



UNIVERSITY OF NEW MEXICO

URBAN HEAT ISLAND
ARCH 634: SYSTEMS INTEGRATION I

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Academic Studies

These three studies collectively synthesize decades of research on Urban Heat Island (UHI) phenomena, each with a distinct lens.

The first (remote sensing study) used **land surface temperature measurement** techniques—particularly using Landsat and ArcGIS—across Asian cities in humid subtropical climates. The second review focuses on the physical and anthropogenic drivers of UHI, such as **urban morphology and surface materials**, while critiquing existing modeling approaches and advocating for mitigation strategies like reflective surfaces and increased vegetation. The third review spans 50 years and 190 studies, highlighting the role of urban zoning metrics (e.g., Floor Space Index and Leaf Area Index) and **geometry** in UHI formation, and introduces algorithmic forecasting tools to guide mitigation planning. Together, these studies underscore the multifactorial nature of UHI and the evolving toolkit for its analysis and mitigation.

1. [Study of the Urban Heat Island Using Remote Sensing Data](#) – A 2021 systematic review analyzing 579 publications from 2000–2020. Focuses on remote sensing (RS) and land surface temperature (LST) techniques, noting heavy use of Landsat data and ArcGIS, with most case studies in Asia and humid subtropical climates.
2. [Causes, Modeling and Mitigation of Urban Heat Island: A Review](#) – Covers urban morphology, surface materials, anthropogenic heat, and critiques modeling approaches. Highlights mitigation strategies such as high-albedo surfaces and urban vegetation.
3. [A Review of the Formation and Mitigation Strategies from 50 Years of Global UHI Studies](#) – Synthesizes over 190 studies across five decades. Emphasizes zoning metrics like FSI and LAI, explores urban geometry’s impact, and proposes algorithmic forecasting tools for mitigation planning.

What each Resource can be Searched for:

Study	Urban Vegetation / Green Spaces	Water Bodies / Blue Infrastructure	High-Albedo / Reflective Surfaces	Land Use Planning / Zoning	Urban Geometry Optimization	Algorithmic Forecasting Tools	Modeling Improvements
Study 1: Remote Sensing Review (2021)	Strong emphasis, especially in humid subtropical zones	Noted for evaporative cooling effects	Commonly recommended (e.g., cool roofs)	Promoted via reduced impervious surfaces	Indirectly addressed via RS analysis	✗ Not discussed	Focused on Remote Sensing and LST techniques
Study 2: Causes & Modeling Review	Highlighted as a key strategy	Mentioned but less emphasized	Strongly emphasized	Discussed in terms of urban morphology	Critiqued in modeling approaches	✗ Not discussed	Critiqued and refined
Study 3: 50-Year Global Review	Central to mitigation, linked to LAI metrics	Included in urban geometry considerations	Included as part of surface material strategies	Central focus—FSI, LAI, and zoning metrics	Major theme—linked to heat dispersion and forecasting	Proposed for mitigation planning	Synthesized across decades

Metrics Used in these Studies:

- RS – Remote Sensing
- LST – Land Surface Temperature
- FSI – Floor Space Index
- LAI – Leaf Area Index

UHI Mitigation Typologies

1. Vegetative Strategies

- Urban greening (parks, green roofs)
- Tree canopy expansion
- Green corridors

2. Urban Morphology & Planning

- Optimized aspect ratios (height/width)
- Open space ventilation design
- Zoning controls (FSI, LAI)¹

3. Surface Material Interventions

- Cool roofs and pavements (high albedo)
- Permeable surfaces
- Thermal mass reduction

4. Climatic & Ventilation Enhancements

- Urban wind corridors
- Thermal gradient design (e.g., ENVI-met-guided cooling axes)²

5. Policy & Behavioral Tools

- Building code mandates and incentives
- Public engagement in UHI reduction
- Forecasting tools integrating land use and vegetative indices

¹ Zoning controls like **FSI (Floor Space Index)** and **LAI (Leaf Area Index)** are key metrics used in urban planning to regulate development intensity and environmental impact

² **Environment for Visualizing Images (ENVI)** - Specialized software application used for processing and analyzing geospatial imagery and environmental data

Parameters & Metrics Available for Design

Architects can design for Urban Heat Island (UHI) mitigation by integrating five key parameters into their planning and material choices:

1. SRI (Solar Reflectance Index) Values

- Reference Guides/Sources: CRRC, LEED, WBDG standards.
- Application: Select roofing and paving materials with high SRI (e.g., ≥ 82 for low-slope roofs) to reflect solar radiation and reduce surface temperatures.
- Design Tip: Use CRRC-rated products and LEED-compliant surfaces to earn heat island reduction credits.

2. Canopy Cover % and LAI (Leaf Area Index)

- Source: ENVI-met simulations, LIDAR, and remote sensing overlays.
- Application: Maximize vegetative density and strategic canopy placement to enhance shading and evapotranspiration.
- Design Tip: Use LAI maps to prioritize tree species and planting density based on cooling potential.

3. Thermal Lag & Albedo Coefficients

- Source: Empirical data from pilot studies (e.g., Phoenix Cool Pavement Program).
- Application: Choose materials with low thermal lag and high albedo to reduce heat retention and accelerate nighttime cooling.
- Design Tip: Incorporate cool pavements and reflective coatings in high-exposure zones.

4. Airflow & Canyon Geometry

- Source: ENVI-met, AIA essays, sustainable zoning codes.
- Application: Optimize building height-to-street width ratios (H/W), orientation, and spacing to promote ventilation and pollutant dispersion.
- Design Tip: Align streets with prevailing winds and avoid deep, narrow canyons that trap heat.

5. UHI Intensity & Vulnerability Indices

- Source: NIHHS, NASA DEVELOP, local open data portals.
- Application: Use satellite-derived LST and socioeconomic overlays to identify heat-vulnerable zones and prioritize interventions.
- Design Tip: Target high-risk areas with cooling infrastructure, shade, and community engagement.

UHI Mitigation Design Best Practice Targets

Module	Metric / Input	Source	Design Strategy	Best Practice Value
1. Solar Reflectance	SRI value (roof)	CRRC, LEED, WBDG	Use high-SRI materials to reflect solar energy	≥82 (low-slope roof), ≥39 (steep-slope)
	SRI value (pavement)	LEED, CRRC	Apply cool pavements to reduce surface heat	≥29 (LEED v4.1 credit)
	Albedo coefficient	Pilot studies	Select surfaces with high reflectivity	≥0.30 for pavements, ≥0.65 for roofs
2. Vegetation & Shade	Canopy cover %	ENVI-met, remote sensing	Maximize shade and evapotranspiration	≥40% of site area (LEED Heat Island Reduction)
	Leaf Area Index (LAI)	ENVI-met, LIDAR	Use high-LAI species for cooling	LAI ≥ 3.0 (dense canopy)
3. Thermal Behavior	Thermal lag (material)	Empirical studies	Use low thermal inertia materials	Air, wood, and aerogels, heat up and cool down quickly
	Surface temperature (day/night delta)	ENVI-met, pilot studies	Promote rapid nighttime cooling	≤41°F. difference by midnight
4. Airflow & Geometry	H/W ratio (canyon geometry)	ENVI-met, zoning codes	Optimize geometry for ventilation	H/W ≤ 0.7 (for good airflow)
	Prevailing wind alignment	Local climate data	Align streets/buildings to enhance ventilation	±30° of prevailing wind axis
5. UHI Risk & Vulnerability	UHI intensity (°C)	NIHHIS, NASA DEVELOP	Target high-UHI zones for cooling interventions	≤35°F above rural baseline
	Vulnerability index	Local open data portals	Prioritize cooling in vulnerable zones	Top 25% of census tracts by risk

Practical Datasets

1. [**NIHHIS Urban Heat Island Mapping Campaign**](#)
Mobile transect data and raster UHI maps across 70+ U.S. cities. Validated via community-led campaigns and used for thermal equity planning.
2. [**Global Urban Heat Island Intensity Dataset \(UHII\)**](#)
Earth Engine dataset tracking monthly UHII trends (2003–2020) across 10,000+ cities. Includes daytime/nighttime and canopy-layer results.
3. [**Making Nature's City – Global UHI Dataset**](#)
Raster data with 1 km resolution showing day/night UHI intensity from 2013. Ideal for calibration or snapshot analyses.

City-Specific Programs and Interventions

City	Mitigation Initiatives	Data Collection Methods	Standout Features
Phoenix, AZ	Cool pavements, tree & shade plan, Heat-Ready framework	Satellite LST, mobile sensors, community engagement	City-wide integration of heat into all planning layers
Los Angeles, CA	Cool Neighborhoods program, cool roofs, green infrastructure	NASA satellite imagery, local sensors	Neighborhood-scale UHI targeting + equity lens
New York, NY	Tree planting, cool roofs, climate resiliency guidelines	Dense sensor networks, research partnerships	Policy-driven integration into capital projects
Houston, TX	Green space expansion, impervious surface reduction	Heat mapping campaigns, resident-led data collection	Strong community science and equity focus
Washington, DC	Tree planting mandates, cool roofs, permeable surface incentives	Remote sensing, urban forestry GIS	Robust zoning code updates for UHI resilience
Windsor, CA	Green Building Ordinance (cool roofs, shade trees)	Local environmental monitoring tools	Fully embedded in zoning and development code
Albuquerque, NM	Community-led heat mapping, data-informed interventions	Mobile sensor campaigns via NIHHIS	High-resolution thermal equity mapping

Applying Most Successful Solutions

The city most frequently cited as a success story for Urban Heat Island (UHI) mitigation is **Singapore**. It’s widely recognized for its integrated, data-driven approach to urban cooling, combining:

- 1. Extensive urban greenery including vertical gardens, green roofs, and tree-lined streets.
- 2. Smart zoning and planning with policies that balance built density and vegetative cover.
- 3. Advanced modeling tools using ENVI-met and other simulation platforms to guide cooling corridor design and optimize microclimates.
- 4. Monitoring and feedback loops for remote sensing and IoT sensors track land surface temperatures and inform adaptive strategies.

Singapore’s success is often attributed to its holistic planning, where UHI mitigation is embedded into broader sustainability and livability goals.

Adaptable Strategies

Singapore Strategy	Adaptation for Albuquerque
Vertical greenery & green roofs	Use drought-tolerant green roofs (e.g., sedum, native grasses); vertical gardens with xeriscaping principles
Cooling corridors with vegetation	Design wind-aligned cooling axes using sparse tree lines, permeable surfaces, and shaded walkways
Zoning with LAI/FSI balance	Implement zoning overlays that require minimum vegetative cover or reflective surfaces per parcel
High-albedo surfaces	Prioritize cool pavements, light-colored roofing, and solar-reflective coatings for buildings
ENVI-met simulations for planning	Use simplified microclimate modeling in Excel or GIS to simulate airflow, surface temps, and shading impacts
IoT-based temperature monitoring	Deploy low-cost sensor networks to track surface and air temps across neighborhoods for feedback and targeting

U.S. Cities Showing the Greatest UHI Reductions

- **Los Angeles, CA:** Cool pavements, equity-targeted tree planting (10–12°F surface reduction)
- **Chicago, IL:** 500+ green roofs = up to 10°F local cooling
- **New York City, NY:** Widespread tree canopy expansion and cooling policy enforcement
- **Houston, TX:** Measurable improvements from greening and data-backed UHI zoning changes

OPEN SOURCE DATA FOR REVIEW

Los Angeles, CA

- Shared thermal imagery and GIS from Cool Pavement & Tree Pilots
- Reported surface temp drops of 10–12°F

Phoenix, AZ

- Published 2021 pilot data showing 10–12°F daytime reduction
- Cool Pavement evaluations guide diurnal lag modeling

Houston, TX

- Open datasets with post-greening overlays and community feedback loops

New York City, NY

- NYC Open Data shares intervention-linked datasets (cool roof installs, canopy growth, LST trends)

Albuquerque's Urban Heat Island Work

A standout case of data-driven, equity-focused mitigation, especially through its collaboration with NASA's DEVELOP program and the *Let's Plant Albuquerque* initiative.

Modeling Frameworks & Tools Used

- NASA DEVELOP + City of Albuquerque partnered to model UHI impacts using:
 - Landsat 8 Thermal Infrared Sensor (TIRS)
 - ECOSTRESS (Ecosystem Spaceborne Thermal Radiometer on the ISS)
 - InVEST Urban Cooling Model (for simulating tree canopy effects)
 - ENVI-met (for microscale thermal modeling)
- These tools were used to simulate tree canopy expansion scenarios and their impact on land surface temperature (LST) across different neighborhoods.

Key Findings

- **Localized Cooling Potential:** Tree canopy interventions could reduce LST by up to 2.7°F within 2–3 meters of the surface, especially in high-density, low-canopy areas.
- **Social Vulnerability Overlay:** Rather than targeting only the hottest zones, the city prioritized frontline communities—areas with high social vulnerability and low existing canopy—for intervention.
- **Geographic Uniqueness:** Albuquerque's UHI patterns are shaped by its **distinct** topography and development patterns, requiring tailored mitigation rather than one-size-fits-all strategies.

Data Sources & Timeframe

- Satellite data spanned April 2016 to August 2022, allowing for both historical trend analysis and forecasting of future canopy impacts.
- The project built on the 2020 CAPA Heat Watch Campaign, which used mobile sensors to map intra-urban heat disparities.

Strategic Applications

- Supports the city's 100,000-tree planting goal under the *Let's Plant Albuquerque* alliance.
- Informs zoning, park planning, and public health interventions.
- Enhances community engagement by visualizing heat risk and mitigation outcomes.

The full technical report from NASA DEVELOP is [here](#), and the city's sustainability portal with maps and results [here](#).

Leading Industry Resources

Breakdown of **Urban Heat Island (UHI)-specific resources** from both the **American Institute of Architects (AIA)** and the **U.S. Green Building Council (USGBC)**—each offering design strategies, technical guidance, and performance frameworks:

AIA Resources on Urban Heat Island

1. [**Designing for Urban Heat – AIA Climate Corner \(Feb 2025\)**](#)

Developed by the AIA Strategic Council, this guide frames UHI as both a public health and equity issue. It outlines:

- **Site & Community Strategies:** Tree planting, minimizing hardscape, and using light-colored surfaces.
- **Building Design Tips:** Tight, insulated envelopes, low window-to-wall ratios, and strategic glazing orientation.
- **Equity Lens:** Emphasizes interventions in low-income, high-heat neighborhoods.

2. [**Urban Cooling Essay by Doug Kelbaugh, FAIA**](#)

A thought-provoking piece that positions UHI as a local motivator for climate action. It explores:

- **Three cooling strategies:** Albedo enhancement, sensible heat reduction, and microclimate creation.
- **Behavioral leverage:** UHI as a more immediate and tangible climate challenge than global warming.
- **Design implications:** Encourages architects to use UHI mitigation as a gateway to broader sustainability.

3. [**Urban Heat Island Effect – AIA-Approved CE Course**](#)

A 2-hour continuing education course covering:

- UHI causes, impacts, and mitigation strategies.
- Benefits of cool roofs, pavements, and urban forestry.
- Tailored content for landscape, residential, and commercial architects.

USGBC Resources on Urban Heat Island

1. [LEED Heat Island Reduction Credit Guide](#)

Part of LEED v4.1, this credit encourages:

- **High-SRI materials** for roofs and hardscapes.
- **Vegetated roofs and shading devices.**
- **Three-year aged reflectance values** to ensure long-term performance.
- Quantifies energy savings potential (\$4M–\$15M/year in select cities) and links UHI reduction to cooling load reductions and GHG mitigation.

2. [Neighborhood Resiliency Resources – City of Albuquerque \(USGBC-aligned\)](#)

While city-specific, this page reflects USGBC-aligned strategies:

- Urban tree planting and green space expansion.
- Community heat awareness and response tools.
- Links to national resources like NIHHS, EPA Smart Growth, and NOAA Heat Watch.

3. [EPA Heat Island Community Actions Database](#) (frequently referenced by USGBC)

Though hosted by the EPA, this database is a go-to for LEED practitioners:

- Catalogs local ordinances, incentives, and pilot projects.
- Includes searchable examples of cool roofs, permeable pavements, and zoning reforms.
- Supports LEED documentation and regional precedent research.

Green Building Advisor (GBA)

Green and Cool Roofs Provide Relief for Hot Cities ([GBA Article](#))

- **Key Insight:** Vegetated (green) and reflective (cool) roofs can reduce UHI effects, but their impact varies across microclimates.
- **Study Highlight:** A University of Notre Dame study in Chicago found that while green and cool roofs lowered surface temps, they also altered **local wind patterns**, which could offset some air quality benefits.
- **Design Implication:** Urban planners and modelers should consider mesoscale (medium scale) airflow effects when deploying reflective or vegetated surfaces at scale.

Integrated Vegetation Strategies (via [Project EverGreen](#), often cited by GBA)

- **Urban Greening:** Emphasizes tree planting, green walls, and community gardens as cooling tools.
- **Policy Levers:** Encourages tree ordinances and incentives for homeowners to adopt reflective materials or plant shade trees.
- **Public Engagement:** Highlights the role of education and community programs in amplifying UHI mitigation.

Urban Planning & Material Guidance

- **High-Albedo Materials:** GBA frequently recommends light-colored bricks, tiles, and concrete to reduce solar absorption.
- **Smart Zoning:** Advocates for compact, mixed-use development to reduce impervious surface area and heat buildup.
- **Cool Roof Coatings:** Offers practical advice on retrofitting existing roofs with reflective coatings to enhance performance.

The Whole Building Design Guide (WBDG)

Developed by the National Institute of Building Sciences ([LINK](#))

Sustainable Design Principles

WBDG emphasizes site-responsive design and integrated systems thinking, which directly support UHI mitigation. Key strategies include:

- **Minimizing impervious surfaces** through compact development and green infrastructure.
- **Maximizing vegetative cover** with native landscaping and green roofs.
- **Optimizing building orientation and massing** to reduce solar heat gain and enhance passive cooling.

High-Performance Building Envelope Guidance

- Cool roofing materials with high Solar Reflectance Index (SRI).
- Thermal mass management to reduce diurnal heat storage.
- Shading devices and overhangs to limit solar exposure on façades.

Especially relevant for modeling thermal lag and surface heat flux in UHI-prone zones.

Landscape Architecture & Site Design

The [Landscape Architecture section](#) promotes:

- Tree canopy integration for shading and evapotranspiration.
- Stormwater management via bioswales and permeable pavements.
- Microclimate creation through vegetated buffers and wind corridors.

Federal Green Construction Guide for Specifiers & Low Impact Development ([Guide](#))

This guide—linked through WBDG—includes UHI-relevant specs such as:

- Minimum SRI values for roofing and paving
- Vegetated roof system requirements
- Urban forestry and shading standards

Other Organizations

Heat Island Group – Lawrence Berkeley National Laboratory ([LBNL](#))

- Offers technical briefs, toolkits, and datasets on cool roofs, pavements, and envelope materials.
- Includes the [Cool Roof Rating Council \(CRRC\) directory](#) and [DOE’s Guidelines for Selecting Cool Roofs](#).
- Hosts the EPA’s Compendium of Strategies, a deep dive into UHI causes and mitigation by surface type (roofs, pavements, vegetation).

Global Cool Cities Alliance ([GCCA](#))

Often cited by LBNL and GBA, GCCA provides:

- A Cool Roofs and Pavements Toolkit for cities and building owners.
- Implementation guides for policy, procurement, and performance tracking.
- Advocacy for urban albedo enhancement and climate equity.

American Society of Landscape Architects ([ASLA](#))

- Publishes design case studies and policy briefs on green infrastructure, tree canopy expansion, and climate-responsive site planning.
- Offers CEU courses on urban forestry, stormwater management, and thermal comfort.

National Integrated Heat Health Information System ([NIHHIS](#))

- A NOAA-led initiative that supports community heat mapping, thermal equity planning, and data transparency.
- Partners with cities and researchers to publish post-intervention datasets and heat vulnerability maps.

Modeling Resources and Tools

From academic studies to city-specific programs and professional organizations, the following resources are grouped into categories based on function:

Remote Sensing & UHI Detection

- **Landsat 8 TIRS and ECOSTRESS** (Albuquerque/NASA DEVELOP): Surface temperature mapping and temporal analysis.
- **Google Earth Engine – UHI Dataset**: Global-scale diurnal UHI intensity trends (2003–2020).
- **NIHHIS Heat Mapping Campaigns**: High-res, ground-truthed thermal transects for dozens of U.S. cities.

Simulation & Environmental Modeling Tools

- **ENVI-met**: Microscale 3D modeling of thermal flux, vegetation, and wind dynamics in urban canyons (used in Albuquerque and Sydney studies).
- **InVEST Urban Cooling Model**: Estimates cooling benefits of vegetation in spatially explicit terms.
- **ArcGIS & QGIS**: Geospatial modeling of UHI gradients and mitigation scenarios (noted in nearly all studies).

Urban Morphology & Material Response

- **GCCA Cool Roofs & Pavement Toolkit**: Albedo performance and policy modeling templates.
- **Heat Island Group Tools (LBNL)**: Empirical cooling data, emissivity lookups, and reflective surface guidance.
- **Cool Roof Rating Council (CRRC) Database**: Validated SRI values and aging curves for reflective materials.
- **Whole Building Design Guide (WBDG)**: SRI targets, vegetated cooling potential, and massing strategies.

Performance Tracking & Benchmarking

- **USGBC Arc Platform**: Real-time energy, LST, and UHI-linked performance scoring.
- **LEED Pilot Credits – Heat Island Reduction**: Quantified mitigation inputs tied to certification pathways.
- **EPA Community Actions Database**: UHI-related zoning, policy, and incentive frameworks.
- **AIA Designing for Urban Heat Guidance**: Building envelope, site, and glazing configurations for thermal relief.