Strategic Plan for Urban Heat Island Mitigation in the Houston Region

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ABSTRACT

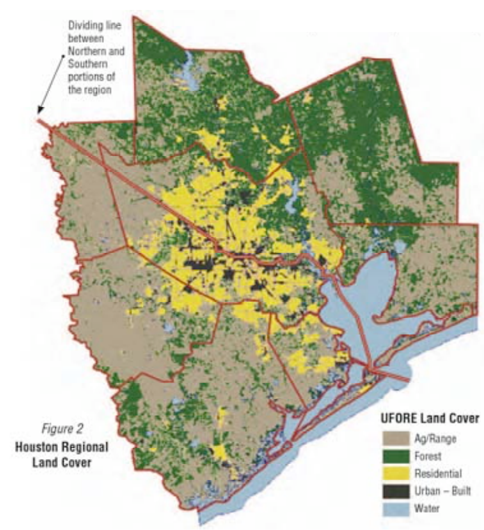
The *Cool Houston Plan* sets forth comprehensive strategies to mitigate regional urban heat island effects (UHI) within 10 to 15 years. The Houston region, with over 5 million people, is located in a hot, humid coastal climate with continuing development of existing land, low development densities, high cooling energy costs, and difficult air quality problems that can be addressed partially through UHI countermeasures. The extent and magnitude of the region's heat island has expanded measurably as the region has grown. A revised air quality plan is being prepared, designed to meet federal ozone standards by 2010. Green infrastructure and energy policies that will help to offset heat island effects are being instituted by several governmental agencies in the region. Features of Houston's strategic heat island mitigation plan include:

Distinguishing Features of Cool Houston Plan

- Comprehensive regional urban heat island strategy
- Regionally-based, rather than central city
- Land cover orientation as a 2-D strategy for changing suitable urban surfaces to reduce heat island effects
- Based on current, readily available (not future) mitigation technologies
- Reliance on current policy frameworks suited to Houston and Texas
- Reliance on "business as usual" changes as much as possible
- Published for general public and decision maker audiences

I. BACKGROUND AND SETTING

The Houston region of over 5 million people[1] is the 7th largest U.S. metro area and occupies a land area of roughly 7,600 mi^2 (19,684 km^2). The urbanized area is estimated to be 1,400 to 1,800 mi^2 (3,626-4,662 km^2).[2] The population center is 46 miles (74 km) north of the Gulf of Mexico.



Land Cover Map Houston Region:
Source: Houston's Regional Forest, 2005

The climate is *humid subtropical* with average annual precipitation levels of 48 inches (1,220 mm). Summer average daily high temperatures range from 85-94 ºF (29-34 ºC), with the official temperatures measured at the major airport located 57 miles (92 km) north of the coast. The Gulf of Mexico has a moderating effect on temperatures such that high temperatures will vary by as much 10ºF (5.6 ºK) or more from north to south. Prevailing winds are from the south and southeast, bringing higher temperatures from semi-arid

[1] 2005 population estimated to be 5.3 million people in the newly designated Metropolitan Statistical Area (MSA).
[2] This range reflects differences in U.S. Census methods for estimating urbanized areas and land use/land cover analysis using satellite imagery.

regions in Mexico and moisture from the Gulf of Mexico.

Topographically, the Houston region is relatively flat varying from sea level to only 170 feet (52 m). It is located at the intersection of several major ecosystems that include dense pine forests to the north and northeast, coastal plains on the south and prairies to the west. As such, the interactions of the large city, complex climate conditions, and diverse ecosystems provide a challenging framework for understanding and mitigating urban heat island effects.

Houston Urbanized and Metropolitan Areas 1950 to 2000

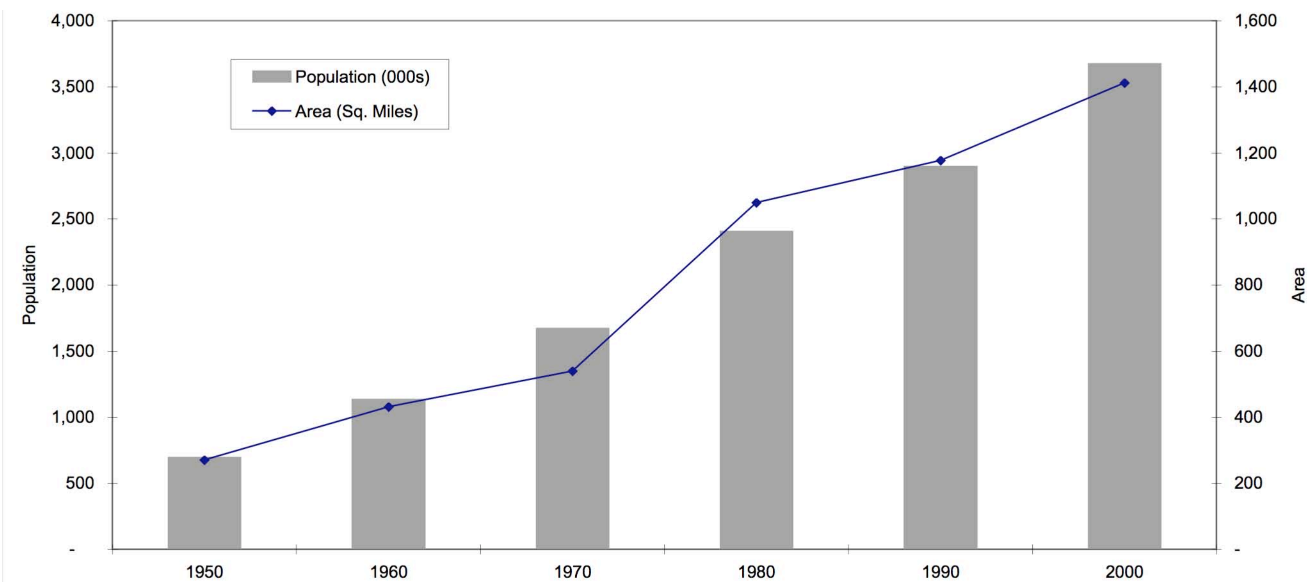
Population, Urbanized and Density: Source: U.S. Census

Urbanized Area	**1950**	**1960**	**1970**	**1980**	**1990**	**2000**
Population (000s)	701	1,140	1,678	2,412	2,902	3,679
Area (Sq. Miles)	270	431	539	1,049	1,177	1,412*
Increase in Population		439	538	734	490	777
Increase in Area		161	108	510	128	235
Added Area per 10,000 people		3.67	2.01	6.95	2.61	3.02
Density (population/sq. mile)	2,596	2,645	3,113	2,299	2,466	2,606
Houston Metro Area[3]						
Population	1,068	1,581	2,181	3,120	3,731	4,670
% Urbanized Population	65.6%	72.1%	76.9%	77.3%	77.8%	78.8%
Area of region (constant value)	7,581	7,581	7,581	7,581	7,581	7,581
% Urbanized of Area	3.6%	5.7%	7.1%	13.8%	15.5%	18.6%

*estimated from prior decades

Population and Urbanized Area 1950 to 2000

Houston CMSA



[3] Based on 8-county Consolidated Metropolitan Statistical Area (CMSA) definition of the metropolitan area, not the recent MSA designation.

II. DRIVING FORCES AND URBAN HEAT ISLAND EFFECTS

The four key factors considered in this paper relevant to Houston's urban heat island effects include:

- Amount and extent of urban development
- Low development densities (jobs and population)
- Heat induced ozone formation as an air quality problem
- Exclusion of global warming/climate change issues

Size, Extent, and Densities of Urban Development: Houston has relatively few policy and physical constraints to growth, and, as such, urban development has been extensive in its coverage and has occurred at relatively low development densities. For example, Houston's heat island dimensions increased from 1985 to 2001 by as much as 250 mi^2 (650 km^2), an 88% increase, and a 35% increase in temperature magnitude (+0.8 °K).[4]


Aerial view of Houston freeway

With low-rise building coverage (typically one- to two-stories) and an expansive growth pattern, the region's heat island phenomenon was viewed in the heat island planning process described here as a two-dimensional, rather than three-dimensional phenomenon. Houston's urban densities have varied somewhat, as shown above, but decadal averages have been roughly 2,600 people per mi^2 (6,704 per km^2). The decades of the 1980s and 1990s experienced increasing population densities and recent levels of central city development and redevelopment will push these densities higher.

Average housing unit sizes in Houston (across all housing types), as in other U.S. cities[5], have increased greatly since 1960, but housing lot sizes on average have remained relatively constant in size (although there has also been growth in exurban large lot development).

Air Quality: The Houston region is in violation of U.S. national air quality standards for ozone. The hot, humid climate coupled with major industrial emission sources and climate conditions combine to produce higher ozone levels on many days during the year, currently exceeding standards on 20 to 30 days. Higher temperatures from urban heat island effects generally aggravate ozone formation in Houston if and when other climatic and emissions factors are present – sunlight, reactive volatile organic compounds (VOCs), and oxides of nitrogen (NOX).

Although there is an established relationship between urban heat island effects and air quality, the complexity of urban heat island phenomena, the state of meteorological and air quality modeling tools, and the regulatory process make it difficult to include heat island countermeasures specifically for air quality credit within a State Implementation Plan.[6 7 8 9 10 11]

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[4] D. Streutker, "A study of the urban heat island of Houston, Texas," Rice University, Ph.D. Thesis, (2003).

[5] Single family residential units in 1950 in the U.S. averaged 1,100 ft^2 (102 m^2) and by 1995 had almost doubled in size to 2,000 ft^2 (186 m^2). Phillips, D.L., Lucy, W.H., Tomorrow's Cities, Tomorrow's Suburbs, APA Planners Press, 1-932364-14-5, 2006.

[6] Nielson-Gammon, J.W., The Houston Heat Pump: Modulation of a Land-Sea Breeze by an Urban Heat Island, The Tenth Penn State/NCAR MM5 Users' Workshop Mesa Laboratory, NCAR, 2000

[7] Jin, M and Shepherd, J.M., Inclusion of Urban Landscape in a Climate Model, BAMS, American Meteorological Society, May 2005, p. 681-689.

Global Warming and Climate Change: To date, global warming and climate change issues have not guided urban heat island analysis and planning in the Houston area. Other driving forces, such as those mentioned above, have offered greater potential for consideration of heat island countermeasures. Carbon sequestration through urban forestation is the one exception, although it has been only tentatively explored as a potential heat island countermeasure.[12]

HARC has been involved in global warming issues as they pertain to urban heat island effects since 1999.[13] In the early 1990s, HARC published two volumes on the regional impacts of global warming.[14]

III. Policy Framework for Houston's Urban Heat Island Activities

Air Quality: The U.S. Clean Air Act (as currently amended) requires the Houston region to meet the federal eight-hour ozone standard by 2010. The State Implementation Plan (SIP) that sets forth how this standard will be reached will be completed in 2007 to achieve the standard by 2010.

Urban heat island mitigation was included in a previous SIP, but was found to lack sufficient substance for quantification and implementation. Due to the continued lack of modeling and data on Houston's urban heat island effects, it is unlikely that the state will include comprehensive heat island provisions in the upcoming Houston SIP.[15] However, incremental mitigation measures, such as tree shade for energy savings or reflective roofing, could be included based on reduced energy consumption (energy efficiency), rather than heat island mitigation.

Energy Policies: Several state energy policies will affect heat island mitigation measures. In 2003, Texas adopted a statewide energy code for all new construction and substantial reconstruction of residential and commercial buildings.[16] Until this, Texas buildings codes have been typically confined to municipal governments only. In 2005, the Texas legislature mandated the development of methods to quantify air emissions benefits of various energy efficiency measures.[17] Air quality regulations and policy practices require rigorous quantification of the effects of an air quality control measure. As such, the development of such measurement and modeling protocols is essential.

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[8] Byun, D., Kim, S.-T., Czader, B., Cheng, B., Stetson S., Nowak, D., Bornstein, R., Estes, M., Modeling Effects of Land Use/Land Cover Modifications on the Urban Heat Island Phenomenon and Air Quality in Houston, Texas, Texas Environmental Research Consortium, Project H17A, June 30, 2005.

[9] Stoeckenius, T., Emery, C., Souten, D., Development of an Ozone Precursor Emission Reduction Credit Program Based on Urban Heat Island Mitigation Measures, ENVIRON International, prepared for Gary Geo, Environmental Affairs Department, City of Los Angeles, May 24, 2001.

[10] Bond, J., Davey Resource Group, The Inclusion of Large-Scale Tree Planting in a State Implementation Plan A Feasibility Study, http://www.treescleanair.org/policymakers/studies/FeasibilityStudy.pdf, March 2006.

[11] Web link for reports on air quality and trees, http://www.treescleanair.org/DocumentIndex.htm, Davey Resource Group, Urban Tree Cover and Air Quality Planning, June 29, 2006.

[12] Greater Houston Partnership and the Houston Advanced Research Center, Carbon Sequestration Workshop, http://www.houstonregionalforest.org/Events/CarbonWorkshop, June 29, 2006.

[13] Sustainable Enterprise Institute and the Houston Advanced Research Center, Workshop Summary Report, Houston Cool and Green Workshop, *A Workshop on Climate Variability in the Houston Region* May 24 and 25, 1999.

[14] Schmandt, J. and Clarkson, editors, J., The Regions and Global Warming: Impacts and Response Strategies, HARC Global Changes Strategies, Oxford University Press, 1992, and North, G., Schmandt, J. and Clarkson, J., editors, The Impact of Global Warming on Texas, University of Texas Press, Austin, 1995.

[15] All urban heat island mitigation measures proposed have been dropped from the draft air quality control measures being considered. Other opportunities for inclusion will occur before the SIP is finalized, however.

[16] 2000 International Residential Code (IRC) and the 2000 International Energy Conservation Code (IECC)

[17] 78(R) HB 2129, http://www.capitol.state.tx.us/tlo/79R/billtext/HB02129F.HTM

In the private and non-governmental sectors, the Greater Houston Builders Association has adopted green building practices (GHBA Green Building Initiative) that include energy efficiency measures for residential development and buildings, including heat island mitigation.[18] The Initiative launched in 2005 is based on a LEED-type[19] rating system for participating builders with training workshops beginning in 2006.

The U.S. Green Building Council's Houston chapter has been instrumental in the adoption of green building policies and practices by local builders, developers and local governments. With the Chapter's encouragement, the Houston Mayor and City Council adopted a 2004 resolution "to establish the U.S. Green Building Council's LEED certification as a standard for new or replacement facilities and major renovation of City of Houston owned buildings and facilities with more than 10,000 square feet of occupied space."

Green Infrastructure Policies: Trees and other vegetation play a crucial role in the region's climate, thermal characteristics, air quality, urban water runoff, and what is frequently referred to as *quality of life*. With Houston's flat topography and expansive urban setting, the region's green infrastructure provides part of Houston's identity.

The general public, government officials and community leaders frequently express concern over the loss of vegetation due to urban development. However, the area's *laissez-faire* view of government coupled with active opposition to governmental regulations[20] leave fewer options for responding. In recent years, green infrastructure policies have been adopted by governmental agencies. These include extensive roadway plantings, revised local government landscape ordinances, and visible support for tree planting and for reducing tree loss in the development process.

The *Green Ribbon* program of the Texas Department of Transportation requires that 0.5% to 1% of roadway construction funds be used for landscaping. In 2005, Houston's leaders acquired $22.8 million from the federal government for freeway landscaping. The Harris County Toll Road Authority, which manages 83 miles of freeway, has also adopted an aggressive tree planting policy along its rights-of-way. The Harris County Flood Control District, with a mission of reducing flooding damage, has adopted green infrastructure policies for urban runoff management, including an aggressive tree planting and conservation program. The District manages 2,500 miles (4,023 km) of land along the 1,500 watershed channels that drain Harris County's 1,756 mi^2 (4,548 km^2).

IV. Strategic Plan for Heat Island Mitigation – Cool Houston!

The *Cool Houston Plan* was prepared to provide the Houston region with a ten to fifteen year strategy for mitigating urban heat island effects at the regional level. HARC had been involved for several years with climate change and urban heat island issues at scientific, technical and program levels. As a non-profit, non-governmental research-based organization, HARC provides an objective, non-advocate position view of such issues. Following two HARC-sponsored regional urban heat island workshops, the need for a formal document was identified that would inform decision-making and help guide mitigation actions.

Because of the diverse target groups for each of the plan components, the plan is organized for cool paving, cool roofing and *cool* trees. The outline of each plan component is: (1) a stated

[18] However, heat island mitigation is not specifically referenced in this guidance.
[19] LEED – Leadership in Energy and Environmental Design
[20] It is often noted that Houston is the only major U.S. city with no zoning ordinance, although there are numerous development controls in place and private deed restrictions often accomplish some of the same purposes as zoning.

achievable goal for each of the three mitigation components, (2) measures of each component as they exist in the Houston region, (3) information and metrics on mitigation technologies, (4) description of benefits – quantified where possible, and (5) proposed actions and strategies.

The first four components are factual, understandable, and objective. Element 5, the proposed actions and strategies, relies on the first four components and an internal strategic logic.

STRATEGIC LOGIC OF PLAN COMPONENTS

Focus on What Changes: In studying surface characteristics, it was understood that urban surfaces change in a dynamic and somewhat predictable pattern. If a regional surface change strategy is to be pursued, the magnitude of the task demands that any strategy should focus first on those surfaces that change more frequently. For example, some surface pavings in Houston (such as driveways and local residential streets) are rarely resurfaced over a period of decades. Others are modified as often as five years (for example, parking area resurfacing). Certain types of roofing are replaced or resurfaced over a 5 to 15 year period and in response to less predictable damaging weather events.

Some surfaces and surface materials are modified when maintenance occurs (seal coat sprays on asphalt paving, for example). Of course, new future surfaces are more susceptible to heat island countermeasures, since the surfaces are not yet built, and surface specifications could be applied through regulations, ordinances or other means. The strategy for such new surfaces should then focus on changing the regulations/ordinances rather than the surface itself. The following surfaces were targeted using this approach:

Focus on What Changes – Strategic Components

Cool Paving	
Parking area resurfacing	A large portion of Houston's paved surfaces
New parking areas	Potential application of new ordinances, alternative materials, best practices, and education of contractors
New streets in residential and commercial areas	Potential application of new performance codes for street surfaces
Cool Roofing	
Low slope/flat roofs	Commercial, retail, office, industrial and public buildings with surfaces changing on existing buildings over a 10 to 15 year period
	Multi-family residential building with low slope/flat roofs
Cool Trees	
Residential properties and home owner	The largest urban land cover category; self interest and support by owners/residents; and the ability to act individually with programs or other funding; simple formula: one tree per household per year x millions of households = millions of trees
Business properties with expressed interests	Existing support and experience of benefits
Public properties, particularly large areas	Existing policy support for green initiatives for economic development and quality of life goals with high visibility of trees
Conservation??	The single greatest strategic need for improvement and learning since vegetation loss is by far the greatest challenge

Focus on Who Decides and at What Point: To change surfaces choices for heat island mitigation (once surfaces susceptible to change have been targeted), the focus must turn to who decides on the surface's characteristics. And, to intervene or inform on this decision, the point or points at which intervention/education can occur must be identified. For example, the decision to reroof an existing office building in Houston would be made by the building owner or the manager of that property. This decision would be informed by a roofing contractor, a building architect, or a construction contractor. Opportunities to intervene with heat island countermeasure information on this decision could occur through large membership organizations that participants interact with; for example, building owners and management associations or roofing product associations. Intervention in the decision process might also occur through governmental regulations, such as California's Title 24 cool roofing mandates.

The Cool Houston Plan identifies organizations and methods by which mitigation/counter-measures can be introduced into the decision matrix in the Houston region to change the results.

Focus on Systemic, Extensive, and Massive Urban Surfaces Change*:* Cities have taken decades or centuries to change the area's temperature, rainfall patterns, and other climate variables that result from urbanization. The idea of reversing these effects in shorter time spans is daunting. If such changes are envisioned through heat island countermeasures within a 10 to 20 year time frame, large, systemic changes are essential. The Cool Houston Plan seeks these kinds of changes within the existing policy, decision, and technology structure.

An example of systemic change is the proposed shift from current roofing surfaces to reflective and/or green roofs. This systemic change could be accomplished in the Houston region through a regulatory mandate, which would likely occur through state legislation, not local codes. Such roofing, compared with other countermeasures that could be applied to change surface characteristics, is technologically and economically feasible, with sufficiently positive benefits to bring about various market transformations. Changing more than one hundred local building codes or increasing consumer awareness in among millions of consumers would be slow, resource intensive, and uncertain. Such a regulatory mandate could not be imagined without others, such as California and Chicago, pursuing such measures.

Replacement technologies for paving and cool tree alternatives are not as readily available for systemic, extensive, massive surface transformations. However, systemic changes in these areas might consist of straightforward proportional changes in surface areas rather than replacement technologies – for example, reducing pavement widths, reducing parking requirements, and reducing grass lawn areas through use of *cooler* plants and vegetation.

Systemic changes in such areas might also be brought about through market measures that better incorporate externalities for inefficient land cover, inefficient buildings, wasteful development practices, and undervalued vegetation (e.g., water detention for flood prevention, carbon sequestration, property valuation/tax values associated with trees).

V. POLICIES TO ADVANCE URBAN HEAT ISLAND COUNTERMEASURES

Texas State and Local Policies: Some state and local policies in Texas have been identified in this paper that are supportive of urban heat island mitigation measures, including building energy codes, green infrastructure investments/policies, and energy efficiency and utility regulations. Such policies provide rich opportunities for expansion and improvement to better achieve UHI mitigation.

The phrase and concept of *urban heat island effects* is more frequently used today in Texas local and state policy language and debate, suggesting some conceptual awareness. However, the concept is not used alone, but as part of related measures, such as energy efficiency, urban green space, or development impacts. In addition, it has not been applied as a comprehensive measure. No existing state or local policies in Texas are designed as urban heat island policies or programs.[21]

UHI strategies that are incremental rather than comprehensive, such as cool roofing requirements or tree shade programs for energy savings, may have greater potential for incorporating in many state and local policy processes. However, these are unlikely to produce measurable reductions of the urban heat island phenomenon over the periods of time included in the Cool Houston strategies (10 to 15 years). They are helpful in raising awareness among decision makers and illustrating potential.

State and local policies that are related to UHI effects have tended to focus on single rather than multiple issues and measures. Urban heat island countermeasures are relevant across several issues – air quality, green space, building materials, energy codes, utility policies, etc. – which makes coordinated or comprehensive policies extremely complex.

Regional and International Variation and Policy Considerations: Within one country or one state, urban heat island effects can be dramatically different and ensuing implications for UHI mitigation policies. For example, the UHI/air quality nexus for the Houston region is much different than that found in the Dallas/Fort Worth region. Two factors alone – climate and air emissions' characteristics – suggest such a difference. However, the same mitigation strategies may succeed. Across the U.S., one urban region will benefit with energy savings from UHI mitigation while another region experiences improved air quality. Despite this complexity, the opportunities seem rich for UHI mitigation due to the convergence of several concerns and conditions. The conditions for such changes include:

- Energy supplies, prices, and the subsequent effects across economic, political, and cultural levels
- Green building practices as a standard rather than the exception
- Technological innovations, including information technologies and much more rapid diffusion of innovations
- Growing inclusion of UHI effects as part of policy development
- Visible and measurable urban climate change effects as part of global warming concerns

Suggestions for International Activities

Policy Leader Awareness	Support common efforts to increase policy leader awareness about UHI effects and countermeasure. UHI countermeasures can be incorporated in many different policy arenas. However, policy leaders need adequate awareness and understanding of UHI concepts and tools for their commitments to act.
Timely Response to Policy Events	Develop and respond to emerging opportunities for policy discussions. The policy arena shifts rapidly over time, and responding with relevant information and data increases the likelihood of adoption of suitable UHI countermeasures.
Networking Across Targeted Common Interests	Widen and target participation in related events and conversations. The target audiences of UHI countermeasures span a wide spectrum of interests, requiring a targeted, but wide network of interaction.
Information Sharing	Expand information sharing on UHI countermeasures. Ongoing and relevant information sharing of experience and knowledge in other national settings is helpful to other nations, as well as cities, states, and NGOs.

[21] See examples, Hitchcock, D., Urban Heat Island Policies, Cool Pavement Conference presenation, Arizona State University, April 2006, http://www.asusmart.org/smart/Publications/Presentations.jsp