center	57.2°	53.2°	−4.0°

Table 16. Median Tmrt at 2 PM on August 22,2025: Existing conditions vs. Canopy Simulation. All measurements are in degrees Celsius.

Campus	Existing Median	Simulated Median	Reduction
Halldale Elementary	65.6°	65.3°	−0.3°
Ninth Street Elementary	68.3°	68.3°	-0.0°
Rosa Parks Learning Center	70.4°	69.5°	-0.9°

Danny J. Bakewell, Sr. Primary Center	56.5°	55.5°	-1.0°

Table 17. Canopy Simulation: UTCI categories at 2PM on August 22, 2025.

Campus	**UTCI -1 (No stress)**	**UTCI -2 (moderate stress)**	**UTCI -3 (strong heat stress)**	**UTCI -4 (very strong heat stress)**	**UTCI -5 (extreme heat stress)**
Halldale Elementary	0.00%	22.95%	77.05%	0.00%	0.00%
Ninth Street Elementary	0.00%	0.00%	24.86%	75.14%	0.00%
Rosa Parks Learning Center	0.00%	0.00%	0.00%	99.77%	0.23%
Danny J. Bakewell, Sr. Primary Center	0.00%	48.62%	51.38%	0.00%	0.00%

Table 18. Change in UTCI Category between Existing Conditions vs. Canopy Simulation.

Campus	**UTCI -1 (No stress)**	**UTCI -2 (moderate stress)**	**UTCI -3 (strong heat stress)**	**UTCI -4 (very strong heat stress)**	**UTCI -5 (extreme heat stress)**
Halldale Elementary	0.00%	+22.64%	−22.64%	0.00%	0.00%
Ninth Street Elementary	0.00%	0.00%	+20.65%	−20.65%	0.00%
Rosa Parks Learning Center	0.00%	0.00%	0.00%	−0.22%	+0.22%
Danny J. Bakewell, Sr. Primary Center	0.00%	+9.31%	−9.31%	0.00%	0.00%

DISCUSSION

Demonstrated Performance of the Green Schools for All Goal + The Influence of Geographic Context

Literature agrees that typical schoolyard design lends itself to overheated campuses, putting children at an elevated risk (Antoniadis, 2015; Antoniadis, 2020; Schulman, 2008; Vanos 2015). As playgrounds typically comprise 60-70% of a school campus (Schulman, 2008) and provide vital social, physical, and emotional services to children, literature agrees that ensuring thermal safety on the playground is a necessary component of playground design and school management (Anderson et al., 2022; Vanos, 2015; Vecellio et al., 2022). LAUSD's Green Schools for All plan aligns with this understanding, seeking to provide outdoor, design-based relief to children on the playground. Theoretically, achieving this goal would make recess safer on hot days, while reducing the reliance on faulty HVAC systems.

The results of this study indicate that the Green Schools for All Plan creates inconsistent results and does not reliably predict thermal safety. Across different regions, schools had very different thermal experiences despite having similar levels of greening. Rosa Parks Elementary reached the goal with 33.1% of eligible schoolyard space 'green'. So did Danny J. Bakewell, Sr. Primary Center, which is 39.9% 'green'. However, geography created extremely different conditions between the two schools. Rosa Parks Elementary is in North Hills, CA, situated in the San Fernando Valley. The Santa Monica Mountains sit between North Hills and the Pacific Ocean and create a mountain barrier blocking a cool coastal breeze. To the northeast and northwest sit the San Gabriel and Santa Susana Mountains respectively, which enclose the valley. This topography traps hot air, a phenomenon further worsened by the extensive urbanization and lack of large-scale vegetation in the Valley. On August 22, 2025- the day of this study- Rosa Parks Elementary had an air temperature of 102°F (38.9°C) at 2 PM. In contrast, Danny J. Bakewell, Sr. Primary Center is located in South Los Angeles, CA, just east of Inglewood. Without any dramatic topographic features preventing ocean air from the Pacific, South Los Angeles is naturally cooler than the Valley despite heavy urbanization and lack of vegetation. On August 22, 2025, Danny J. Bakewell, Sr. Primary Center had a 2 PM air temperature of 82°F (27.8°C), 20°F cooler than Rosa Parks Elementary.

The divergence in regional climatic conditions was reflected in the schools' modeled existing thermal experiences, as shown in FiguresFigure 9. Existing Conditions: Tmrt at 8 AM across all four sites, in degrees Celsius. andFigure 10. Existing Conditions: Tmrt at 2 PM across all four sites, in degrees Celsius. Despite both reaching the Green Schools for All Goal, Danny J. Bakewell, Sr. and Rosa Parks had vastly different thermal experiences. Rosa Parks had a schoolyard median Tmrt of 70.4°C, the highest of any of the study sites, while Danny J. Bakewell, Sr. had a schoolyard median Tmrt of 56.5°C, the lowest of any study site. When converted to UTCI, Rosa Parks again had the hottest results, with 99.99% of its area in the 'very strong heat stress' category (category 4). Rosa Parks' results were extremely similar to Ninth Street Elementary's schoolyard, which was only

6% ‘green’. Danny J. Bakewell, Sr. had nearly 40% of its schoolyard area in the ‘moderate heat stress’ category (category 2), making it the most thermally comfortable campus studied. These results indicate there is a threshold baseline condition beyond which interventions are not capable of providing meaningful cooling; if local climatic conditions are severe enough, greening will not reliably contribute to usable space.

The canopy scenario effectively equalized greening across all campuses, with all schools having the same amount of canopy coverage (30%). In the absence of confounding factors, the canopies should have created similar microclimates across the four campuses. However, geography also played a primary role in the success of the 30% canopy coverage scenario. Shade is widely accepted to be the most effective landscape design intervention against mitigating heat (Johanson, 2006; Joshi, 2024; Vanos, 2015; Vanos, 2017; Vecellio et al., 2022). Even so, certain campuses had such extreme existing conditions that even narrowing the definition ‘greening’ to the most reliable form of heat mitigation could not ensure thermal safety or comfort. Rosa Parks Elementary had reached the Green Schools for All goal as ‘greening’ is defined in the Green Schools for All plan. However, it only had 10.4% canopy coverage. Increasing it to 30% brought no improvement in UTCI category; in fact, Rosa Parks experienced a slight increase in UTCI (likely due to a decrease in air flow). Ninth Street Elementary experienced a reduction in UTCI in 20.7% of its area, but existing conditions were so extreme that the improved cells were only considered “strong heat stress” (category 3) rather than ‘very strong heat stress’ (category 4). Once again, we see that design-based interventions have limits past a certain heat threshold.

Halldale Elementary and Danny J. Bakewell, Sr. Primary Center, the two campuses with cooler geographies, both experienced effective reductions in UTCI with the canopy simulation. Since existing conditions on these two campuses were more favorable, their reduction occurred between ‘strong heat stress’ (category 3) to ‘moderate heat stress’ (category 2). Due to an existing geographical and climatic advantage, canopy was effective at creating pockets of moderately comfortable conditions scattered throughout the schoolyards. Even in the best-case scenario (canopy), geographical conditions limit the effectiveness of design-based heat mitigation. This supports the larger finding that the success of microclimate interventions is impacted by the macrocontext and regional variation, in addition to small scale features. See existing UTCI in Figure 11. Existing Conditions: UTCI results at 2 PM..

These results, which emphasize regional and climatic variation’s influence on small scale interventions’ effectiveness, raise questions about the applicability of a subjective threshold for schoolyard heat safety. LAUSD spans 700 square miles. Their jurisdiction comprises diverse urbanization patterns, topography, and climatic systems. Furthermore, LAUSD oversees 800 unique campuses. Even within an n of 4, this study revealed dramatic variations in baseline conditions. Narrowing the definition of ‘greening’ to a demonstrably effective mode of cooling and targeting plantings to the hottest areas of campus had varied results across sites. The success of the canopy scenario simulation largely depended on how extreme baseline climatic conditions were.

When considering the site, urban planners, designers, and policy makers must also consider the broader context in which the site exists. This study attempted to examine microvariations at the site-scale, which can offer more insight into how individuals experience a space (Vanos, 2015). However, it revealed that the sites had vastly different starting points, which ultimately resulted in entirely different results even after normalizing 'greening' across all campuses. City-scale variations in topography, natural areas, and proximity to the ocean can create vastly different climatic conditions within a city (Brown et al., 2015; Ka-Lun Lau et al., 2021; Johannson, 2006; Joshi, 2024; Wong, 2016). This study, in an effort to examine site-scale variations, ultimately emphasized the significance of considering the city-scale in tandem with the site scale, as neither can stand alone. This is especially true in a policy area as large and diverse as LAUSD's jurisdiction, with hundreds of unique sites.

Shade Widens Diurnal Variation in Temperature

In addition to geography, time also played a huge role in heat stress across campuses. Current policy recommends that administrators cut school days short if heat is severe, a problem that the Green Schools for All Goal seeks to alleviate (Dale and Brenneman, 2024). By that logic, design-based interventions should alleviate heat at the hottest part of the day (which would otherwise be cut from school hours). As such, I compare the applicability of Green Schools for All in alleviating the diurnal temperature variation, or the natural changes in temperature between the coolest and hottest part of the day.

Across the existing conditions and canopy simulations, all schools experienced an increase in temperature throughout the day, aligning with the literature and common sense expectation that midday is hotter than early morning. This jump is visible in Tables 8 and 13 and by comparing FiguresFigure 9. Existing Conditions: Tmrt at 8 AM across all four sites, in degrees Celsius. andFigure 10. Existing Conditions: Tmrt at 2 PM across all four sites, in degrees Celsius.

In the existing conditions model, Danny J. Bakewell, Sr. Primary Center saw the smallest diurnal jump in median Tmrt, experiencing an increase of only 3.1°C throughout the day. Rosa Parks, on the other hand, saw the largest diurnal variation in median Tmrt- 11.3°C. This aligns with the literature regarding geographic variations in diurnal temperature variations. Valleys typically experience high diurnal temperature variation. At nighttime, cold air from the surrounding high elevation mountains sinks into the valley, bringing about cold morning temperatures. In daytime, the limited airflow and reduced access to coastal breeze heats the valley, resulting in larger diurnal swings than other, non-valley areas (John et al., 2024).

The diurnal variation grew across all campuses with the canopy scenario simulation. This is visible in Table 14. Canopy Simulation: Summary of increase in Median TMRT from 8 Am to 2 PM. All measurements are in degrees Celsius. and by comparing

Figures 9 and 10. Danny J. Bakewell, Sr. Primary Center saw only a modest difference, with a canopy scenario diurnal variation of 3.4°C. Again, Rosa Parks saw the largest diurnal variation, with an increase of 13.5°C. This increase in diurnal variation can best be explained by the differences in canopy's cooling power across daytimes. Median Tmrt values at 2 PM saw little overall reductions, while most reduction occurred in median Tmrt values at 8 AM, thereby widening the gap between 8 AM and 2 PM temperatures. In other words, in the canopy simulation model, morning cooling outpaced afternoon cooling. This is likely because at 8 AM, the simulated trees cast longer shadows, shading a larger region of the school yard. This adds to the literature assessing the effectiveness of individual design interventions by demonstrating that the performance of individual interventions depends also on the time of assessment.

The Site Scale Microclimate: Existing Conditions and Simulation

Zooming in to the microscale, the results demonstrate the vastly different hyperlocal benefits that arise from generic thresholds with broadly defined 'greening' versus targeted shading, highlighting the need for nuanced, individualized design guidelines which prioritize shade.

Halldale Elementary in Torrance is the closest site to the ocean. Geographically speaking, it benefits from a coastal breeze and delayed heating from a late Summer marine layer which blocks sunlight for several hours in the morning. Ninth Street Elementary in Downtown LA, on the other hand, is quite far from the Pacific - too far to significantly benefit from an ocean breeze. Their air temperatures, which are more indicative of geography than microclimate (Antoniadis, 2020; Holst and Mayer, 2011), reflect this - Halldale Elementary had an 8 AM air temperature of 22.7°C (72.3°F) and a 2 PM air temperature of 32.2°C (90.0°) while Ninth Street Elementary had an 8 AM air temperature of 25.0°C (77° F) and a 2 PM air temperature of 35.0°C (95°F). Despite this, Halldale had a higher average Tmrt at 8 am (56.8°C as opposed to 51.9°C). Halldale and Ninth St's 2PM averages were quite similar (Halldale had a 2 PM average Tmrt of 65.5°C, while Ninth St Elementary had a 2 PM average Tmrt of 67.4°C).

This geographically unexpected result emphasizes the importance of the built form. At 8 AM, shadows are long. Despite having a warmer air temperature, the building coverage at Ninth Street Elementary, which nearly completely covers the perimeter of the schoolyard, cast long shadows over the schoolyard. Halldale had very few structures casting shadows at 8 AM. Further, the sun rises in the east, so all shadows that did occur shaded the west side of buildings. The schoolyard is situated primarily east of the buildings, so it did not receive even minimal building shading at 8 AM. By 2 PM, when the sun is mostly overhead but slightly to the west, we see that this shading effect has been reduced. The buildings at Ninth Street are less able to provide shade due to the angle of the sun. Here, we see the effect of Ninth Street Elementary's vegetation. Ninth Street had limited vegetation - only 6.0% of the schoolyard - but it combines with the limited building shadows at 2 PM to create pockets of cooler areas. Halldale, in contrast, experiences the shade from only one tree in the southeast corner of campus. Other than that, the wide expanse of asphalt absorbs direct sunlight readily. So, even though air temperatures may suggest otherwise, the microclimate at Halldale Elementary, created by a near total lack of shade and an extreme reliance on pavement, reduces nearly all of the geographic benefit it may otherwise experience. Compare the 8 AM and 2 PM Tmrt values for Halldale Elementary and Ninth Street Elementary in FiguresFigure 9. Existing Conditions: Tmrt at 8 AM across all four sites, in degrees Celsius. andFigure 10. Existing Conditions: Tmrt at 2 PM across all four sites, in degrees Celsius.

This effect is reinforced by the canopy simulation. Increasing Halldale from 1% to 30% canopy brought average Tmrt down considerably (from 56.8°C to 47.5°C at 8 AM and 65.6°C to 60°C at 2 PM). Increasing canopy on Halldale's campus allowed it to take advantage of the 8 AM shadows and created pockets of coolness at 2 PM. Ninth Street Elementary saw slightly less benefit from the canopy increase at 8 am (from 51.9°C to 44.7°C at 8 AM), as a portion of the shade here was redundant to the existing shade from the buildings. By 2 PM, when building shade is minimal, Ninth Street Elementary experienced a similar reduction in average Tmrt to Halldale (from 67.4°C to 62°C at 2 PM). Compare the 8 AM and 2 PM canopy scenario Tmrt values for Halldale and Ninth Street Elementary in Figure 12. Canopy Scenario: Tmrt at 8 AM. and Figure 13. Canopy Scenario: Tmrt at 2 PM.. This finding sits in agreement with the literature, which finds that fields with high sky view factors tend to have higher heat exposure than narrow street canyons with limited airflow, purely due to the lack of shade (Johnasson, 2006; Vanos, 2015. This study, like the ones before it (Johanson; 2006; Joshi, 2024; Vanos, 2015; Vanos, 2017), finds that shade - from any source, including buildings - is a vital means for cooling urban space.

However, shade cooling is hyperlocal. Across campuses, only areas directly underneath the simulated trees experienced a reduction in Tmrt and UTCI, while unshaded areas of campus were often still in dangerous UTCI categories even in the canopy scenario. See Figure 14. Canopy Scenario: UTCI at 2 PM. for a visualization of UTCI in the canopy scenario. Between the existing conditions and scenario models, results demonstrate a reduction in average Tmrt by as little as 3.8°C and as much as 5.5°C. Median Tmrt, however, is reduced by as little as 0.0°C and as much as only 1.0°C. This is representative of shaded areas on campus: small locations got much cooler, bringing down the average, but overall, the schoolyard at large stayed constant, as reflected in the minimal reductions in median Tmrts.

Policy Recommendations

This study, first and foremost, emphasized the importance of considering individual sites in planning for thermal safety. Even ambitious, well-meaning goals can produce unreliable, inequitable results. If a policy's goal is to reduce thermal danger at the site level, then the site level should be the scale at which the policy is designed.

LAUSD should conduct a needs analysis focused on understanding site-specific conditions of each specific campus. More fundamentally, LAUSD should refine the goal and the methods by which to reach it; If it truly is heat mitigation, then they should not assume that greening or trees create a linear heat mitigation benefit.

With a clearer understanding of site-specific needs and goals, LAUSD can tailor their heat policies to the most effective methods for each campus. Schools in the South Bay, like Halldale Elementary, have a climatic and geographic advantage, while schools like Rosa Parks Elementary desperately need intervention. A policy accounting for geography and microclimate may recommend increased playground shading for schools like Halldale Elementary, while Rosa Parks desperately requires air conditioned, indoor space for extreme heat days.

The Green Schools for All Goal introduces a lot of variables, including where on campus ‘greening’ is implemented and what ‘greening’ looks like. Combined with the geographic and microclimatic variations in the county, this goal cannot stand alone as a heat safety measure. While increasing greenspace on schoolyards offers a host of co-benefits, this goal must be refined to ensure that results are equitable and effective.

Uniform thresholds without consideration of existing conditions yield extremely different results. With a topic as threatening as heat safety, LAUSD would benefit immensely by considering their campuses as unique sites with similarly unique needs.

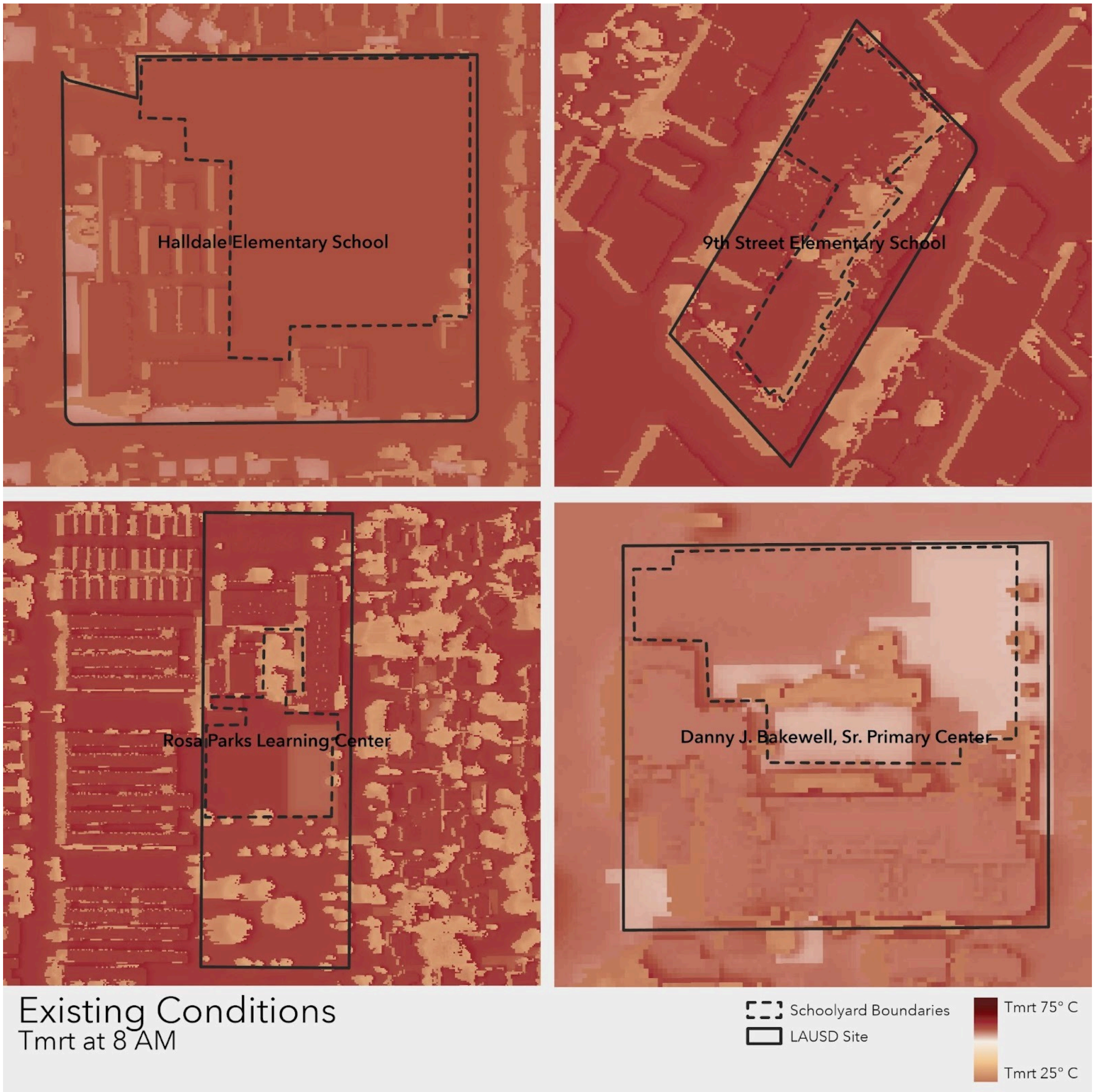

Figure 9. Existing Conditions: Tmrt at 8 AM across all four sites, in degrees Celsius.

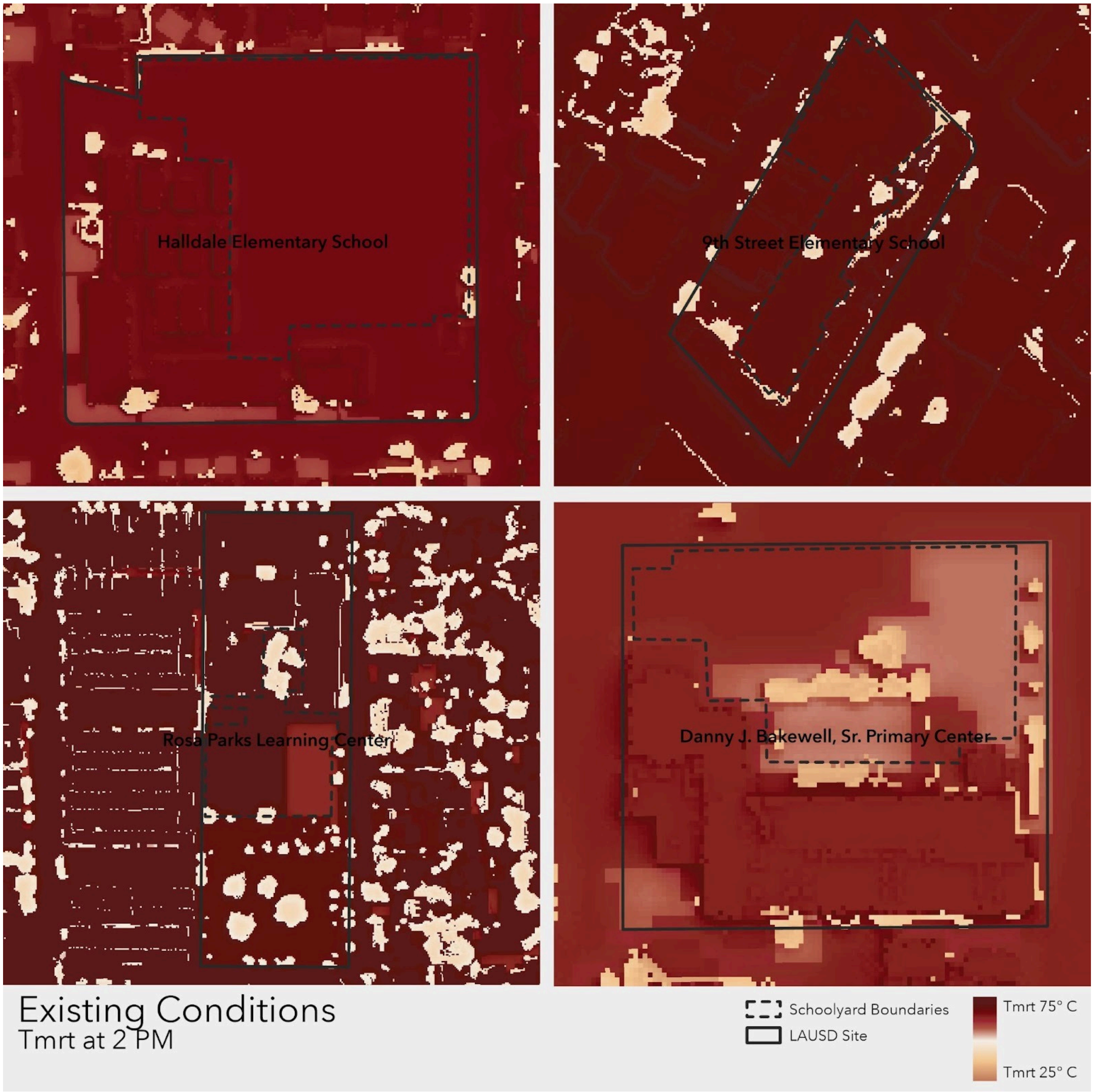

Figure 10. Existing Conditions: Tmrt at 2 PM across all four sites, in degrees Celsius.

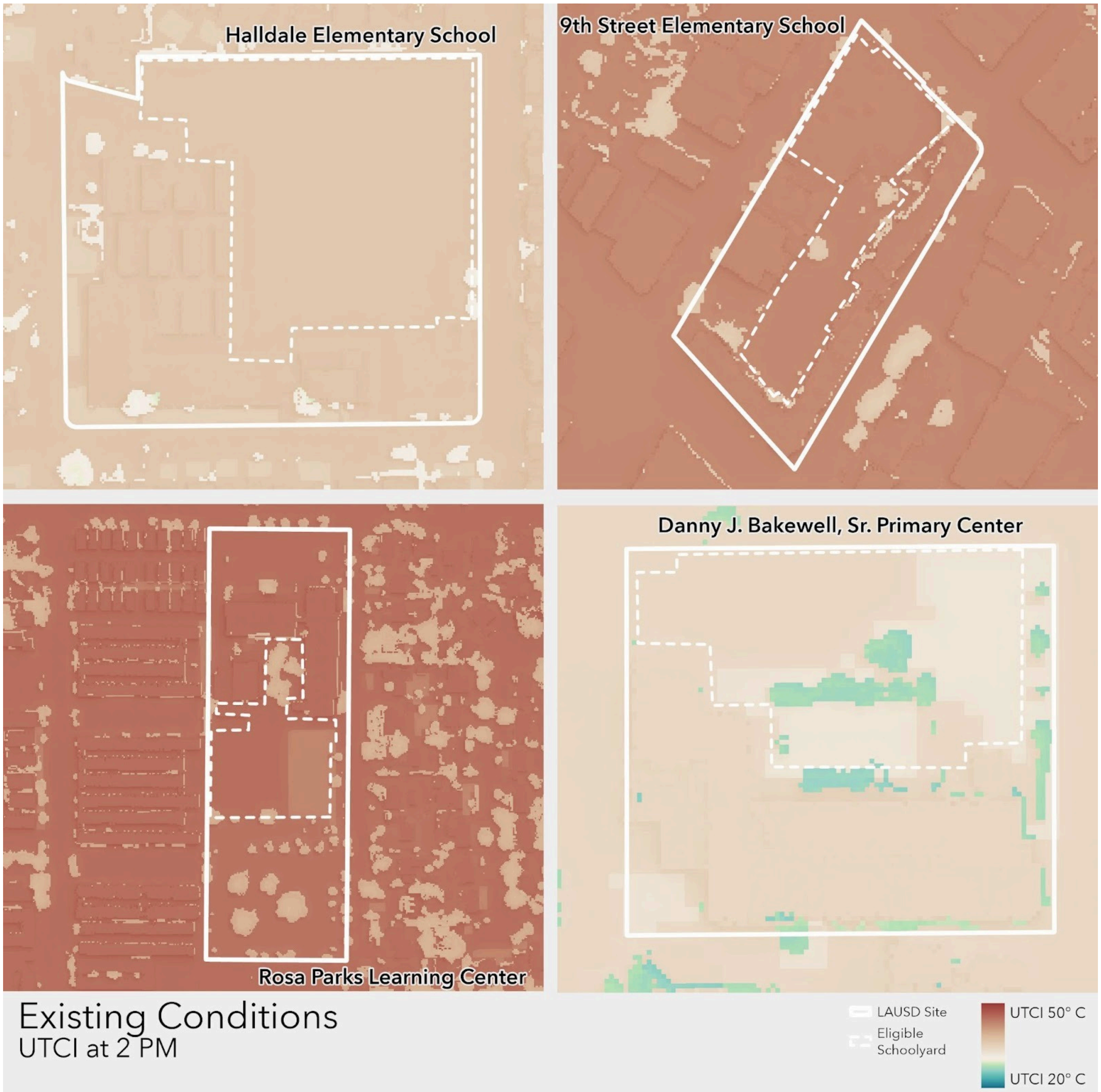

Figure 11. Existing Conditions: UTCI results at 2 PM.

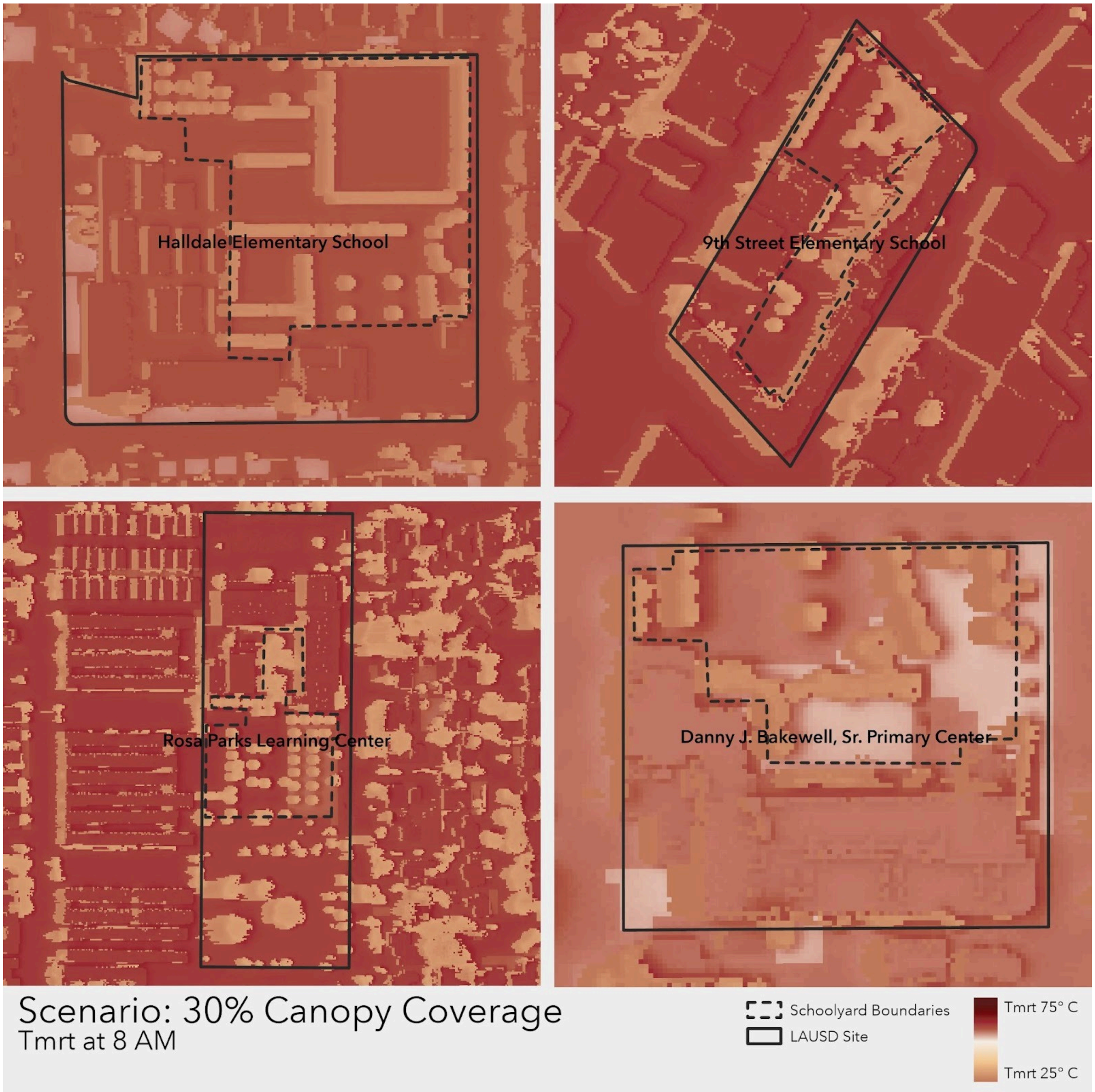

Figure 12. Canopy Scenario: Tmrt at 8 AM.

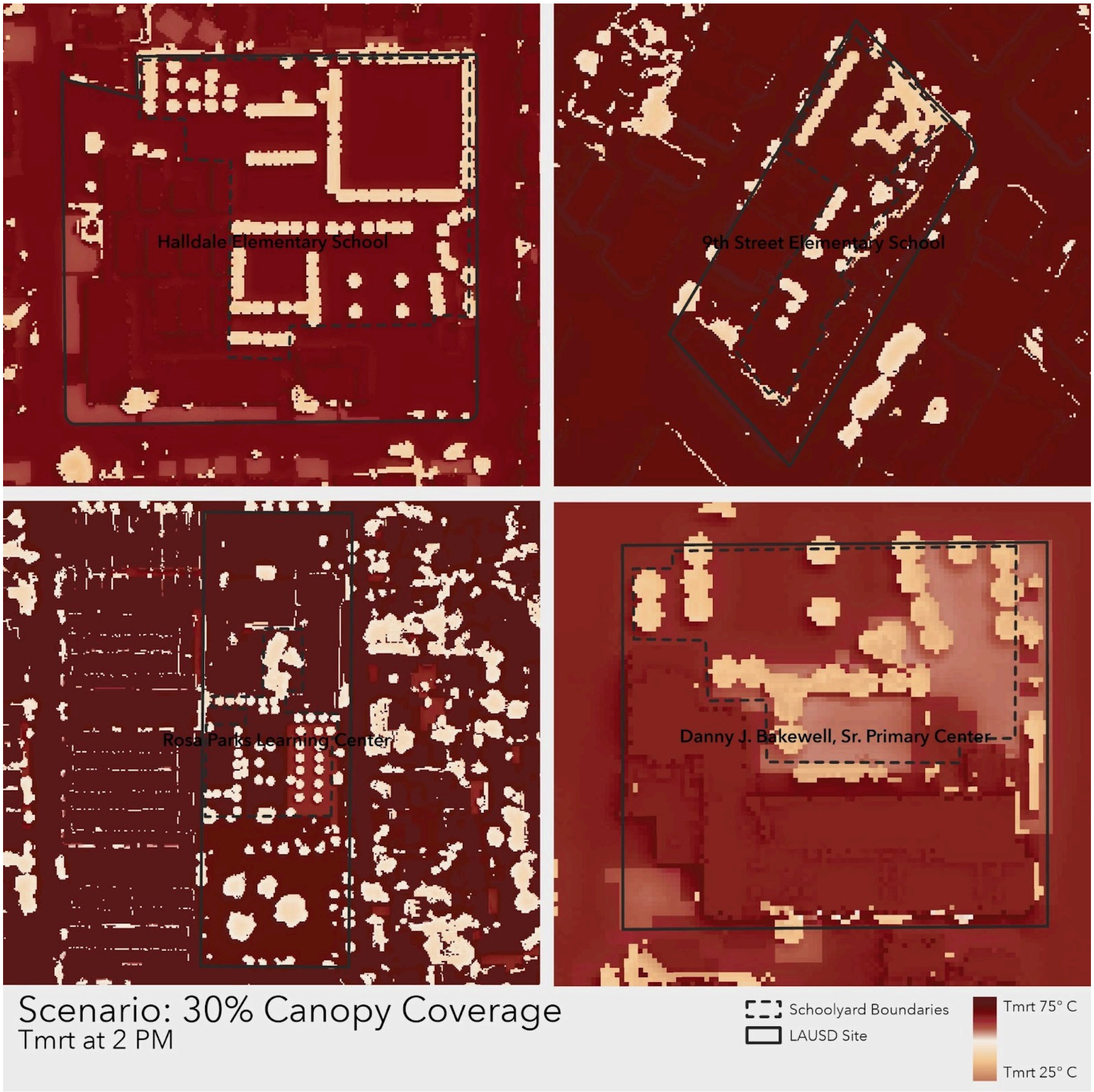

Figure 13. Canopy Scenario: Tmrt at 2 PM.

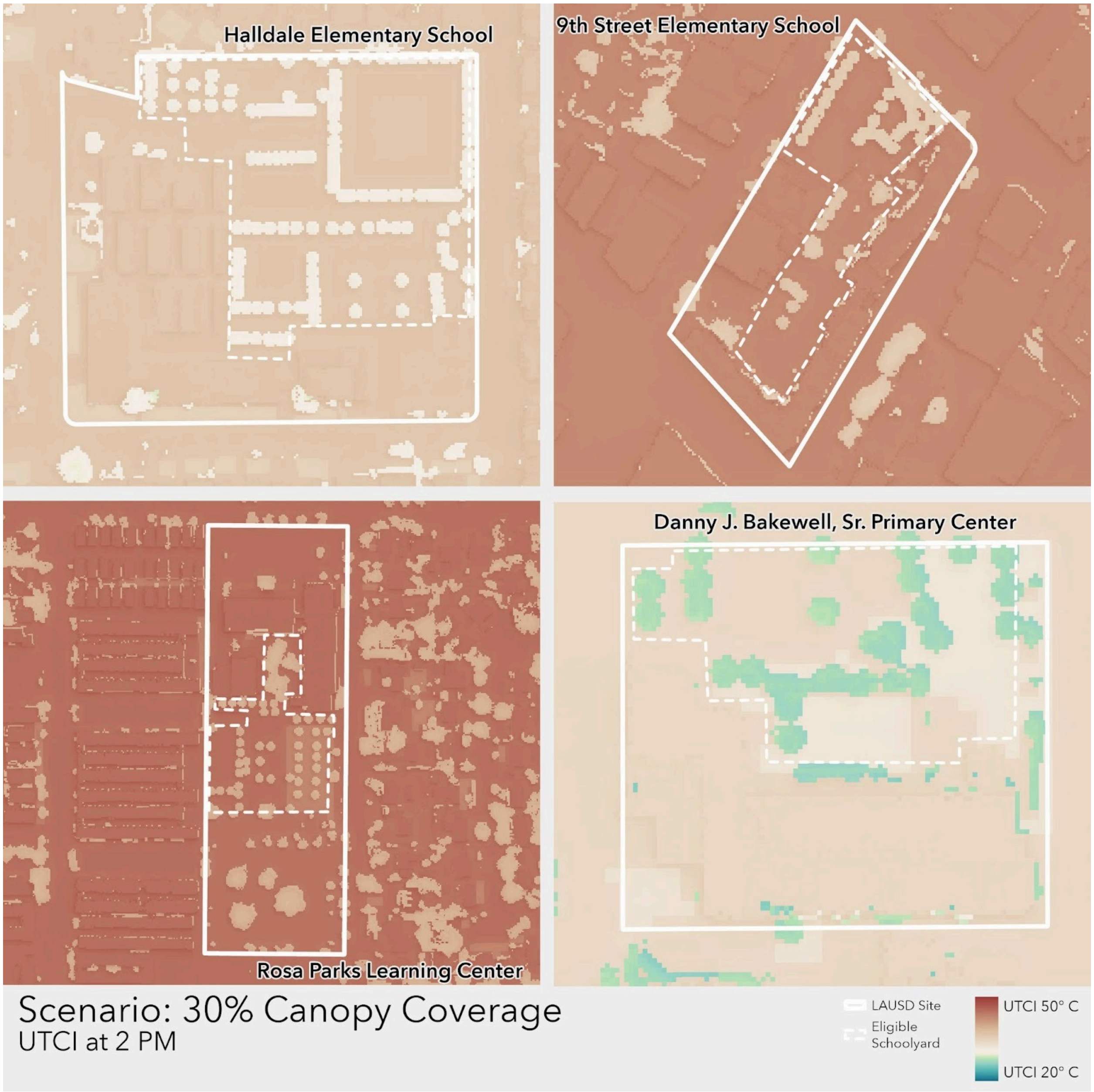

Figure 14. Canopy Scenario: UTCI at 2 PM.

CONCLUSION

This study sought to assess if greening and canopy thresholds were a meaningful indicator of thermal safety on elementary school campuses. Literature on this subject emphasizes the pressing need for effective policies targeting heat exposure on school campuses. Children are among the most vulnerable to heat-related illnesses and are required to spend the hottest hours of the day at school. Furthermore, heat on campus poses an equity issue, with children in low-income neighborhoods, which tend to be hotter, less likely to return home to air conditioning. Greening can be an effective way to mitigate heat on campus and provide a host of co-benefits, including aesthetic improvements and outdoor education opportunities.

Through modeling the outcomes of a heat policy in a real landscape, this study demonstrated that uniform thresholds create vastly inconsistent results. Rosa Parks Learning Center and Danny J. Bakewell, Sr. Primary Center had similar levels of greening, but in the existing conditions simulation, 39.31% of Danny J. Bakewell, Sr. Primary Center was deemed useable space, compared to 0% of Rosa Parks Learning Center. Even the canopy scenario simulation, which normalized canopy coverage to 30% across all campuses, created different levels and patterns of usability depending on existing regional and climatic conditions. These results indicate that there is a thermal threshold beyond which heat design interventions fail to increase usable space.

Zooming into the micro-scale, existing built form and surrounding neighborhood context created additional variables for which the threshold does not account. Halldale Elementary had cooler air temperature than Ninth Street Elementary on the day of the study, but Ninth Street Elementary's enclosed built form created extensive shade that cooled the school yard effectively in the morning hours.

The results of this study also add to existing literature supporting that shade is the most effective means of outdoor heat mitigation: across all simulations and times studied, areas shaded by both trees *and* buildings were consistently the coolest and most usable spaces on campus.

Finally, the results of this study offer important policy implications for LAUSD's heat mitigation program. Green Schools for All is well intentioned, but the efficacy of the policy on extreme heat days is limited by confounding factors, especially geography and existing campus design. Improving the law to the best possible case of greening, canopy, largely provided a cooling effect. However, the usability of space even after the cooling effect of shade was tempered by the campus' baseline conditions. Improving the policy to focus on the unique needs of individual campuses and coupling greening with air conditioning increases the effectiveness of the policy as a heat safety measure. For a district as large and diverse as LAUSD, subjective, district-wide design thresholds for heat safety run the risk of achieving a numerical target without meaningfully impacting the heat concerns that prompted its creation.

When considering heat mitigative policies such as greening thresholds, planners must consider the baseline climatic, regional, and built form conditions. Equal targets will not yield the equitable results necessary to reduce the gap in recess access, educational development, and children's thermal safety.

Study Limitations and Plans for Future Research

This study is not without limitations. First, due to the master's thesis timeframe, I was not able to attain the appropriate permissions to collect qualitative data on the school sites. This prevented a planned interview series that would have provided context into how heat affects each campus, the bell schedule and times of day the playground is in use, the off-season uses of the campus (church, community meetings, scouts, etc.), and how children use their play areas during heat days. The results of this study are biophysical, not experiential. By using satellite data and publicly available built environment data, precision is limited and results should be field verified. Further research should be augmented with an interview series and site visits. Additionally, site observations can better inform targeted interventions.

Second, human thermal comfort indices are developed for adults. More complex thermal comfort models tailored to children consider their higher energy budget (Cheng and Brown, 2020; Vanos, 2015; Vanos, 2017). UTCI is an imperfect measure for children and undervalues heat stress, which would be more extreme in youth (Antoniadis, 2020). As such, this study underestimates the threats posed by heat on campus. Future iterations of this study would benefit by utilizing thermal comfort indices designed for children, such as Physiological Equivalent Temperature (PET) adapted for a child's physiological parameters.

Additionally, this study occurs on only one day, the hottest day of the school year. By its nature, the results are extreme. Future iterations of this study should consider the entirety of the heat season to also assess how 'greening' interacts with existing form on warm or hot, but not extreme, days.

Finally, LAUSD spans 710 square miles and enrolls more than 520,000 students. Combined with surrounding smaller districts, over 1.3 million students are enrolled in a school within LA County (Los Angeles County Office of Education). LA County itself is over 4,000 square miles and contains beaches, deserts, mountains, chaparrals, and highly urbanized environments. The incredible diversity of built form, enrolled population, biome, and climate cannot be captured in 4 schools.

This master's thesis inspired additional research questions related to heat, the urban form, and school campuses. Future iterations of this study will examine thresholds of effectiveness for different forms of greenspace, to examine at what point greenspace peaks in heat mitigative capacity. This research could inform effective and efficient investment in heat mitigative design on school campuses.

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