DALLAS URBAN HEAT ISLAND

DALLAS SUSTAINABLE SKYLINES INITIATIVE

Prepared by:

Houston Advanced Research Center

Prepared for

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THE SUSTAINABLE SKYLINES INITIATIVE

The Sustainable Skylines initiative is a three-year partnership between the City of Dallas, the U.S. Environmental Protection Agency, and the North Central Texas Council of Governments to promote sustainability within the City via voluntary programs which emphasize air quality improvements.

The Sustainable Skylines Initiative (SSI) at EPA provides a framework that, when implemented in an area, can achieve measurable emissions reductions and promote sustainability in urban environments. Under the SSI, an area can choose to perform projects from seven categories: central city livability, stationary and area sources, energy and climate change, land use transportation strategies, diesel engines emission reduction, green building and green building development, and off-road/non-road sources (emission reductions).

HOUSTON ADVANCED RESEARCH CENTER
4800 Research Forest Drive • The Woodlands, Texas 77381 • http://www.harc.edu

HARC is a 501(c)(3) not-for-profit organization based in The Woodlands, Texas dedicated to improving human and ecosystem well-being through the application of sustainability science and principles of sustainable development. HARC's mission is to move knowledge to action to improve human well-being and the environment.

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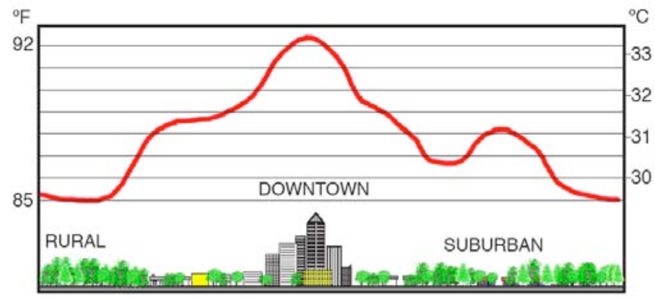
This report was prepared as part of the Dallas Sustainable Skyline Initiative, a project of the U.S. Environmental Protection Agency.

The report describes Dallas urban heat island effects and options that could be implemented to help reduce these effects.

Many people understand from their own experience that cities are often hotter than rural areas. Research suggests a difference of 6 to 8ºF. As cities develop, trees and vegetated areas are reduced, natural surfaces are paved, and buildings constructed. Together these changes produce the "*urban heat island effect*" illustrated in Figure 1.

Figure 1. Urban Heat Island Effect



Dallas has recognized heat island concerns in plans and discussions, and there are several references in the 2006 Dallas Comprehensive Plan, *forwardDallas!* The plan's *Vision* mentions the heat island effect as a component of policies to help ensure environmental stewardship.[1] Heat island policies are also found in other sections of the plan.

> "Central to this Key Initiative is identifying, inventorying and protecting important natural resources, sensitive ecosystems, open spaces and cherished views. Included are *policies to mitigate the urban heat island effect*, improve storm water management within the city, reduce smog, expand the absorption capacity of floodplains and allow the restoration and rehabilitation of Trinity River riparian corridors." (emphasis added)

The Dallas Urban Heat Island Study examines how and where heat island effects occur in Dallas and some of the basic tools for reducing impacts, such as expanded tree planting and conservation, use of cool roofing, and application of cool and porous paving. The study describes costs and benefits associated with these tools.

FORMATION OF URBAN HEAT ISLANDS

Urban heat island effects were recognized in the 19th century by climatologists who measured differences in city temperatures and the countryside. Current urban development practices often start with removal of trees and other vegetation. This reduces the cooling effects provided by vegetation and moist soils. This also adds buildings, rooftops, and pavement that absorb, store, and then radiate heat. In areas with tall buildings and narrow streets, heat can be trapped and airflow reduced. In addition, waste heat from air conditioning, vehicles, and industrial processes adds further to the city's heat load.[2]

THE DALLAS URBAN HEAT ISLAND

An urban heat island is often thought to be a summer daytime event, but in reality its most common occurrence is generally before sunrise (Figure 2). At that time, the difference between urban and rural temperatures is often at its peak. There are two basic types of heat islands: *surface* and *atmospheric*. Surface temperature differences occur primarily in the daytime and can range from 18 to 27ºF. Atmospheric differences are primarily at night and can range from 13 to 22ºF. A study of Dallas and Houston found that urban summer nighttime temperatures (atmospheric) were almost 4ºF warmer than rural temperatures (averaged over 2000 to 2006). The greatest differences occurred around 6 a.m. During the day, urban temperatures averaged almost 2ºF warmer.[3] The same study showed that the Dallas daytime heat island was more evident than Houston's.

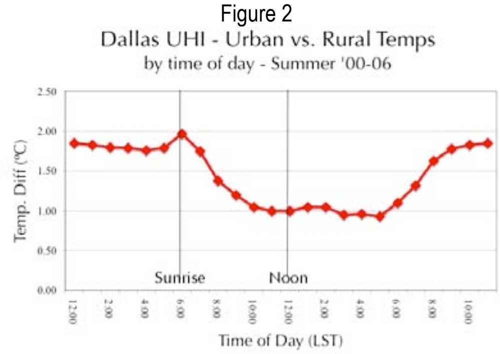
Table 1.
Average Land Cover in U.S. Cities

Surface	Percent	Temp Range ºF
Pavement	40%	120-140º
Roofs	22%	150-190º
Vegetation	26%	120-140º
Other	12%	na

LAND COVER AND HEAT ABSORBING SURFACES

As land is urbanized, the size of the urban heat island often grows at a similar or faster pace. A study of Houston calculated that its surface heat island increased in geographic coverage by over 38% in the 15 years following the mid-80s, expanding at a faster pace than population growth.[4]

Figure 2



URBAN SURFACE CHARACTERISTICS

Pavement and buildings occupy over half of the developed surface areas of cities. As shown in Table 1, pavement on average in U.S. cities covers 40% and rooftops 22%.

Commercial and residential areas shown in Figures 3 and 4 are examples of urban surfaces in Dallas. The commercial area (Figure 3) consists almost entirely of pavement and rooftops with an average area surface temperature of 140ºF (from thermal analysis in this study).

Figure 3. Dallas commercial site

Two adjacent single-family residential areas developed more than 50 years apart illustrate how tree cover changes over time in urban development. The area on the left was developed in the last three to five years and the other area over 50 years ago. The older area has extensive tree cover, narrower streets (less pavement), and more areas suited for tree cover (larger lots, deeper setbacks). Both areas have alleys and sidewalks.

IMPACTS OF URBAN HEAT ISLANDS

Higher temperatures add to the critical challenges facing Dallas, including rising energy costs, air quality, and health. Higher temperatures require more electricity for air conditioning, with the highest summertime temperatures coinciding with peak electricity demand. For Dallas, the cost of additional electricity from urban heat island effects likely amounts to several hundred million dollars per year based on estimates for other cities.[5] Widespread heat island mitigation measures, such as cool roofs and extensive tree planting, could produce energy savings of $40 to $50 million annually.[6] These savings would be offset somewhat by the costs of implementing these measures, but the net benefit would be substantial.

Figure 4. Newer and older single family residential areas in Dallas

Higher temperatures are also associated with higher levels of ozone, the key pollutant of concern for the Dallas-Ft. Worth area.[7] Higher temperatures also increase evaporative emissions of volatile organic compounds, such as gasoline, while forcing biogenic emissions from trees to higher levels.[8] VOCs are a key ingredient in ozone formation. Estimates from the heat island Mitigation Impact Screening Tool (MIST) suggest that a 1ºF temperature reduction could reduce ozone by as much as 1.2 parts per billion (ppb), equal to 1.6% of the new federal 8-hour ozone standard of 75 ppb.

Higher temperatures, particularly during heat waves, are of concern for human health. Heat related illnesses occur during such events, even in Texas where there is more adaptation by people and buildings to higher temperatures than in cooler climates. Dallas experienced extended heat waves in 1980, 1996, and

1998 with several weeks of 100º and higher temperatures. Accompanying increases in heat related health impacts included at least 23 reported deaths in the 1998 event.[9]

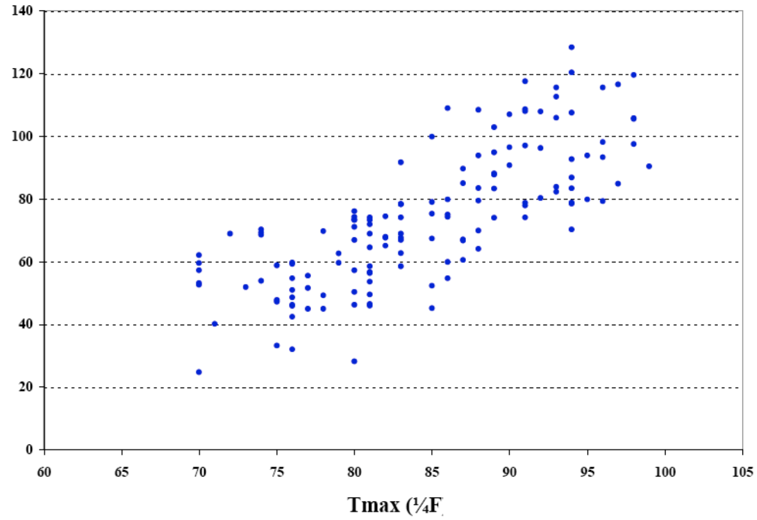
Reducing urban heat island effects can reduce these impacts while providing other benefits. For example, adding trees helps cool the city and, at the same time, assists in the control of urban runoff, improves the quality of life, sequesters carbon emissions, and contributes to human well-being. Cool roofs help cool the city by reflecting solar radiation, and can pay for themselves quickly through energy savings, particularly for older, less energy efficient buildings. The "cooling impacts" of such roofing are essentially free at the same time that the economic viability of the building is improved.

Dallas Air Quality

Ozone is formed in the atmosphere by interactions of volatile organic compounds (VOCs) and oxides of nitrogen (NOx).

Sunlight and heat are part of this equation, with higher temperatures often producing higher concentrations of ozone.

Figure 5.
Scatter plot of daily 8-hour peak ozone over the Baltimore Non Attainment Area versus the daily maximum temperature at BWI Airport for the year 2002 (May-September, N=138, Tmax ≥ 70ºF).[10]



DALLAS SURFACE TEMPERATURES

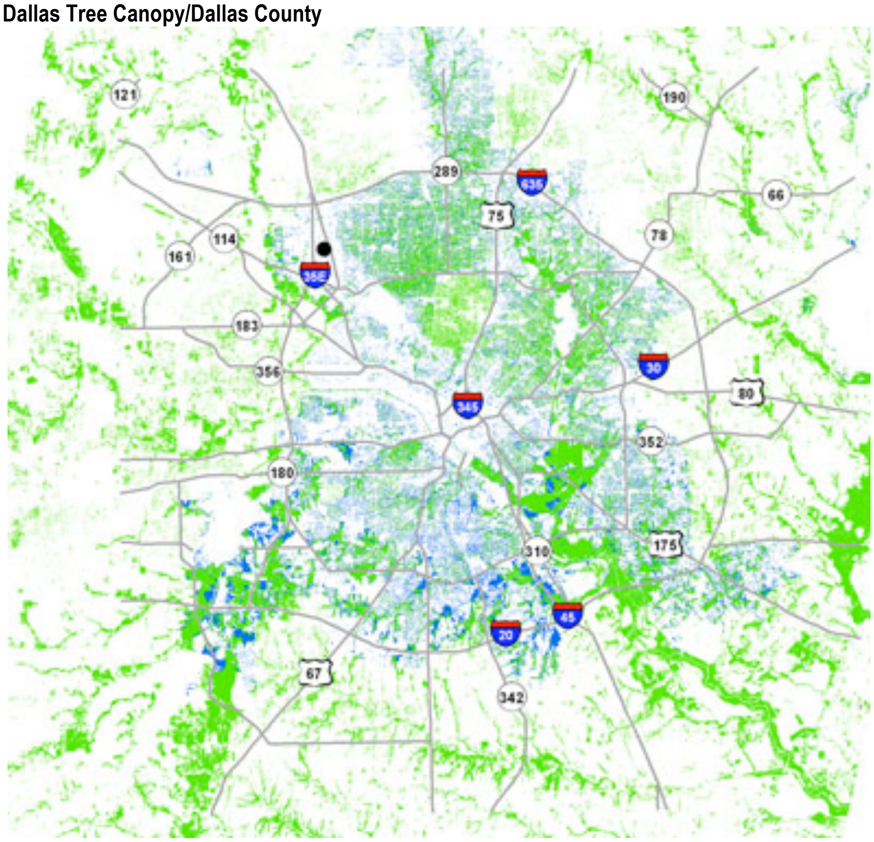
The most prominent high surface temperature areas as shown in Figure 8 include: (1) an area extending northwest from downtown Dallas northwest along the Stemmons Freeway, (2) the two major airports, DFW and Love Field, and (3) several large industrial and warehousing areas. There are also large outlying areas where bare soils reach high temperatures during the day (large, plowed unplanted agricultural areas). It may seem surprising that central Dallas temperatures are lower than some of the outlying areas. This illustrates one of the differences between surface temperatures, which are time-specific and localized, and the urban heat island effect, which is a more complex phenomenon that includes surface temperatures as one component. Surface temperature imagery used in this report provides a useful indicator of urban heat island conditions.

Higher surface temperatures in the warmest part of the day will be found wherever exposed, unshaded pavement and rooftops exist. Some paved surfaces and rooftops cool more quickly after sunset than vegetated areas due to their thermal properties, such as emissivity (the ability of a material to release heat energy) and thermal mass. Surfaces may release heat more quickly after the energy source (the sun) is gone (after sunset). In addition, horizontal and vertical air movement affects overall temperatures.

The cooler daytime surface areas are due primarily to the Dallas urban tree canopy and wetter areas along waterways, such as the Trinity River and all of its tributaries. In general, the more tree cover, the cooler the daytime surface temperatures. Areas with older, larger trees do not reflect a great deal of solar radiation, but shade surfaces that would otherwise absorb and store this energy. In comparison, the air temperature in heavily vegetated urban areas (as opposed to surface temperatures) may stay somewhat warmer during nighttime in the summer due to reduced airflow.

At a more detailed level (Figure 7), hotter surface temperatures can be found throughout the city. These occur in association with commercial areas, schools, and even parks. These smaller "hot spots" exist wherever large exposed expanses of heat absorbing surfaces are found.

Figure 6
Dallas Tree Canopy/Dallas County

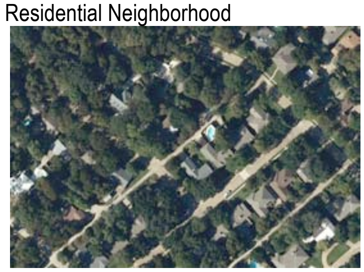


SURFACE COVER IN DALLAS

These two maps illustrate the major features of Dallas that affect the urban heat island – impervious surfaces such as paving and rooftops, and the tree canopy.

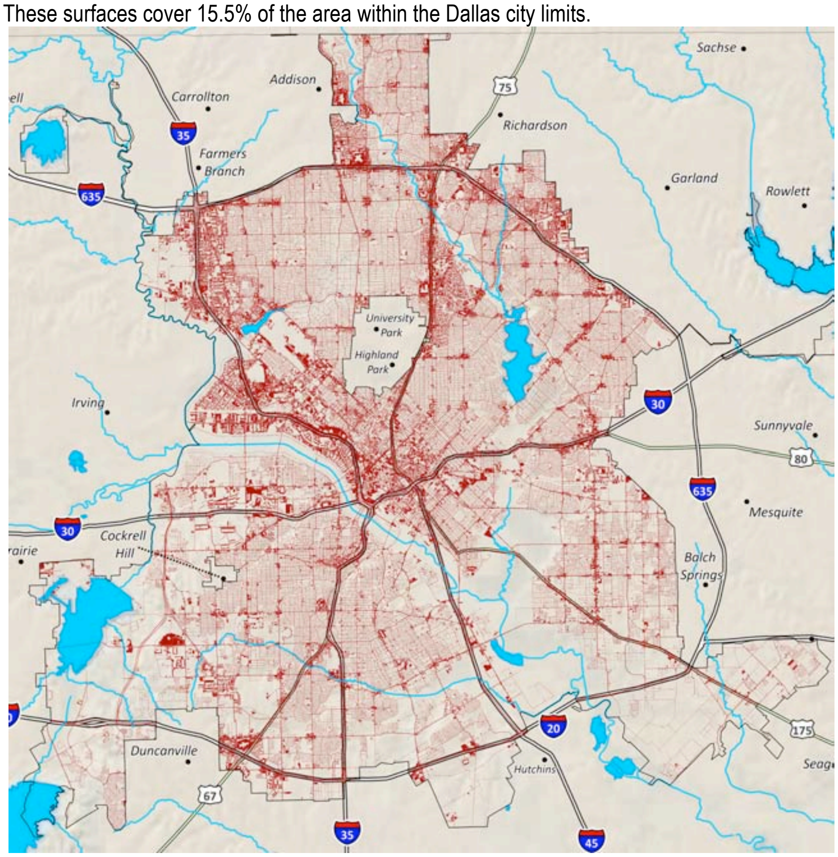
Concentrated Tree Cover

Residential Neighborhood



Area Parks

Figure 7. **Impervious Surfaces**
These surfaces cover 15.5% of the area within the Dallas city limits.



Concentrated Areas of Impervious Surfaces

Retail Center

Industrial Area

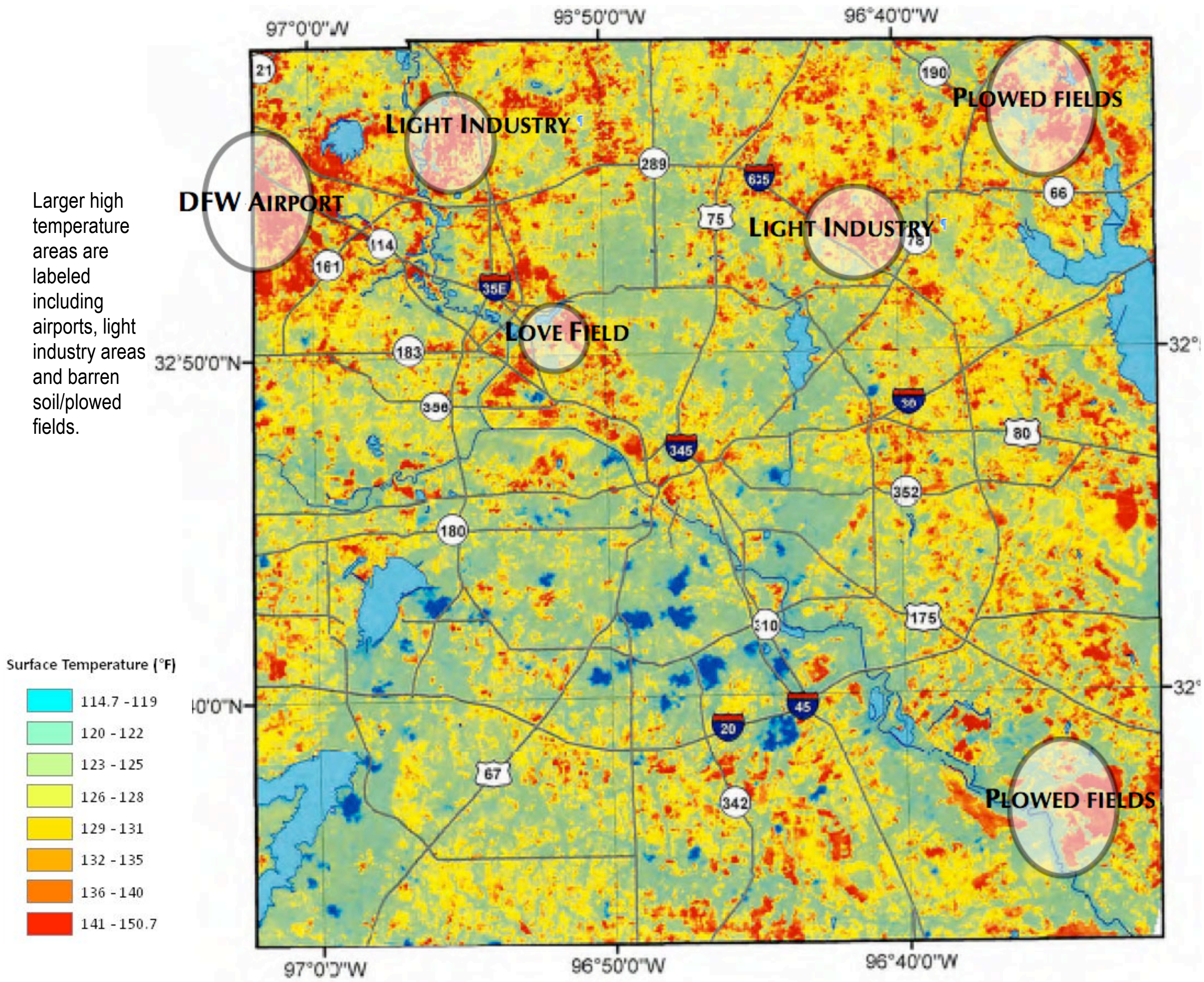


Figure 8
Dallas Surface Temperatures
Kinetic Thermal Corrected Aster Image – September 28, 2006, 5:25 pm

This thermal image of Dallas County surface temperatures was developed from 2006 ASTER satellite imagery . The hotter surfaces, shown in red, range upwards above 150ºF. The light blue-green areas are cooler, more vegetated areas, as seen along the Trinity River Basin. The dark blue areas are cloud cover that was present at the time the images were taken.

Surface Temperatures and Air Temperatures

Air temperatures are usually measured at about 5 feet above the ground, where standard weather observations are gathered, such as DFW International or Love Field. There are not enough locations in most cities to adequately measure the variety of temperatures that occur across the city. Surface temperatures from satellite data show a snap shot in time of various surfaces, particularly flat, horizontal surfaces of rooftops and pavement. Some surfaces, such as barren soil and plowed agricultural land have high temperatures, but change rapidly as crops are grown or soil moisture changes.

REDUCING DALLAS URBAN HEAT ISLAND EFFECTS

"Everyone talks about the weather, but no one does anything about it." When Charles Dudley Warner, the 19th century author made this statement, he was likely unaware of how urban climates have been altered. Urban heat island effects include not only higher temperatures, but also rainfall locations and patterns, windflow, and moisture levels.

Heat island effects are primarily due to the way cities are built and the key surface characteristics. Urban surfaces can be changed to reduce these effects. The primary ways of accomplishing this are:

SURFACE CHANGES REDUCE URBAN HEAT ISLAND EFFECTS

Trees	Substantially increased tree cover and vegetation to provide shade and natural cooling due to evapotranspiration
Cool Roofs	Use of roof surface that reduce heat absorption through higher reflectivity or with green roofs
Cool Pavements	Use of pavement surfaces that are more reflective or that minimize impervious surfaces

There are other approaches being analyzed, such as reducing waste heat from air conditioning or industrial processes. Even reducing motor fuel use (gasoline and diesel) reduces heat that is generated by car and truck engines. From an efficiency and engineering standpoint, waste heat is energy that could have been used for more beneficial purposes than making the city hotter.

Fortunately Dallas has already recognized many of the principles of urban heat island mitigation in its plans and regulations.

Changing a city's overall temperature is challenging and requires a longer term view and a thorough consideration of the additional benefits that result from mitigation measures. As an example of the magnitude, a multi-city study estimated that almost one million additional trees would be needed in the Dallas/Ft. Worth region to reduce the hottest areas by 1ºF.[11] However, based on a per capita distribution of such planting, the Dallas portion would be smaller. In addition, the time frame for expanding the Dallas tree cover would need to be considered, such as adding trees over a five-year period or setting an equivalent annual tree planting goal. Urban heat islands have been created over decades, and solutions will also take time.

Technologies and methods are available for the most part. *Trees* provide an effective strategy that is welcomed by most. The effects of trees are fairly well understood, they are commonly used, and they are available today. In addition, trees offer many other economic and community benefits, summarized below.

Cool roofing technologies exist for many building applications. This includes highly reflective roofing as well as newer roofing products that increase reflectivity through changing pigment chemistry to reflect infrared rays in the solar spectrum. *Green roofs/rooftop gardens* are also attractive for many applications, although less common in the U.S.

Trees are embedded as a singular feature throughout the Dallas Comprehensive Plan, forwardDallas!.

Cooler, more reflective pavements are already in common use in Dallas, and there are ways of improving their effectiveness further. Many types of *porous or permeable pavement* materials are also available that provide unique attributes to help cool the city while managing stormwater runoff. Engineers and developers are not as familiar with porous paving materials as with more commonly used pavements. There is less field experience that is needed to help overcome uncertainties about such materials.

INCREASING THE DALLAS TREE CANOPY

Dallas has a large and vital tree canopy, and conditions for tree growth are good in most parts of the city, as evidenced by existing tree cover. However, much of today's urban development and redevelopment begins with clearing tree cover and vegetation. Trees are an effective and inviting addition for Dallas, while

Figure 9: Dallas School with Cool Reflective Roof

helping to counteract urban heat island effects. The challenge is to increase tree cover, while also conserving and protecting the existing canopy.

Dallas is currently planting, protecting, encouraging, and requiring trees as part of the urban environment. This report outlines additional options that can be considered for enhancing the Dallas tree canopy. Air temperature data collected across the city in Portland, Oregon found that "the most important urban characteristic separating warmer from cooler regions was (tree) canopy cover, regardless of day of week or time of day." [12]

IMPLEMENTING COOL ROOFS AND GREEN ROOFS

Roof surfaces play a large role in heat island mitigation since they cover 20 to 30% of development, and they reach higher temperatures than other surfaces. In commercial and industrial areas, these percentages are even higher. Residential roof surfaces play an important role since they can account for more than half of the total roofing area.

Roof colors and the type of roofing material have the greatest effect on roof temperatures, which rise to more than 150ºF. on clear days. The added thermal load on air conditioned buildings can increase demand for electricity, produce higher peak demand from the electric power grid, and possibly accelerate deterioration of the roof and rooftop equipment.

Cool roofing materials widely available today are highly reflective and installed primarily on low-slope (flat) roofs. Dallas has included cool roofs in recent building code revisions aimed at environmental and energy improvements. There are also cool roof products for sloped roofs, including various tiles, coated metal roofing, and, more recently, reflective asphalt shingles. California has incorporated cool roofs into its statewide building code for low-slope roofs, and is considering requirements for sloped roofing, which would affect the residential roofing market.

Green/garden roofs incorporate vegetation into the roof assembly. A green roof cools the building by shading the roof membrane, which keeps out moisture, and also cools the roof through evaporating moisture from plants and the engineered soils holding the plants. Water quality and management have been the primary driving forces for green roofs in U.S. cities and in Europe. Energy savings and building standards are becoming more important in this regard.

Due to repair or replacement, low-slope roof surfaces are replaced or substantially changed as often as every ten to fifteen years. Maintenance can include changes in surface color and reflectivity over even shorter intervals of five to six years. As such, changing most roof surfaces is achievable in a ten to fifteen year period. Older, less energy efficient buildings particularly benefit from cool roofing energy savings.

Figure 10. Open mesh porous paving supporting vegetative cover

CHANGING PAVEMENT SURFACES: COOL PAVING

Paved surfaces are the largest portion of urban surfaces, averaging 40% in U.S. cities. This includes streets and roadways, but also parking, driveways, sidewalks and other impervious surfaces. Most paved surfaces change at less frequent intervals than roofing, but cool paving can be incorporated in new development or possibly as maintenance occurs. Some paving maintenance and resurfacing occurs at more frequent intervals, providing additional opportunities for creating cooler pavement surfaces. Redevelopment can also include changes to parking design and characteristics.

Cool paving technologies have a more reflective surface and may also include permeable pavements, which allow water to flow through creating a cooler surface. They can include cement or asphalt concrete paving and overlays, and many types of pervious/porous paving products.

Reflective pavements that use lighter color aggregates or bonding agents can be 15% to 30% more reflective. They can reduce surface temperatures by more than 20ºF. However,

Figure 11. Chip Seal Overlay with Reflective Aggregate

higher reflectivity also reduces nighttime lighting requirements for streets and parking areas.

Pervious, cool paving products are made from conventional cement and asphalt sources, but also include a wide variety of other technologies that include pavers, structural meshes, turf, and gravel. Pervious paving allows water to drain through, slowing its movement and helping to control urban runoff. It may also improve runoff water quality in other ways, such as reducing the temperature of runoff. If used as part of an area's drainage system, pervious paving may reduce the amount of impervious surface needed for stormwater detention.

Figure 12. Porous pavement

CONCLUSIONS

Dallas has an urban heat island problem that contributes not only to higher temperatures, but also problems of energy use, air quality, human health, and the quality of life. Dallas has recognized these problems and incorporated provisions in plans and regulations to help mitigate heat island effects.

Dallas has available mitigation measures and technologies that include acceptable strategies for adoption, demonstration, and testing. These include:

- Expanded use and care of trees and vegetation that help cool and green the city
- Cool and green roofs that produce energy savings for the Dallas economy while helping to address air quality concerns
- Paving strategies that can reduce solar energy gain, implement various LEED standards, and address stormwater issues

The benefits to Dallas of these measures need to be meshed within a longer term view that incorporates several policies. Dallas leaders already understand from air quality experience that there are no simple quick-fix solutions. Heat island effects are created incrementally year-by-year over decades and more. Similarly, mitigation measures require systematic actions year-by-year to reverse.

OPTIONS FOR URBAN HEAT ISLAND MITIGATION

The following page briefly summarizes options that can be applied to mitigate Dallas urban heat island effects. Detailed descriptions of these options are included beginning on the pages referenced with each set of options.

Options for Trees and the Urban Forest – page 30

Goals
- Establish an overall target for tree planting, such as the "Million Trees" initiatives organized in other cities

Outreach and Education Activities
- Consolidate existing information on city-based tree and urban forest activities within a common framework, such as a new tree planting initiative
- Actively include organizations outside of city government in achieving tree planting and conservation goals.

Urban Forest Management Data
- Initiate an on-going tree inventory program to establish baseline data
- Launch an urban forest analysis project

Funding for Tree Planting and Conservation
- Increase the Dallas Reforestation Fund to leverage additional tree planting and conservation
- Establish capital improvements set-asides for tree planting and landscaping on public projects
- Support establishment of a utility-based, energy savings program to encourage tree planting on private property

Regulations and Incentives
- Include tree planting and conservation in future State Implementation Plans (SIP) as a voluntary control measures
- Modify landscape and tree preservation ordinances to protect larger trees, increase tree placement, and increase trees planting during development

Options for Cool Roofing Actions – page 50

Outreach
- Inform target audiences of cool roof requirements as part of Phase 1 of the Green Building Program
- Through outreach efforts, emphasize the use of cool roofing for all re-roofing of low-slope buildings
- Showcase existing green roofs for their energy and stormwater management benefits

Cool Roof Policies
- Encourage other entities in the region to adopt cool roof requirements and standards
- Consider inclusion of Energy Star cool roof standards for sloped roofs (25% or greater solar reflectance)

Incentives and Regulations
- Include cool roof requirements in the Green Building Program for re-roofing
- Encourage electric utilities to provide cool roof rebates as part of their energy efficiency requirements
- Create specific provisions in building codes for green roofs
- Use stormwater fees to fund demonstration projects for public sector greenroofs and porous paving
- Support explicit inclusion of cool roofs in the State's energy code

Options for Cool Paving Actions – page 71

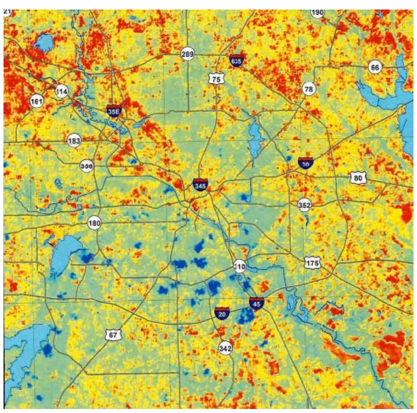
Demonstration and Outreach
- Foster and support cool paving demonstration projects
- Create a database of existing cool paving applications to illustrate current uses
- Provide cool paving product workshops for staff, developers, and builders

Policies
- Create a unified cool paving policy that applies to parking, street medians, and freeways. Incorporate existing policies including:
    - Comprehensive Plan – forwardDallas!
    - Green Building Program
    - LEED Rating System provisions
    - Landscape Ordinance
    - Storm Water Management

Incentives and Regulations
- Provide points in the Green Building program for cool paving
- Ensure supportive provisions in stormwater management regulations
- Add provisions to the zoning ordinance to limit impervious surfaces

forwardDallas! Vision
cooler and greener

Mature Trees



Dallas surface temperatures 2006

EXECUTIVE SUMMARY

Trees help cool the city and, in many parts of Dallas, they are the defining feature. Dallas citizens and leaders are well aware that trees provide important benefits to the city and are a valued asset.[13] For example, *forwardDallas!*, the City's comprehensive plan adopted in 2006, includes trees as a singular feature throughout. In some ways, however, unless trees are threatened, they can be taken for granted.

We know from research that trees add value to property; that human health responds positively to trees and greenspace; that people prefer shopping areas with good landscapes and vegetation; and that trees are an important part of the Dallas quality of life.[14] We also know that areas without trees can be substantially hotter.

> Dallas residents say what they want to change most in the city is its appearance — they want it to look beautiful, with trees and pedestrian-friendly neighborhoods.
>
> forwardDallas! Neighborhood Elements, 2006, p. II-7-1.

This report identifies the role that trees play in cooling the city; it quantifies the benefits; and it sets forth actions to reduce the urban heat island effect through expansion and protection of the Dallas urban tree canopy.

Dallas has a vibrant tree canopy over much of the city, but there are many areas that can be targeted for improvement. Like most growing cities, the Dallas tree canopy is continually challenged by new development and redevelopment. In addition, older and unhealthy trees are lost over time and not fully replaced.

To keep Dallas cooler while capturing the benefits of urban tree cover, the following conditions are needed:

- Identifying new planting areas
- Targeting of area hot spots
- Protecting the existing canopy.
- Adequately replacing trees lost as the city continues to grow

COSTS AND BENEFITS

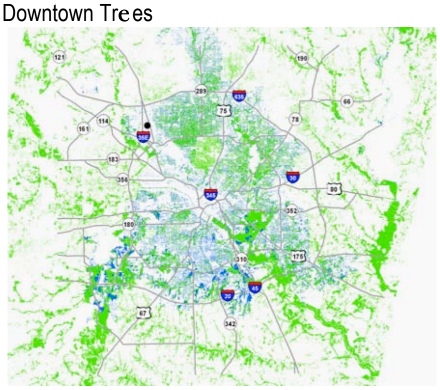
The net benefit of trees has been found to outweigh the cost by as much as three to one. The net annual benefits of street trees have been estimated to range from $30 to $90 per tree.[15] The initial cost of planting new trees can be substantial, ranging from $200 to $400 per tree (Table 8). Cities also incurs costs such as pruning, removal/disposal, litter management, liability, administration and inspection.

Planting costs for tree programs are often shared among property owners, neighborhoods, businesses, and other governmental bodies. The Dallas reforestation fund, the MOWmentum program, and the emerging Adopt-A-Median program are examples.

Economic benefits of the Dallas urban tree canopy are substantial. Studies of other cities suggest the benefits amount to several hundred million dollars annually.[16] This includes benefits such as energy savings, carbon storage, air quality improvements, human health, quality of life, and stormwater management. Loss of trees in the city also means loss of these benefits, making maintenance and reforestation essential.

Tree Lined Residential Area

Downtown Trees



Dallas area tree cover

OPTIONS FOR DALLAS TREES

There are many actions that can be taken for tree planting and conservation. These are described in detail within this report and summarized to include:

GOALS

- Establish an overall target for tree planting, such as the "Million Trees" initiatives organized in other cities

OUTREACH AND EDUCATION ACTIVITIES

- Consolidate existing information on city-based tree and urban forest activities within a common framework, such as a new tree planting initiative
- Actively include organizations outside of city government in achieving tree planting and conservation goals.

URBAN FOREST MANAGEMENT DATA

- Initiate an on-going tree inventory program to establish baseline data
- Launch an urban forest analysis project

FUNDING FOR TREE PLANTING AND CONSERVATION

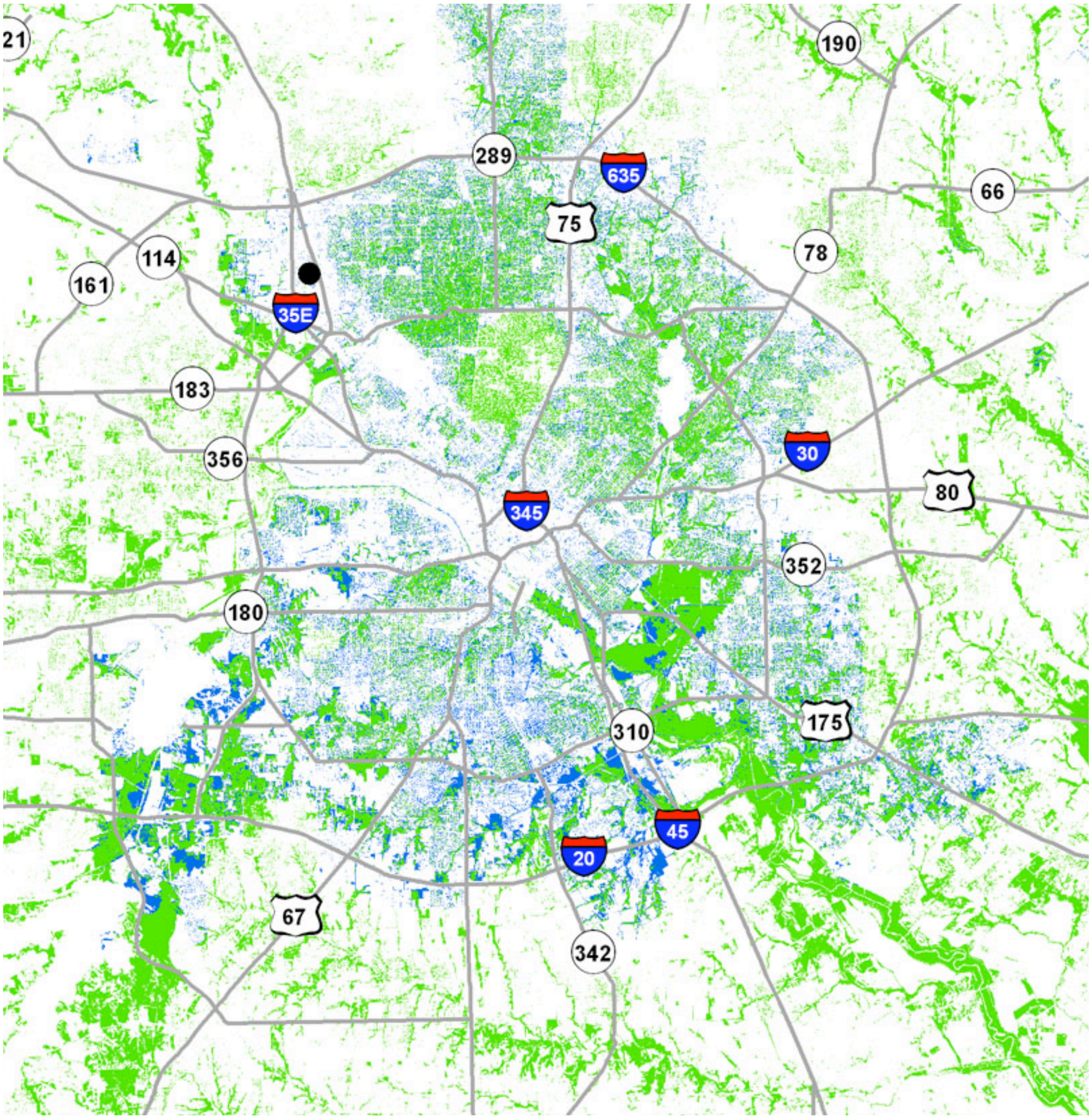
- Increase the Dallas Reforestation Fund to leverage additional tree planting and conservation
- Establish capital improvements set-asides for tree planting and landscaping on public projects
- Support establishment of a utility-based, energy savings program to encourage tree planting on private property

REGULATIONS AND INCENTIVES

- Include tree planting and conservation in future State Implementation Plans (SIP) as a voluntary control measures
- Modify landscape and tree preservation ordinances to protect larger trees, increase tree placement, and increase trees planting during development

Figure T1.

DALLAS URBAN TREE CANOPY



This image of the Dallas County tree canopy was developed from 2006 satellite imagery (green) and higher resolution regional land cover data (blue). Concentrations of trees are found in and around the waterways, creeks, and streams, particularly in the southeast and southwest areas. Developed corridors heading northwest out of downtown have relatively little tree cover.

Within the city limits of Dallas there is an estimated 26.2% tree cover, roughly 90 square miles (footnote 50). Based on estimates from other studies, the canopy likely includes more than 15 million trees with many of these located along the area's watersheds (footnote 51). An assessment of the Dallas urban canopy would provide more accurate measures of the number of trees, species, sizes, and economic value.

Figure T2
HOW TREES COOL THE CITY

Tree shade reduces surface temperatures by blocking the sun's rays, preventing roofs, walls, and paving from absorbing this heat. Roof and wall surfaces have been shown to be cooled by 20 to 45ºF.[17] A car parked in the shade can have interior temperatures that are cooler by 45ºF.[18] Temperatures in large parks can be 5 to 10ºF cooler than other parts of the city. We are cooler in the shade for the same reason; trees are blocking the sun from our skin and clothing.

In addition to cooling through shading, trees cool the city through "transpiration", a process similar to our own perspiration that cools our bodies. Trees draw water through their roots which is eventually released through the leaves. One large tree can transpire thousands of gallons of water per year.

Trees also affect wind speed and flow. A stand of trees may block or redirect the wind. While the cooling effect of breezes may be diminished somewhat, trees may be located so that they direct windflow into area for cooling.

HOW MUCH COOLING FROM TREES?

Tree shade and transpiration combine to lower air temperatures in and around urban areas.

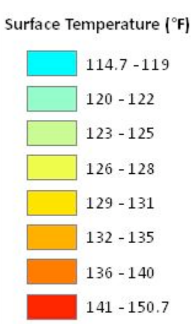
- Peak air temperatures in tree groves that are 9ºF (5ºC) cooler than over open terrain.
- Air temperatures over irrigated agricultural fields that are 6ºF (3ºC) cooler than air over bare ground.
- Suburban areas with mature trees that are 4 to 6ºF (2 to 3ºC) cooler than new suburbs without trees.
- Temperatures over grass sports fields that are 2 to 4ºF (1 to 2ºC) cooler than over bordering areas.

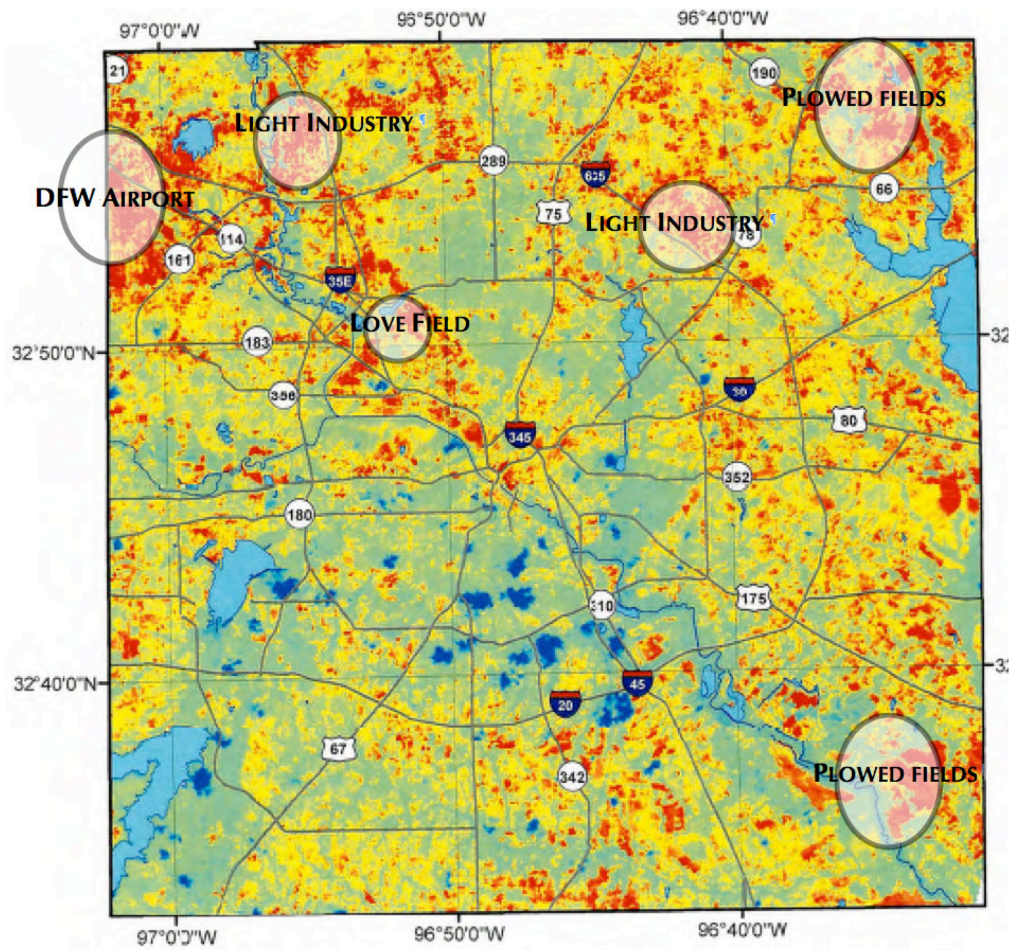
Reducing Urban Heat Islands: Compendium of Strategies: Trees and Vegetation, see http://www.epa.gov/heatisland/

Figure T3
Kinetic Thermal Corrected Aster Image – September 28, 2006, 5:25 pm
DALLAS SURFACE TEMPERATURES

Some of the larger high temperature areas are labeled including airports, light industry areas, and barren soil/plowed fields.

This thermal image of Dallas County surface temperatures was developed from 2006 satellite imagery. The hotter surfaces, shown in red, range upwards above 150ºF. The light blue-green areas are cooler, more vegetated areas, as seen along the Trinity River Basin. The dark blue areas are cloud cover that was present at the time the images were taken.





INTRODUCTION

Trees are a valuable Dallas asset and without them the city would be several degrees hotter. The following section features of the Dallas tree canopy as it pertains to the urban heat island effect.

A. TREE COSTS AND BENEFITS

Trees in Dallas provide many benefits to the city. This section briefly describes the economic and other contributions that trees provide, as well as costs associated with future planting and maintenance of the urban forest.

B. PLANTING TREES FOR HEAT ISLAND REDUCTION

Trees may be planted in ways that provide the greatest level of benefits. This includes locations that shade buildings or parking surfaces, and added tree cover in areas that are predominately pavement and rooftops (e.g., commercial and industrial areas).

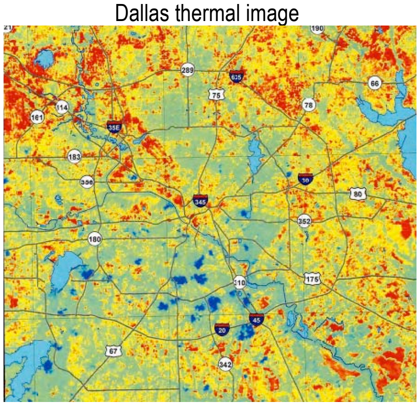
"Plantable areas" are identified as they occur in various types of developments. Those examined here include single and multi-family housing, neighborhood tree cover, various types of retail, office clusters, industrial/warehousing areas, and school sites.

C. OPTIONS FOR HEAT ISLAND REDUCTION

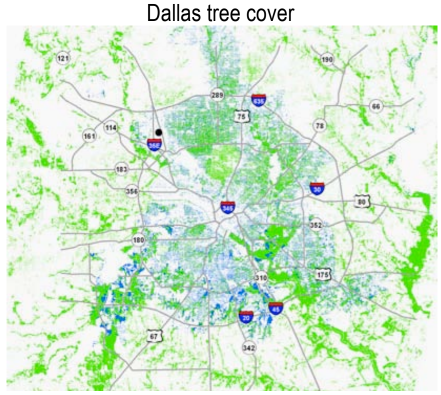
This section sets forth details of ten key options that can consider for use in Dallas for heat island mitigation through expanded tree planting and conservation.

- *People need trees and green space.*
  Gabriel Barbie-Mueller, CEO Harwood International, D-Magazine, 12/14,07
- *Planting trees can reduce traffic-related pollution and lessen solar impact and energy demands.*
  Michael Hellman, Dallas Park an Recreation Department, D Magazine, 12/14/07
- *Trees contribute to cleaner air, cleaner water, cooler temperatures and many more benefits. Every person can make a difference.*
  Dallas green website, www.greendallas.net

Dallas thermal image



Dallas tree cover



Trees in new and older areas

Trees and DART Light Rail

Trees and Shade Downtown

Urban Greenspace and Trees

Images from forwardDallas!, the Dallas Comprehensive Plan adopted in 2006

A. TREE COSTS AND BENEFITS

Trees in Dallas have a cost. Governmental entities (city, county, and state) and private property owners pay these costs whether for initial planting or ongoing costs of pruning, pest and disease control, and irrigation. Other costs to local government can include administration, liability, root damage, trimming, and stump removal. For trees on private property, costs are generally borne by property owners.

COSTS OF PLANTING NEW TREES

The direct cost of planting new trees includes the purchase cost of the tree, delivery, and planting. In reviewing tree planting programs in various cities, direct costs range widely with a typical range of $200 to $400 per tree (Table 8). A tree in such programs would have a 1.5" to 2" caliper (tree diameter at breast height) and be 10' to 12' tall. Costs and other factors from two major tree organizations in Texas are shown in Table 1.

Planting costs for seedlings are much lower, but require more growing time to reach an equivalent size. Other expenditures are needed for on-going conservation and protection of urban trees. From these estimates, it is easy to see that goals set by major U.S. cities for planting millions of trees requires many participants, effective strategies, and sufficient funding.

Table T1
EXAMPLES OF TREE COSTS
FROM TREE ORGANIZATIONS IN TEXAS

	COST FACTORS (2006)
TEXAS TREE FOUNDATION DALLAS http://www.texastreesfoundation.org	$35/tree $4/mile for delivery $20/tree for planting with $200 minimum 1.5" to 1.75" caliper 8-10 ft

	COSTS (2006)	SIZE
TREES FOR HOUSTON	$150	15 gallon
Includes planting and tree cost	$300	30 gallon
http://www.treesforhouston.org	$675	65 gallon
	$1,150	100 gallon

COSTS OF TREE CONSERVATION, PROTECTION AND MAINTENANCE

The loss of existing trees is also costly. Dallas, like other growing cities, loses portions of its urban tree canopy each year, thus making conservation and maintenance of the existing tree canopy particularly important. The loss of trees, especially larger trees, results in the loss of the benefits described below. The costs of conserving and protecting urban trees are variable and depend on the approach, whether through direct land purchases or regulatory measures. Maintenance of the urban canopy in Dallas is limited primarily to hazard mitigation from fallen trees and branches. Dallas costs for these activities likely range from $1 to $2 million annually.

FigureT 4

TREE CANOPY AND THERMAL CHARACTERISTICS

Southwest Downtown

Potential Targets for Heat Island Mitigation

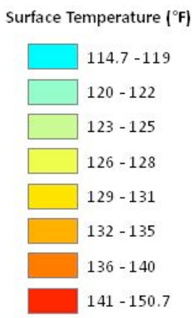
These three images show heat island features in a portion of downtown Dallas. The first image is an aerial photo with hotter and cooler areas highlighted.

The image just below the aerial shows surface temperatures from 2006 satellite imagery analysis.

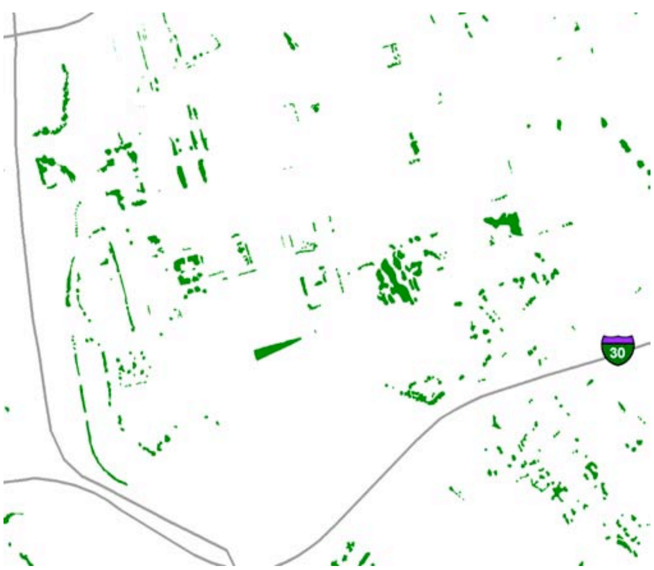
The third image illustrates the limited tree canopy in this area of downtown.

The hottest areas range from the Reunion Arena parking northeast across the Convention Center area. The Arena roof itself is likely cooler due to its reflective surface, but is not be easily distinguished due to overall surface temperatures.

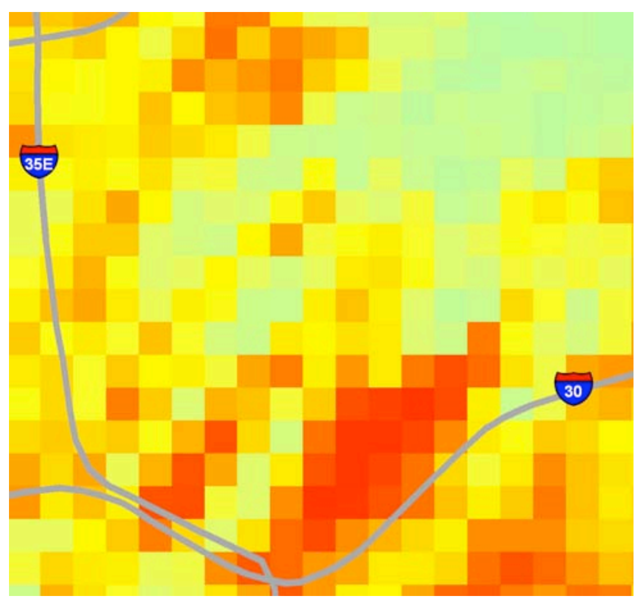
Cooler areas shown in green are where high-rise buildings in the east portion of downtown shade the nearby buildings and ground surfaces, resulting in lower temperatures.



Southwest Downtown Tree Canopy



Southwest Downtown Thermal Image



BENEFITS OF TREES

Trees more than pay for themselves in benefits. The major heat island benefits from tree cover include saving energy, improving air quality, shading paved surfaces (i.e., human comfort, cooler parked vehicles), and reducing urban temperatures through shade and transpiration.

Other direct and indirect benefits of trees include improved property values, human health benefits, reduction of stormwater requirements, improved quality of life, and reduced greenhouse gases.

Trees and Energy Savings

Trees directly save energy by shading buildings and thereby reducing the heat load. Trees placed on the east or west side and relatively close to the building generally provide the most energy savings. Older, less energy efficient buildings benefit more from tree shade than newer, more energy efficient buildings. Estimates of such savings vary widely due to different conditions and methods. Examples of energy savings include:

- *Per Tree Savings*
  - $480 to $720 per tree over 30-year period (residential), Houston[19]
  - $907 per tree over 30-year period, Sacramento (buildings)[20]
  - 2 to 3% energy savings from a 5% increase in tree canopy[21]
- *Urban Area Savings*
  - Ranging from $27.8 million in Chicago (added shade for residential and commercial)[22] to $131 million per year (building energy savings from existing tree shade), Houston[23]

Table 2

RESEARCH SUMMARY – ENERGY SAVINGS FROM TREES[24]

- Joint studies by the Lawrence Berkeley National Laboratory (LBNL) and the Sacramento Municipal Utility District (SMUD) placed varying numbers of trees around houses to shade windows and then measured the buildings' energy use.[25] The cooling energy savings ranged between 7 and 47 percent and were greatest when trees were planted to the west and southwest of buildings.[26]
- A USDA Forest Service study investigated the energy savings resulting from SMUD's residential tree planting program. This study included over 250 program participants in the Sacramento, California area, and estimated the effect of new shade trees planted around houses.[27] An average of 3 new trees were planted within 10 feet (3 m) of each house. Annual cooling energy savings were 1 percent per tree, and annual heating energy use decreased by almost 2 percent per tree. The trees provided net wintertime benefits because the positive wind shielding effect outweighed the negative effect of added shade.
- Another LBNL study simulated the effects of trees on homes in various communities throughout the United States. Assuming one tree was planted to the west and another to the south of a house, the model predicted that a 20 percent tree canopy over the house would result in annual cooling savings of 8 to 18 percent and annual heating savings of 2 to 8 percent.[28] Although this particular model included benefits from trees planted to the south of a building, experts generally suggest planting to the west and east of buildings, taking care when planting to the south to avoid blocking desired solar heat gain in the winter.[29]

Trees and Air Pollution

Trees improve air quality by removing pollutants from the air (dry deposition), and indirectly by cooling the city. In addition, cars that are shaded in parking areas produce lower evaporative emissions. Cooler temperatures, which result from the urban canopy, help reduce ozone formation and concentrations.

Trees also emit volatile organic compounds (VOCs), which play a role in ozone formation. These "biogenic emissions" could counteract some of the air quality benefits from trees. However, since biogenic emission rates are partially dependent on temperature, lowered temperatures can may in a net overall reduction of these emissions.[30]

Trees also *reduce ozone.* Research on New York City projected that expanding the urban canopy by 10% would reduce ozone by about 3%.[31] A study of the Houston region showed that the loss of urban trees increased temperatures as much as 5ºF over an 8-year period.[32] Another Houston study showed that increased tree cover would lower daytime temperatures levels while slightly increasing nighttime temperatures.[33] Estimates from the Mitigation

Impact Screening Tool (MIST)[34] indicate that increasing the urban canopy by 5% would decrease ozone concentrations by 0.3 to 0.5 parts per billion (ppb). Dallas has previously demonstrated measures that would come within a few ppb of meeting the Federal ozone standard.

The value of *pollution removal* by trees has been estimated in American Forests studies and in U.S. Forest Service studies that use the UFORE model.

Table T2
VALUE OF POLLUTION REMOVAL BY URBAN FOREST

Study Area	Annual Pollution Removal Value
Houston Region[35]	$209 million/year
Houston 8-County Region[36]	$296 million/year
San Antonio Region[37]	$87.5 million per year
Atlanta Metro Area[38]	$28 million/year

The MIST screening tool was developed to provide a way of estimating the effects of increased vegetation on ozone levels in urban areas. Estimates such as these have not been used to date for state air quality plans, nor has modeling been done that meets State criteria for inclusion in these plans.

Some air quality modeling experts have indicated that current modeling tools fail to adequately capture urban heat island effects. Improving results would require improved meteorological modeling and other changes that would better incorporate heat island effects. The uncertainties in such analyses are substantial due to great variations in regional climate and air modeling factors.

Trees and Stormwater Management

Trees reduce the need for and cost of stormwater infrastructure by catching and slowing rainfall runoff. The leaves and branches catch rainfall, allowing time for more evaporation and reduced peak flows. As estimated for Sacramento, trees may catch 35 percent of the rainfall that hits them.[39] The total capital cost savings of the stormwater function of an urban canopy have been estimated in various studies by American Forests.

Table T3
ESTIMATED STORMWATER MANAGEMENT SAVINGS FROM EXISTING URBAN FORESTS

Study Area	Cost Savings
City of Garland[40]	$2.8 million*
San Antonio Region[41]	$2.8 billion**
Houston 8-County Region[42]	$133 billion**
Atlanta Metro Area[43]	$2.36 billion**

*Annualized savings using 6% discount rate.
**Total capital cost to replace estimated stormwater reduction by trees.

For the Houston area, the stormwater savings amount to roughly $200 per tree. Comparisons with other cities (listed in Table 4) suggest that stormwater benefits can range from $100 to $300 per tree in total infrastructure savings.

Greenhouse Gases

As part of the growth process, trees take up carbon dioxide, a major greenhouse gas. The amount of carbon that is then stored by trees increases as the tree grows and is retained over the tree's life. Likewise, loss of trees whether through harvesting, removal, or tree death releases stored carbon. The study of Houston's urban forest estimated an annual value of carbon being stored in the current tree canopy at $29 million per year. A Charleston, South Carolina study estimated that carbon sequestration could be valued at $1.50 per tree per year. This 2006 study included 15,000 street trees and was based on average carbon credit prices.[44]

Tree species and growth rates vary from area to area directly affecting the sequestration values. Fast growth or higher density tree species yield greater carbon storage.

Trees also reduce greenhouse gas emissions by reducing energy demand. The direct energy savings from shade trees and vegetation has been estimated to reduce carbon emissions from power plants by roughly 1.5 to 5 percent (depending on types of fuel used in power generation).[45] The modeling study for this finding assumed that eight trees would be strategically planted around all residential and office buildings and four trees adjacent to retail buildings.

Health Benefits

Trees benefit human health by reducing air pollution, blocking harmful UV rays, and minimizing the impacts of summer heat waves. Research also shows that human physiology responds positively to trees and greenspace.[46] UV rays have a negative effect on the skin and eyes, and high levels of UV exposure are linked to skin cancer.[47,48]

Quality of Life Benefits

Most people consider trees to add substantially to the quality of life in their city. Trees and shrubs along roadways can reduce urban noise and serve as noise barriers for highways.[49] Urban trees are found to be associated with reduced crime rates, higher property values and positive health benefits, such as reduced stress.[50,51,52,53] The replacement value of trees in the Houston area was estimated to be $206 billion, or roughly $300 per tree (trees over 5” in diameter).[54]

Other Economic Benefits

Studies have shown that trees also increase residential property values by three to ten percent.[55] In retail areas, better landscaping and trees increase the time shoppers spend in the area and purchases are greater.[56,57,58,59]

The Net Value of the Dallas Urban Canopy

The net benefit of trees has been found to outweigh their costs by as much as three to one. In a 2006 study of five cities the net benefits of street trees were found to range from $1.35 to $3.10 per tree for every dollar of cost. The annual benefits ranged from $30 to $90 per tree.[60] The costs include such factors as planting, pruning, removal/disposal, litter management, liability, administration and inspection. Benefits included energy savings, carbon storage, air quality, stormwater management, and property value. Benefits and costs in Dallas would likely vary from those identified in this study, but such studies have generally confirmed that tree benefits outweigh costs by a substantial margin.

The challenge for local government is matching the costs and benefits with the questions of “who pays” and “who benefits”. Local governments must weigh the costs and benefits of planting and caring for trees on public lands and rights-of-way. While city government may incur costs described above, the benefits, such as improved air quality and energy savings, go to the broader public. Some benefits can offset city government costs including energy savings for city buildings, decreased energy demand from cooler temperatures, increased property values that add to the tax base, and stormwater management benefits. City governments may also benefit from air quality improvements and other quality of life improvements that increase the city’s economic competitiveness.

B. Planting for Heat Island Reduction

From an urban heat island perspective, trees should be planted and conserved in locations that best reduce air temperatures. Planting sites include (1) locations that shade buildings to reduce energy use, (2) locations that shade for surfaces, such as buildings and pavement, and (3) locations that conserve and expand the urban tree canopy for an overall cooling effects. It is important to realize that without the current tree canopy, Dallas would be several degrees hotter.

The following section illustrates *hot spot analysis* for two Dallas hot spots located near downtown. Following that various land use types are examined for locations of existing trees and possible planting sites. These include:

- Single family and multi family developments

- Neighborhood tree planting
- Commercial/office/retail
- Light industrial and warehousing areas
- School sites

Hot Spot Analysis

Daytime surface temperatures in cities are governed by the thermal characteristics of surfaces as well as their exposure to solar radiation. “Hot spots” are those areas that exhibit high surface temperatures that are well above air temperatures. On a thermal image such as the one used in this report, areas with sufficient tree cover exhibit lower temperatures.

By examining an area’s land cover and thermal features, hot spots can be identified at various scales. Although satellite imagery provides only a snapshot in time of surface temperatures, they provide a useful comparison of urban conditions related to the tree canopy. Thermal satellite imagery is not high enough resolution to distinguish individual buildings, but can be used to examine neighborhood and larger commercial areas. It is easy to see cooler forested areas along the Trinity River and heavily treed residential areas as well as the heat signature of large parking and industrial districts.

Hot spots were indentified above in the southwest portion of downtown (Figure 3), showing the effect of extensive parking areas and the lack of tree cover. Two additional areas are examined in Figures 5 and 6 below. These include an area just south of downtown and another area along the Stemmons Freeway just north of downtown. Area hot spots and cool spots are identified in each.

Residential Areas: Single Family and Multi Family

Residential areas comprise much of the land area in Dallas, and where many possible tree planting sites are found. Trees are often located along residential streets in public rights-of-way.

Most single family homes, even in areas with substantial tree cover, have planting spaces that would be suitable for additional trees. Planting locations serve different purposes and include yards (front, side or back), strategic shade next to houses, and street trees (in public easements). The images in Figure 7 below illustrate conditions in four Dallas subdivisions of various ages. The characteristics which affect tree planting sites are described.

Newer single family residential lots are often narrow with relatively small front setbacks and limited side yards. These conditions limit the amount of space that is available for new tree planting (see Area 1).

In older areas, trees planted at the time of development may die or be removed, thus providing planting spaces for additional trees (see Areas 1 and 2). Older developments, such as Areas 3 and 4, may have larger, mature trees, but as these trees die, homeowners have often planted replacement trees. The lots in these older areas have sufficient setbacks and depth for both street and front yard trees.

Planting in side yards is often restricted due to utilities and insufficient space between houses. Larger lots, particularly in older areas, have fewer limitations on planting locations.

Higher density residential developments, including apartments, townhouses, and condos, may have limited space for trees. Some older properties have tree cover that is large enough to shade building surfaces and even rooftops. These trees were planted primarily along streets in public street rights-of-way (see Figure 6 top images). Newer developments may use vehicle circulation for parking and building access that is not part of public rights-of-way. In such designs, there may be fewer new planting locations and most of these will be on private property rather than public rights-of-way.

Figure T5

HOT SPOT SOUTH OF DOWNTOWN NORTH OF TRINITY RIVER

See temperature scale on page 13

Image 1: Aerial Photo

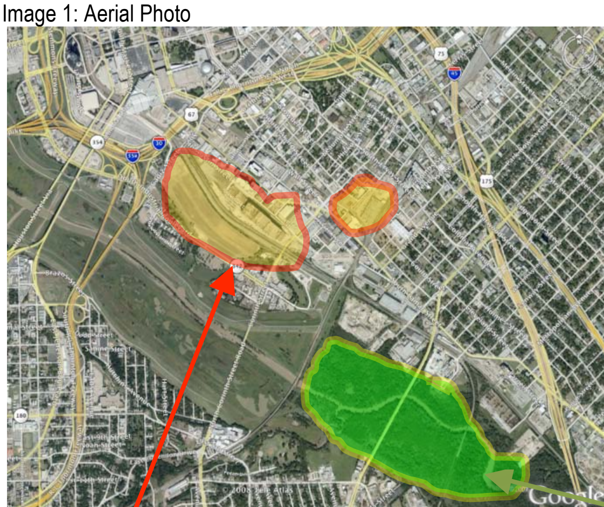


Image 2: Surface Temperature

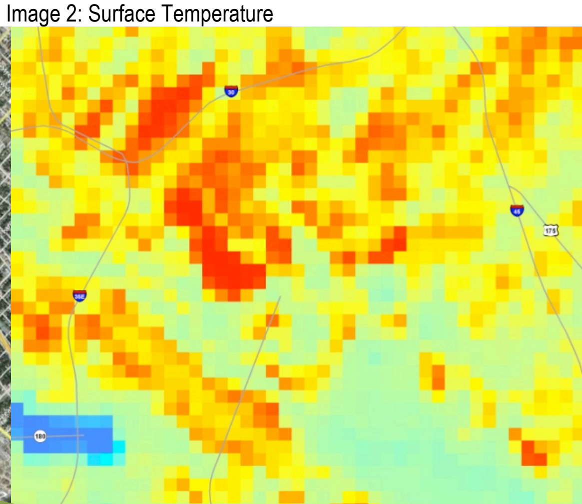


Image 3: Vegetation/Tree

Image 4: Hot Spot: Industrial area with large cleared site

Image 5: Cool Spot: Tree area along the Trinity River

The area shown in Images 1, 2 and 3 is an industrial area just south of downtown along the Trinity River corridor. Image 1 highlights the hottest and coolest areas cover). Image 4 is a close-up of the larger hot area in Image 1. Image 5 shows the cooler forested area along the Trinity. Hot spots in such industrial area can pr roofing. Tree planting locations may be limited to roadways. Any redevelopment in such areas would be the primary opportunity for expanded tree cover.

Figure T6

Hot Spot along Stemmons Freeway Northwest of Downtown

See temperature scale on page 13

Image 1: Roadway Map

Image 2: Surface Temperature

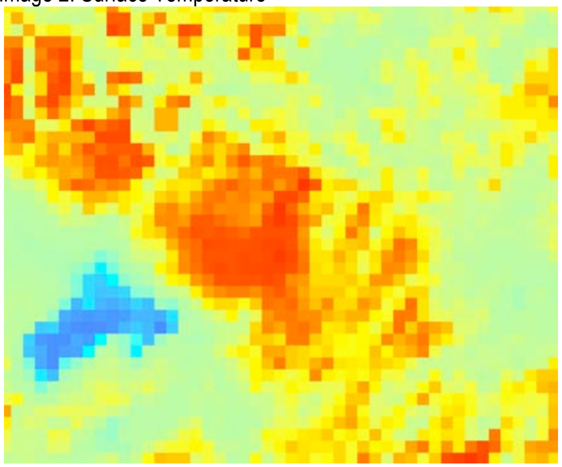


Image 3: Vegetation/Tree Canopy

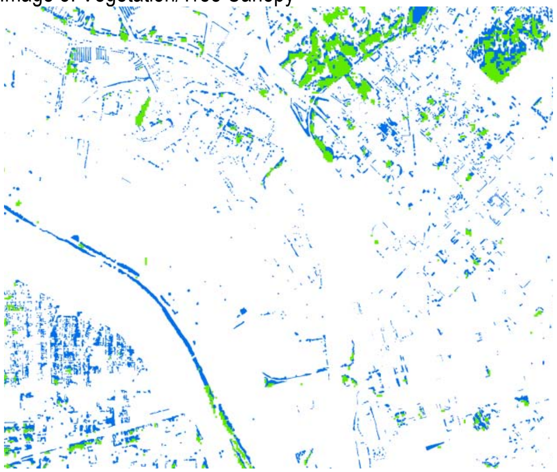
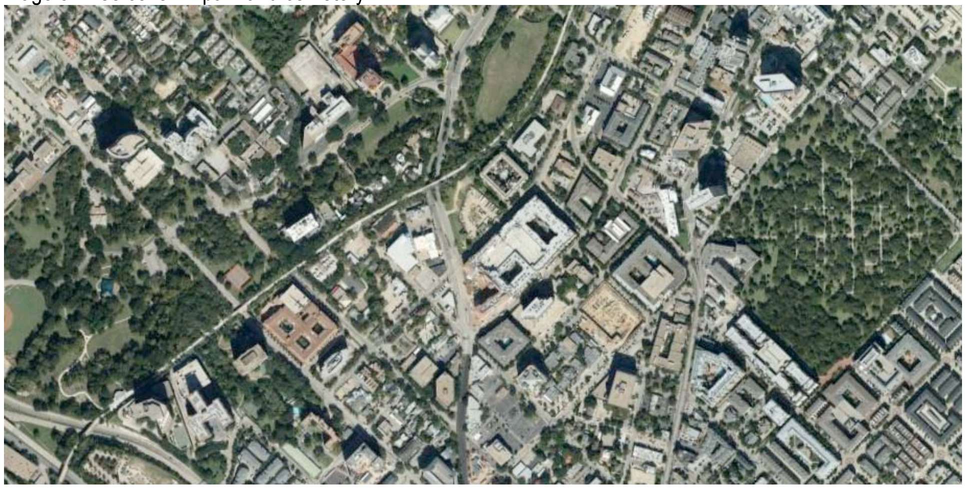


Image 4: Close up of industrial area

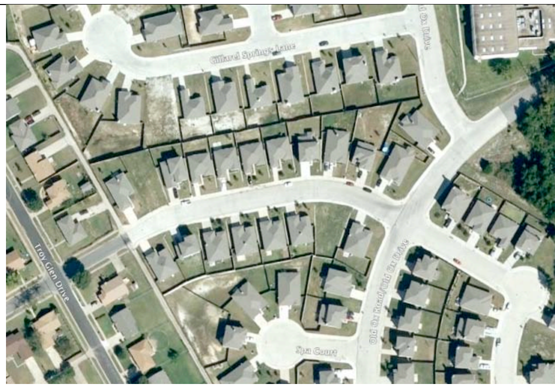
Image 5: Tree cover – park and cemetery.



An industrial area west of Stemmons Freeway just north of downtown is highlighted in Image 1. The cooler area is along the Trinity River (blue is cloud cover). The industrial/ warehousing area is shown in Image 4. As shown in Image 3, there is little vegetation near area hot spots. The tree cover in the upper right portion of Image 3 is Reverchon Park and Greenwood Cemetery (see aerial close-up at left).

Figure T7

TREES IN SINGLE FAMILY RESIDENTIAL AREAS: FROM THE 1930S TO 2007



Area 1: Newer Development

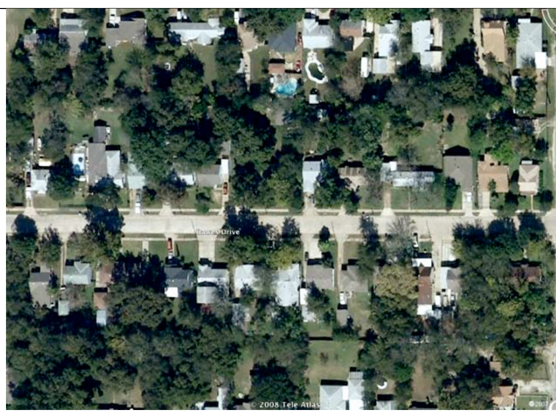
- Subdivision developed 2003 to 2007
- Lots 60' x 100'
- Two small trees in front yards
- No trees in back or side yards
- Little space in front yards for trees

Little space is available for additional tree planting on most lots. Larger, irregular shaped lots may have backyard or side yard planting spaces. New developments have higher surface temperatures since they lack tree cover and may have heat absorbing roofs and paving. This will change over time, as shown below, with sufficient tree planting.

Area 2: Ten Years of Trees

- Subdivision developed in 1998
- Lots 50' x 105'
- Two small trees initially planted in front yards
- Loss of some trees in ten years and 1998
- Very few backyard trees
- Limited front yard space for additional trees, except where initially planted trees have died.

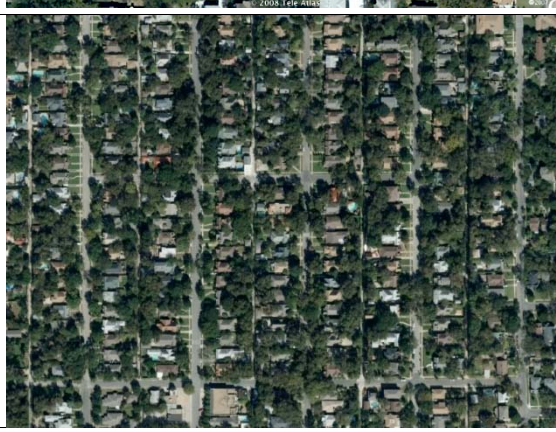
There are locations for replacement in front yard trees due to loss of trees initially planted following construction. There are limited opportunities for either side yard or back yard trees. The single trees planted here have grown substantially over ten years providing some building shade.



Area 3: 50 Years of Trees

- Subdivision developed in 1950s
- Lots 60' x 125'
- Varying number of trees in front yards
- Many trees in backyards
- Trees in side yards
- Ample space in front yards for trees
- Loss of some trees over time, but large amount of growth in 50+ years

There are some opportunities for replacement front yard trees and sufficient backyard space in many locations for additional trees. Areas such as this may have scattered hot spots.



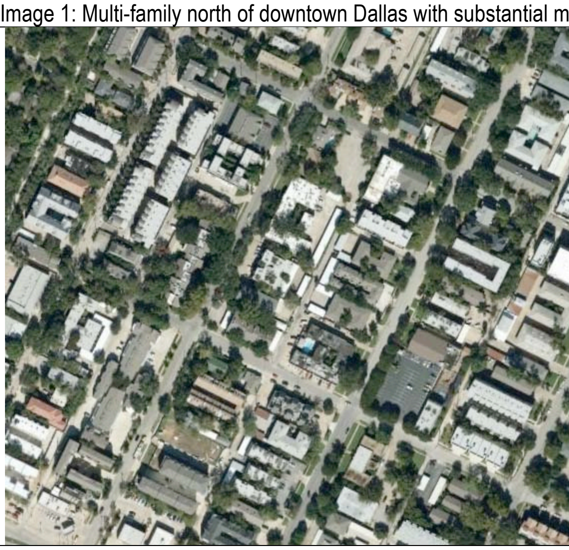
Area 4: 70 Years of Trees

- Developed in the 1930s
- Lots 50' x 160'
- Street trees often replanted
- Many trees in backyards
- No sideyard trees
- Setbacks allow some front yard planting

Scattered opportunities for tree planting. Building setbacks and lot size provide sufficient space for front yard or backyard planting. The heavy tree canopy in such older areas results in lower surface temperatures.

Figure T8
MULTI-FAMILY RESIDENTIAL DEVELOPMENT

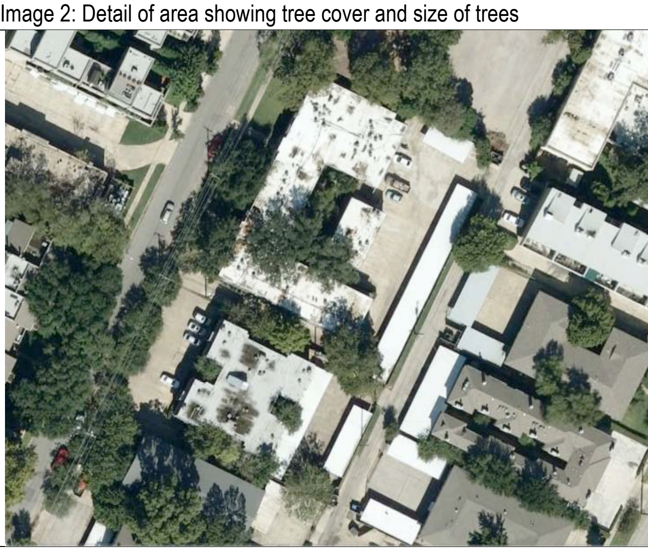
Image 1: Multi-family north of downtown Dallas with substantial mature tree cover



Higher density residential areas, such as apartments, town houses, and condos, have limited land area for tree planting. However, there is wide variation in the amount of planting in such areas.

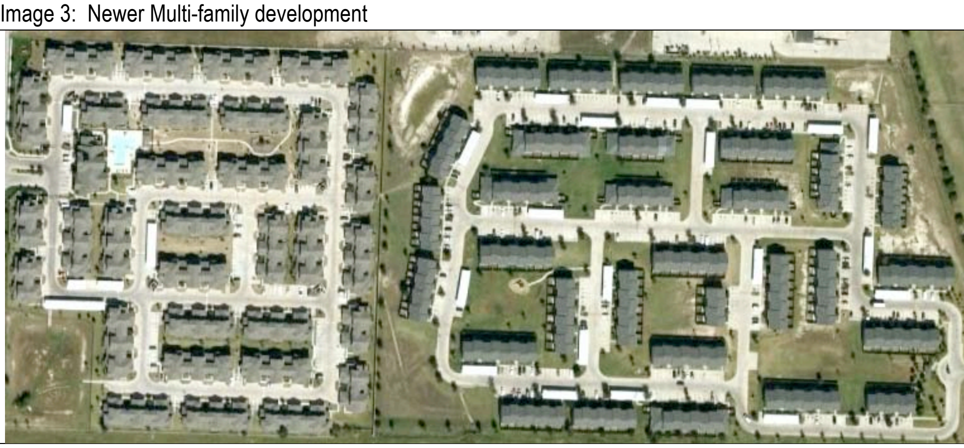
Some multi-family developments have substantial tree cover as seen in the examples here. At the street level, trees line and sometimes shade entire streets. Much of the tree cover is in public rights-of-way. This illustrates that substantial tree cover can be achieved in some multi-family areas where trees were planted at the time of development.

Image 2: Detail of area showing tree cover and size of trees



This is a closer view of one of part of the area above (center of Image 1) showing the extent of tree cover in a mature multi-family area. Most of the available planting sites are scattered street tree locations, perhaps replacing trees that may have died over time.

Image 3: Newer Multi-family development



In newer multifamily developments, tree planting may limited to adjacent streets and property boundaries, as shown here. Possible locations for new trees in the development on the right include the property corners, which could be heavily planted with tree groves and the addition of large trees in the interior courtyards. These would provide building shade as they mature.

Neighborhood Hot Spots and Planting Areas

Figure T9
Local Hot Spots in Vegetated Residential Area

This mature Dallas area has substantial tree cover throughout. However, there are also small hot spots within the area that contribute to heat island effects. Use of trees in some of these areas could provide heat island as well as aesthetic and economic benefits.

Multi Use Commercial Area
Limited tree cover in area

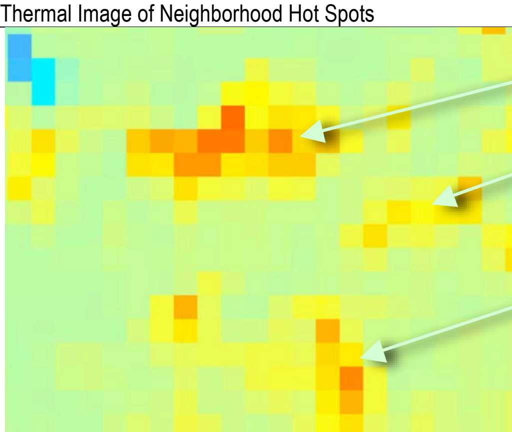
School Site

Park
Extensive unshaded lawn areas contribute to heat islands.

Retail And Strip Commercial

Extensive tree cover in the surrounding residential areas indicates good growing potential for additional trees.

Thermal Image of Neighborhood Hot Spots



Multi-Use Commercial Area

School Site

Retail and Strip Commercial

Commercial Development Hot Spots and Planting Areas

Figure T10
Community Shopping Center

Retail centers, such as this, may have 200,000 square feet and more and are hot spots due to the extent of paved surfaces and rooftops. Trees are primarily planted along adjacent roadways with many planting spaces available between existing trees. Planting areas within the parking lot are turf, although they may have had trees at one time. Parking lot trees are often planted in spaces too small and may have inadequate care resulting in stunted growth or tree loss.

Figure T11
Strip Commercial and Convenience Shopping

Any trees in smaller retail development are typically along roadways. Because these are separate buildings, paved areas between them are used for vehicle access. The planting area along the roadway is deep enough to support large trees, but in this case utility lines either restrict tree size or prohibit larger trees. Adding trees adjacent to the buildings for shade and cooling is difficult once paving is in place.

Figure T12
BIG BOX RETAIL

Retail centers that are primarily single large stores located on sites 15 or 20 acres in size. The parking area here is roughly twice the size of the building itself. Trees have been planted both within the parking area and along perimeter streets. The street trees are large, but additional planting spaces are available. The trees in the parking lots have cars parked under them, even in spaces far from the building itself.

Trees are also found across from the building entryway, although not close enough to shade the building itself.

Reflective roofing has been used, which helps reduce heat island effects of this site. The extent of darker paving somewhat offsets the heat island benefits of the cool roof.

Figure T13
OFFICE DEVELOPMENT

Office developments may have several buildings that range up six stories or more. This site has more planted trees due to multi-story parking structures which offset the amount of surface area devoted to parking. For example, the small one-story retail on the west side of this development requires more surface parking than a single office building.

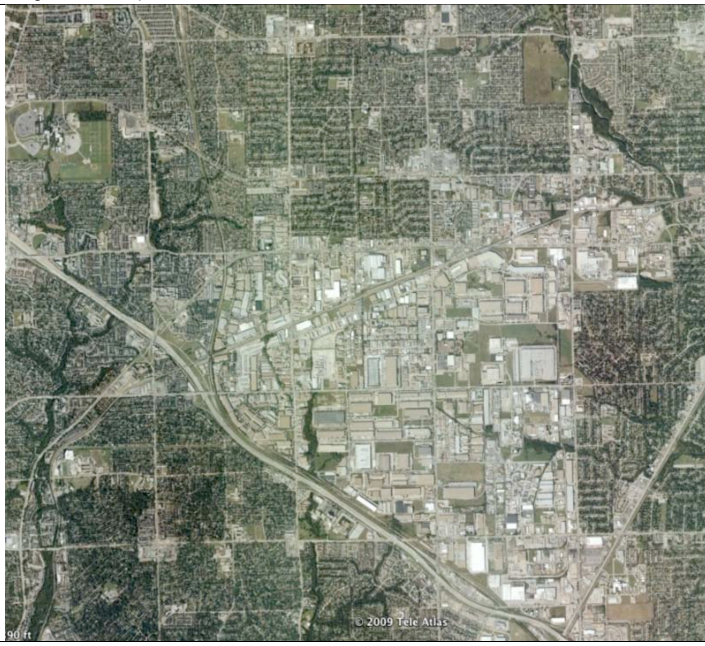
With more opportunities available for tree cover it is possible to plant adjacent to the buildings themselves. This site's tree canopy covers much more of the surface than the retail examples and has less heat island effect.

Industrial and Warehousing Areas

Figure T14

Industrial Warehousing Area (northeast Dallas along I-635)

Image 1: Aerial photo



This large industrial/warehousing area covers more than 3 square miles along the northeast portion of I-635 and represents one of the larger hot spots.

As shown in Image 3, rooftops are the primary contributor to this hot spot, offering the great heat island reduction potential. Trees in areas like this are generally limited to street tree planting and along larger waterways. Only undeveloped sites offer the potential for more extensive planting. Trees could also be included more intensively in future development of such sites.

Image 2: Thermal image

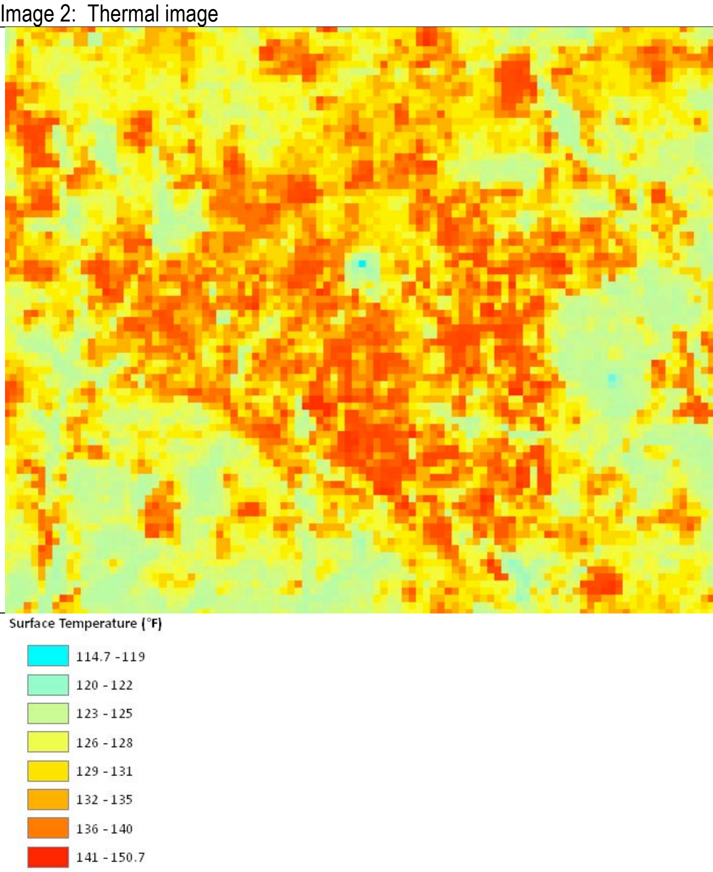


Image 3: Close-up of site

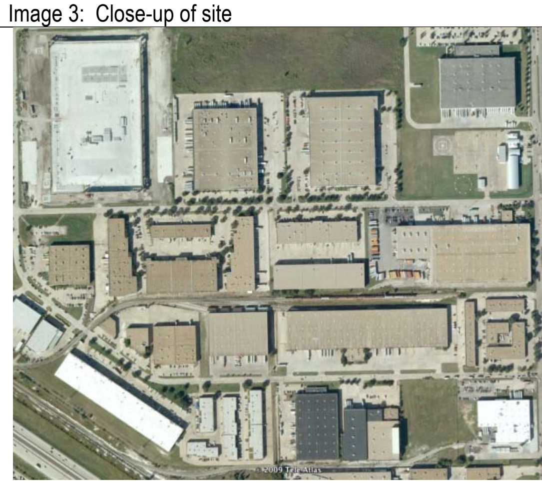


Figure T15

SCHOOL SITES

There are many planting spaces on school sites such as these including locations along site perimeters and adjacent roadways. Property corners provide enough space for concentrated trees planted in groves. Housing that faces school also offers potential street tree planting sites as part of overall efforts to reduce heat island effects.

On these example sites, there are several mature trees similar to those in surrounding residential areas that were likely planted at the time the school was built. Trees adjacent to the school provide shade, helping to reduce energy use.

School sites often show higher surface temperatures than surrounding areas due to the extent of turf areas (playgrounds and ball fields). The schools shown here have reflective roofs, which help reduce the urban heat island effect, while saving energy.

C. OPTIONS FOR TREES AND THE URBAN CANOPY

We know from research that trees add value to property; that human health responds positively to trees and greenspace; that people prefer shopping areas with good landscapes and vegetation; and that trees are an important part of the Dallas quality of life.[61] We also know that areas without trees can be substantially hotter.

Options are described below for adding trees and conserving the Dallas urban tree canopy. They include specific initiatives, policies, and programs. Aggressive tree planting and conservation are needed if Dallas is to reduce urban heat island effects. Furthermore, air quality benefits and energy savings are unlikely without these intensive efforts.

1. SETTING GOALS

<u>Goals such as those set in "million tree" campaigns are needed to establish the importance and scale of tree planting.</u> Such initiatives in major cities now include Million Trees LA, Million Trees NYC, Million Trees Salt Lake City, The Mile High Million – Denver, and Houston's million tree program. These cities have established partnerships to achieve these goals, and are providing citizens with multiple opportunities to actively participate through planting and contributing funds.

The Million Tree initiatives have common features that are needed to accomplish whatever goals are adopted. These include:

1. Registering and tracking of tree planting
2. Opportunities for direct donations by citizens, businesses, and organizations to Dallas tree planting
3. Volunteer coordination in close cooperation with other organizations along with on-going volunteer planting opportunities
4. Establishment of internet communication tools that engage individuals and organizations in tree planting and conservation
5. Consumer education on tree planting and tree care

MILEHIGH TREES – DENVER: A MAJOR COMPONENT OF GEENPRINT DENVER

The mission of *Tree by Tree* in the *Denver Mile High Million* is to inspire individuals, neighborhood associations, schools, nonprofits and businesses to plant and nurture one million trees in the Denver region by 2025. Program features include:

- *Make Your Tree Count*: registering and tracking tree planting (on-line)
- *TreeBank* and the *Memorials and Tributes* program: contributions for tree planting and methods to establish memorial trees.
- *Tree 4 All Events*: coordinating and providing volunteer planting opportunities with other organizations (on-line calendar and links) and with mapping of volunteer planting opportunities and planting programs
- Electronic communications with individuals and organizations (via email system), including e-mail sign up with tree registration, e-mail news and e-mail sign-up for other information; availability of RSS feeds of various types
- Consumer outreach and education on tree planting (on-line): basic planting instructions; recommended trees list (by city); tree site selection instructions (link to utility involved in tree planting); extensive on-line library of tree related documents (pdfs for download); 27 documents on tree selection, tree care, and pruning.

LOS ANGELES: MILLION TREES LA

This is a partnership between the City of Los Angeles, community groups, businesses and individuals, working together to plant and provide long-term stewardship of one million trees, planted all over the city with a focus on areas that need it most. LA Mayor.

- Report Tree Planting: registering and tracking of individual tree planting (on-line)
- Direct on-line donations for tree planting: Direct donations as a *ConTREEbutor*;

handled through non-profit partner, *Community Partners*

- Volunteer planting opportunities: coordination with volunteer planting opportunities with other organizations, including on-line calendar and links
- Establishing electronic communications with individuals and organizations (via email system) – on-line calendar of tree planting activities; location specific sign up for volunteer opportunities with program partners; e-mail sign up; e-mail sign up for friends; photo gallery
- Consumer education on tree planting (on-line) – *Plant the Right Tree in the Right Place* (on-line tutorial on all features of tree planting including instructions on contacting utilities prior to digging); tree selection from 50 tree species appropriate for the area;

NEW YORK CITYNYC

Program Statement: "Getting to a million of anything seems daunting, but if anyone can plant a million trees, it's New Yorkers! It will take a lot of hard work - and a lot of outdoor fun - but we plan to achieve this goal in the next decade. The City will plant 60% of trees along streets, in parks, and in other public spaces. The other 40% will come from homeowners, the business community, and non-profit organizations."

- Registering and tracking tree planting (on-line) – *A Million Ways to Get Involved*, *Report A Tree Planted* (distinguishes between 10 or fewer and more than 10); on-line counter showing trees planted to date (98,000)
- Providing opportunities for direct donations to tree planting (on-line)
- Coordinating and providing volunteer planting opportunities with other organizations (on-line calendar and links) – on-line form for volunteering by general location in the city
- Establishing electronic communications with individuals and organizations (via email system) – includes e-mail when reporting forms for tree planting; process for requesting free street trees from City, including permit forms and instructions for resident or landscaper street tree planting; community calendar of tree relevant events
- Consumer education on tree planting – links to monthly *Caring for Street Trees Workshop* offered by non-profit and on-line educational materials.

2. CONSOLIDATED OUTREACH AND EDUCATION

To achieve tree planting and urban canopy retention goals, consolidated outreach and education efforts are necessary within city operations. To focus these efforts, a "million tree" initiative can provide a useful framework. Key features include (1) a consolidated, unified effort within city government itself, and (2) active inclusion of organizations outside of city government, including non-profits, businesses interested in sponsoring activities, and other governmental entities, including electric power utilities.

Increased awareness through outreach and education is a cost effective means to develop critical support for tree programs, promote tree planting, and conserve the existing urban tree canopy. Such efforts help build an improved foundation for achieving the city's urban forest goals, as well as heat island reduction goals.

Benefits include (1) expanded tree planting activities by targeted audiences and areas (not reliant on direct city investment), (2) improved tree protection and urban canopy health (potentially reducing service demand for city functions), and (3) establishment of a stronger base of support in the community for urban forestry. Through outreach and education, citizens, leaders, and neighborhoods can be directly engaged. Simply put, major tree initiatives are too costly for a single governmental entity acting alone. Outreach and education is a way of tapping the energy and support that already exists for trees.

Urban foresters, arborists, and related professionals should guide and inform tree initiatives, however, outreach expertise is needed. Existing advisory committees can provide general guidance for consolidating relevant urban forest outreach and education activities within city government.

Many of the relevant education and training functions are described on http://www.dallastrees.org, including training for citizen foresters, tree care, and volunteering.

As websites have become key portals for messages and information, they are also the places where outreach and education can be consolidated, regardless of functional organization (responsibilities in different departments, for example). There are several websites that now provide Dallas citizens with relevant tree information. This information needs to be coordinated more effectively if it is to serve as outreach and education. This information can also be consolidated as part of tree information in a million trees initiative.

Table T4

CITY OF DALLAS TREE INFORMATION SITES

Department/Division	Type of Information: Website Location
Building Inspection	Replacement Trees: http://www.dallascityhall.com/building_inspection/approved_trees.html
Dallas Urban Forest Advisory Committee	Committee Site: http://www.dallastrees.org/
Department of Street Services	MOWMentum Tree Program: http://www.dallascityhall.com/html/mowmentum_program.html
Development Services	City Arborists Website: http://www.dallascityhall.com/arborist/index.html Reforestation Fund: http://www.dallascityhall.com/arborist/Fund_proposal.html
Office of Environmental Quality Green Dallas Program	Comprehensive Environmental Site with Tree Info: http://www.greendallas.net/
Parks and Recreation	Urban Forestry: http://www.dallascityhall.com/Parks/forestry/index.html Tree Trimming: http://www.dallascityhall.com/html/tree_trimming.html

Urban forestry functions in local government have wide ranging roles that can include everything from tree trimming to the implementation of ordinances. Urban foresters are called upon to participate in community activities, often with organizations that are interested in community tree programs, planting and tree maintenance, and urban beautification. Larger cities usually have one or more professional urban foresters and arborists within a particular division, but there may also be foresters or professionals trained in related areas within other departments of city government, such as public works or planning. These skills and knowledge can be tapped for coordination of outreach and education.

3. OBTAINING URBAN FOREST MANAGEMENT DATA

An on-going inventory of the city's tree population and an analysis of the urban forest are needed management components. The Dallas urban forest is a major asset that has not been inventoried or evaluated to date. The data and analysis provide a baseline for forest management as well as a basis for investing in tree planting and maintenance.

Most *tree inventories* focus first on trees located on public property, such as street trees and trees in city parks. *Urban forest* analysis assesses the specific values that the overall tree canopy provides to the economy, air quality, tax base, storm water management, and carbon sequestration.

Tree Inventory: Based on prior Dallas recommendations, a tree inventory project should first investigate and test the most cost-effective methods available through improved technologies and analysis, including remote sensing applications. If testing of these methods proves feasible in test sites, they should be applied to other areas in the City. Examples of how urban forest data are used include:

New York City: "Our urban forest totals over 5 million trees (5.2 million from UFORE analysis) and 168 species. It can be found throughout the city along streets and highways, in neighborhood playgrounds, backyards and community gardens, and even along commercial developments. There are 6,000 acres of woodlands in parks alone!" The New York City target area is the entire city.

Denver: Denver's goal is to increase the tree canopy within their target area from 6% to 18% - tripling the current canopy. Part of achieving this is through the Mile High Million tree initiative. The Denver target area includes Denver County as well.

Los Angeles: "Through a recent tree canopy study, we have learned that Los Angeles has 21% tree canopy cover, which is below the national average of 27%. We hope to bring our tree canopy cover up to the national average, through this Initiative." Los Angeles studies in the 1990s inventoried 670,000 street trees and 133,000 street tree planting sites. The Los Angles target area includes the area within the city limits.

Dallas has an extensive urban tree canopy that includes an estimated 26.2% of the area within the city limits, or roughly 90 square miles of tree coverage.[62] The canopy likely includes more than 15 million trees with many of these located along the area's watersheds.[63] An assessment of the Dallas urban canopy would provide more accurate measures of the number of trees, species, sizes, and value to the City.

Two examples of tree inventory information are shown below for Washington DC and Plano, Texas. In Washington DC, the Casey Tree website provides detailed information on every street tree in the District. The tree data include estimates of the tree value in dollars and environmental benefits. In Plano, the tree inventory is available for urban forest management, but also provides analysis for estimating the value of trees to the city.

Urban Forest Analysis: A Dallas urban forest analysis would provide the economic, energy and environmental value of trees. Measuring these values is accomplished through use of tree inventories and supporting analytical tools, such as:

Table T5

FOREST ANALYSIS TOOLS

TOOL[64]	DESCRIPTION
i-Tree	A suite of tools used in urban forest management
STRATUM	Street tree management
UFORE	Overall urban forest effects

A regional urban forest analysis through the North Central Texas Council of Governments could be used in air quality modeling of the DFW region, as well as any regional stormwater management planning. Non-profit regional groups could also support such analysis with environmental interests (such as Envision North Texas) and multi-city participation that spreads the cost across several participants.

Figure T16
EXAMPLE OF TREE INVENTORIES
WASHINGTON, DC

Figure T17
DETAILED TREE DATA FROM DC TREE INVENTORY

Maple, Norway (ID: CA-0640-097)
Scientific Name: *Acer platanoides*
Tree Value: $ 1,907

Height: 30 feet **Diameter at Breast Height:** 11 inches **Crown Radius:** 15 feet

Leaf Area: 406.91 m2 **Leaf Biomass:** 21.96 kg **Leaf Area Index:** 6.20

SITE INFORMATION:

Overhead Wires: None	**Tree Grate:** None
Curb: Permanent	**Sidewalk:** Permanent

ENVIRONMENTAL AND ECONOMIC VALUE:

Carbon Storage:	162.94 kg
Carbon Sequestration:	8.06 kg/year
Carbon Monoxide Removed:	32.914 g/year
Ozone Removed:	286.586 g/year
Nitrogen Oxide Removed:	95.473 g/year
Particulate Matter Removed:	229.899 g/year
Sulfur Dioxide Removed:	95.150 g/year
Total Pollution Removed:	$ 3.8049 /year
Tree Value:	$ 1,907

Figure T18
PURPOSES OF CITY OF PLANO TREE INVENTORY

Data is collected to serve several purposes. The main purpose is to create a GIS layer of the trees. This layer is a digital point coverage file that can be used as a map overlay in mapping software such as ArcView. The following is information that we use to develop in-house work plans and management plans:

- Species
- Diameter
- Health
- Insect
- Disease
- Cavity location
- Weak fork
- Percentage of deadwood
- Type of maintenance
- Removal priority
- Site problem

Since starting the project in March of 2003, we have collected data in more than 75 parks totaling over 2700 acres. We have collected data on over 12,000 trees. Using CityGreen5 we have found that the value of the air quality benefits provided by the trees inventoried is worth more than $190,000 a year, and the annual value of storm water runoff benefits is worth more than $3.9 million. The tree appraisals reveal that the trees inventoried thus far have a value of more than $110 million.

4. FUNDING FOR TREE PLANTING AND CONSERVATION

Three options that can be used for funding tree planting and urban forest conservation: (1) the Dallas Reforestation Fund, (2) capital improvements set-aside, and (3) a utility-based tree planting program.

- "Free Trees": The Dallas Reforestation Fund can be increased[65] and used to leverage additional tree planting and conservation funding. Matching funds can be sought from organizations and businesses that want to be tree planting sponsors.
- Tree Set-Aside: The City could institute a ½% set aside for planting as part of capital improvements programs, while seeking similar commitments from the Texas Department of Transportation and other government entities undertaking capital improvements within the city limits.
- Utility Tree Program: Oncor can be encouraged to develop a shade tree program for the Dallas area. A pilot shade tree program has been completed in Texas that provides guidance on how utilities can provide financial support for shade tree planting. The program is intended to reduce energy consumption for single family homes (similar to other energy efficiency measures). It can be used in hard-to-reach (lower income) neighborhoods in support of energy efficiency goals, and can be implemented in coordination with non-profit organizations.

"Free" Trees

Many cities use a city-citizen cost-sharing concept to get trees planted on public property (streets trees and parks). Cities may offer a "free tree", a rebate, or simply plant the tree with property owners paying the city a specified fee. The Dallas Reforestation Fund tree planting program is a similar concept. The Texas Tree Foundation and other tree planting organizations also use this basic concept to extend the impact of available resources.

In practice, the Reforestation Fund has not worked as expected since funds are not being fully and rapidly expended. This means that trees are not being planted. This fund is clearly an opportunity that Dallas can further develop. The Fund can be a key feature of any major initiative. This "free tree" approach is being used in the million tree initiatives described above. An efficient process is essential for getting trees in the ground. This also requires sufficient staffing to better coordinate with citizens and organizations, or outsourcing of the program. Increased fund revenues are needed to cover associated costs for a program expansion.

EXAMPLE "FREE TREE" PROGRAMS

New York City: The Parks Department plants street trees, free-of-charge, along sidewalks in front of homes, apartment buildings, and businesses in all five boroughs. Citizens can request tree planting, and the tree planting budget determines the number of trees planted (some cities set street tree goals for the number of trees planted annually). Citizens can also plant street trees by obtaining a planting permit.

Los Angeles: The city provides "free trees" as part of its water and power utility operation, primarily for energy conservation. There are residential and non-residential programs. To receive the free trees (up to 7), an electric power customer must (1) complete an online workshop, which takes 20 minutes, (2) submit a completed tree order and site plan, and (3) agree to plant and maintain the trees. The city delivers the trees to the home.

Denver: Denver has the "Denver Digs Trees" program operated through volunteers by The Park People. They provide street trees for a nominal cost of $20. They distributed 3,000 street trees for the 2008 planting season involving 2,000 volunteers.

Tree Set-Aside Funding

A capital improvement set-aside for landscaping can be used effectively to ensure that trees and landscaping are provided in many public projects. With this policy, ½% to 1% of the total project budget can be set aside for landscaping. This can also be applied to state and Federally funded projects in Dallas, such as freeways and thoroughfare improvements, and as part of public building costs for new or extensive renovations. The cost for a set-aside is essentially the percentage that is established for such projects. For example, a $10 million capital project would set aside at least $100,000 for planting and landscaping. Landscaping budgets are often one of the first items cut as building costs are incurred in capital projects. Seeking to finance trees after construction is complete is difficult to accomplish since costs move from capital expenditures to operating budgets.

Utility Shade Tree Programs

Energy efficiency and conservation programs are conducted by electric utilities to reduce energy demand, particularly during peak periods. In 2006, the Public Utility Commission of Texas (PUCT) approved a pilot study for residential tree planting for this purpose. In Texas, electric utilities are required to meet energy efficiency measures, and are authorized to expend funds on qualified programs, such as high efficiency air conditioning, EnergyStar homes, and weatherization. CenterPoint Energy conducted the *Trees For Efficiency* pilot project to determine how a shade tree program could be offered by a utility and the associated energy savings that could be approved by PUCT. That project has been completed and submitted to the PUCT.

The details of such a program would be developed in concert with the electric utility, which in Dallas would likely be Oncor. A utility-based tree program can include features such as provision of "free trees", a tree planting rebate for homeowners, tree planting in target neighborhoods (hard-to-reach customers), or funding for planting by non-profit organizations. It can provide the opportunity for adding trees on private property, which is usually not the approach used by local governments. Programs such as these include restrictions on the types and locations of trees, as well as agreements for care of the trees.

5. INCENTIVES AND REGULATIONS

Regulatory measures can be coupled with various types of incentives to achieve desired goals. The following describes two major areas for action: (1) air quality requirements and (2) conservation measures.

Options for increasing tree cover associated with paved surfaces (e.g., parking areas) are included in the cool paving section of this report. Dallas has over 25 square miles of surface area devoted to parking lots (based on land cover/land use datasets, 2006). Reducing the heat island effects of these surfaces can be accomplished through the provision of shade and alternative surface materials (i.e., porous paving and reflective paving).

TREES AS AN AIR QUALITY MEASURE

Tree planting and conservation can be included as an Innovative and Voluntary Control Measure in the DFW State Implementation Plan (SIP). The new federal 8-hour ozone standard (75 ppb) and uncertainty about Clean Air Interstate Rules (CAIR) suggest that non-attainment areas must consider innovative measures to help achieve air quality standards. In addition, non-attainment areas must consider how they will maintain air quality once attainment is achieved.

Trees (tree canopy) have been successfully included as an innovative and voluntary measure in the Washington, DC-Maryland-Virginia ozone nonattainment area SIP (although there is no specific ozone reduction credit claimed). With this control measure, local governments commit to tasks that qualify this measure for SIP inclusion. Tasks include (1) measurement of existing resources and tracking changes, (2) programs that enhance and increase tree benefits, (3) public outreach, (4) regional canopy management plan, (5) species selection, and (6) monitoring programs. Although there has been no specific request for credit under this voluntary measure, the area's decision process concluded that it is directionally correct for ozone attainment.

The DFW nonattainment area has previously included trees in various ways in the master list of control measures considered during SIP discussions, including the following:

Table T6
NCTCOG EMISSION REDUCTION CONTROL STRATEGY MASTER LIST
September 7, 2005

LIST NO.	DESCRIPTION
63	More reflective glass, efficient buildings, tougher energy use standards, white roofs on new houses, native plants, and add more trees (low VOC emitting species), xeriscaping/buffalo grass for reduced water use and less frequent mowing
67	Cool cities approach to reduce heat build-up; Urban heat island initiatives
124	Shaded parking areas
160	Preserve green space and replant cleared wooded areas
162	There should be 100% mitigation of trees taken during development of land.
163	Provide more protection for trees
164	Protect natural areas; Minimize use of motorized vehicles and pesticides
165	Strengthen the current tree ordinance to require more large trees established in new subdivision developments

A voluntary SIP measure is not enforceable, but through SIP inclusion, it encourages planting and conservation of trees. The Center for Chesapeake Communities, in support of tree inclusion, concluded that this creates a strong need for collaborating on urban canopy data and monitoring the urban tree canopy. As a SIP measure, it has stimulated new thinking on more effective actions, funding, and collaboration in the DC/MD/VA non-attainment area.

The Texas Commission on Environmental Quality (TCEQ) has previously indicated in its review of urban heat island mitigation measures that they will not provide for inclusion of trees or urban heat island measures. The Texas Legislature requested that TCEQ determine how urban heat island measures would be given air quality credit in the Houston nonattainment area.

In 2007, the Texas Legislature passed House Bill 2129 that required the following from TCEQ: "The commission shall assure that emission reduction credits may be received in the Houston-Galveston nonattainment area for energy efficiency and urban heat island programs in connection with the State Implementation Plan for the eight-hour ozone standard."

In responding to this requirement, TCEQ observed the following about trees and the uncertainties of air quality modeling in regard to urban heat island measures:

> "The most sophisticated studies on tree planting to date, however, show that ozone will decrease in some areas and increase in other areas if widespread tree planting occurs. With the planting of new vegetation, additional biogenic VOC emissions are created. Studies also show that increasing biogenic VOC emissions in the urban core

is likely to increase ozone formation on most days because the ozone chemistry in the urban core is complex and can be VOC-limited. Additionally, if urban temperatures go down, the depth of the mixing layer may decrease, which means that emissions could be trapped in a smaller volume of air, resulting in higher concentrations of emissions and their byproducts. Further, most of the studies that estimate possible ozone reductions from measures like tree planting were done in smaller, arid cities like Sacramento, California. Results in a large, humid city such as Houston will likely differ considerably. At this time, modeling is not capable of determining the effects of urban heat island measures, like tree planting, in the HGB area using the most currently available data.

Since the science and the modeling tools are not adequate for accurately estimating ozone reductions, these measures can only be examined in a qualitative rather than a quantitative way. As the science around the effect of urban heat island measures progresses, the TCEQ will take new information into account as part of the ongoing effort to appropriately account for useful air quality improvement measures in the HGB SIP."[66]

CONSERVATION OF THE URBAN TREE CANOPY

Current landscape and tree preservation ordinances can be modified to (1) protect more of the larger trees, (2) increase replacement tree planting, and (3) increase the amount of trees in landscape requirements. If Dallas seeks to retain and possibly expand the existing tree canopy, such measures are needed.

Specifically, the definition of "protected trees" could be expanded to include trees with calipers of 6" or more. Replacement trees could be replaced on a "two-for-one" basis rather than an "inch-for-inch" basis. The number of required trees in single family districts could be increased to at least six trees.

Protecting Larger Trees: The benefits of trees (shade, air quality, stormwater management, etc.) increase rapidly as a tree matures. As such, if tree benefits are to be retained, protecting larger trees is essential. Changing the definition of a protected tree from 8" to 6" would help accomplish that. Other city ordinances provide varying definitions of protected tree size ranging from 4" to 12".

- Austin uses 8" as a standard for tracking in development; 19" is a "protected" size
- Garland uses 6" or larger as protected tree.
- Frisco uses 8" or larger and then 20.1" as a larger category.
- McKinney uses 6" or larger.
- College Station uses 8" or larger.
- Harris County (the only county with a tree ordinance like this) uses 12" or larger.
- North Richland Hills uses 4" or larger.
- Chicago protects 4" or larger trees and ones damaged at that size must be replaced with 4" trees.

Tree Replacement Formula: Additionally, replacing a larger tree with several smaller trees on an inch-for-inch basis results in lost benefits, rather than equivalent benefits. Recommended here is a "two-for-one" formula that would require 2" for every 1" of tree replacement. For example, loss of an 18" caliper tree would require replacement with 36" of replacement trees (9-4" trees or 12-3" trees). Since tree benefits do not increase in a linear fashion as the tree matures, if equivalent tree replacement is the goal, the replacement needs to reflect these differences. To some extent, the higher replacement level also replaces the loss of smaller, understory trees that occurs when protected trees are removed.

Increased Landscape Requirements: Single family districts are currently required to have three trees, including retention of existing trees. Reviews of tree cover in existing development generally shows that trees planted at the time of development are likely to be the only trees planted for the next decade or more. Homeowners rarely add trees as part of new landscaping on new development, preferring shrubs and garden beds instead. As such, trees planted at the time of development are the key defining aspect of the future urban canopy. Often planted in poor growing conditions, any tree loss/death substantially reduces the future canopy. If only one of three trees dies, the loss is essentially one-third of the future urban canopy. Thus, requiring the developer/builder to plant more trees at the time of development is crucial to achieving urban tree canopy goals. Additionally, the cost per tree to the developer and the home buyer are likely to be the lowest at the time of development since tree planting can occur at the same time as initial lot landscaping.

Table T7

EXAMPLES OF LOCAL GOVERNMENT AND NON-PROFIT TREE PLANTING COSTS AND PROGRAMS

NOTE: Initial Costs are generally those paid by property owners for trees with property owner being responsible for planting and care

LOCATION	INITIAL COSTS	DESCRIPTION
Urbana, Il	• $115	• Property owner pays • City Plants • City pays ½ of wholesale cost if plant must be replaced • Owner agrees to water and care for tree/protect
Tree blog sites	• Rule of thumb: multiplier times cost of tree	• 3 times cost of tree for delivery and planting: $100 tree + $300 = $400 • If several trees, then lower cost/tree • Double to triple tree cost (2004)
Albany, NY	• Owner and city split costs	• City pays half of cost of tree and planting
Champaign, IL	• $100/tree	• Owner pays for planting
City of Woodstock, IL	• $100/tree	• Reimbursement to owner toward cost of tree and planting • Owner can plant tree or have planted
Wheaton, IL	• Free tree	• City provides tree to residents; 1.5" caliper; owner plants
Decatur, IL	• Free tree and planting	• CDBG funds used to plant trees in identified "vacant" tree planting sites (already identified)
Cambridge, MA	• $140 • $200/ commemorative tree	• Owner pays this for new tree and planting • Owner pays for commemorative tree
Berkeley, CA	• Free	• City places 800 trees/year • Owner agrees to care for tree
Skokie, IL	• $230 - $310	• Owner and city split cost • 2.5" caliper/12' tall
Watertown, NY	• Free	• City selects 10-15 sites/year • Modeled after Rotary Club program
Salinas, CA	• Developer requirements	• Developer pays city the total cost of all trees to be planted before street improvements are accepted; city then plants all trees
Auburne, Maine	• $100/owner • $225/city	• 2.5" caliper trees
Hudson, OH	• $360/tree • Owner pays $120	• City pays for extra trees on corner lots
Normal, IL	• $60/tree	• City pays remaining costs for tree and planting
Cedar Falls, ID	• 50% of cost of shade trees • Up to $1,500	• On private property with cost sharing by local electric utility
Village of East Aurora, NY	• $50 paid by applicant	• Can contribute to Rotary Club instead
Trees for Houston	• $150/15 gallon • $300/30 gallon • $675/65 gallon • $1,150/100 gallon	• Covers planting and tree cost
TxDOT/Dallas Woodall Rogers planting	• $350/tree including irrigation	• Freeway planting
Texas Tree Foundation/Dallas	• $35/tree • $4/mile for delivery • $20/tree for planting with $200 minimum	• 1.5" to 1.75" caliper 8-10 ft
TxDOT Houston Region	• $200 to $225/tree	• Freeway planting and landscaping

Table T8

CITY OF DALLAS EXAMPLE TREE LIST COMPLYING WITH ARTICLE X

http://dallascityhall.com/arborist/TreeList.pdf

Large Canopy Tree

Minimum 30 feet height upon maturity; branching starts above 6' upon maturity; use for street, site, or parking lot tree, buffer

Replacement Trees

Texas Ash
White Ash
Gum Bumelia
Cedar Elm
Lacebark Elm
Ashe Juniper
Kentucky Coffeetree
Caddo Maple
Bigtooth Maple
Trident Maple
Live Oak
Durrand Oak
Escarpment Live Oak
Bur Oak
Chinquapin Oak
Shumard Oak
Pecan
Common Persimmon (M)
Chinese Pistache
Western Soapberry
Sweetgum
Texas Black Walnut

Non-replacement Trees

Marshall Seedless Ash
Raywood Ash
Gingko
Dawn Redwood
Tulip Tree

Large Non-Canopy Tree

Minimum 30 feet height upon maturity; branching starts below 6' upon maturity; use for site and street tree, buffer

Replacement trees

Eastern Red Cedar
Bald Cypress
Pond Cypress
Southern Magnolia
Austrian Pine
Japanese Black Pine
Mondell Pine
Eastern Redbud

Non-replacement trees

Deodar Cedar
Chitalpa
Goldenrain Tree

Replacement trees

Deciduous Holly
Yaupon Holly
Eve?s Necklace
Texas Persimmon
Mesquite
Mexican Plum
Rusty Blackhaw Viburnum
Desert Willow

Non-replacement trees

Mexican Buckeye
Flowering Dogwood
Roughleaf Dogwood
Saucer Magnolia
Japanese Maple
Texas Red Oak (*Q. buckleyi*)
Purple Plum
Smoketree
Prairie Flameleaf Sumac

Small Tree

Under 30' height upon maturity; use for site tree, buffer

Replacement trees

Deciduous Holly
Yaupon Holly
Eve?s Necklace
Texas Persimmon
Mesquite
Mexican Plum
Rusty Blackhaw Viburnum
Desert Willow

Non-replacement trees

Mexican Buckeye
Flowering Dogwood
Roughleaf Dogwood
Saucer Magnolia
Japanese Maple
Texas Red Oak (*Q. buckleyi*)
Purple Plum
Smoketree
Prairie Flameleaf Sumac

Large Evergreen Shrub

Minimum height of 6 feet or more upon maturity; retains green foliage throughout the year; use for buffer, parking lot screening; foundation planting strip

Shrubs

Abelia
Agarita
Acuba
Azalea
Cleyera
Elaegnus
Burford Holly
East Palatka Holly
Foster Holly
Nellie R. Stevens Holly
Savannah Holly
Weeping Yaupon Holly
Italian Jasmine
Cherry Laurel
Variegated Ligustrum
Wax Ligustrum
Leather Leaf Mahonia
Wax Myrtle
Nandina
Oleander
Chinese Photinia
Frasier's Photinia
Podocarpus
Texas Sage
Gray Santolina
Hard Yucca
Soft Yucca

EXECUTIVE SUMMARY

Roofing is perhaps the hottest of all urban surfaces with temperatures of 150 to 180ºF on a clear sunny day, enough for a third degree burn. Rooftops cover 20 to 30 percent of developed areas and even more in commercial and industrial areas. Residential roofing is the largest portion making up more than half of all urban roof surfaces. These large, very hot surfaces are major contributors to urban heat island effects.

A "cool roof" reflects solar radiation lowering rooftop temperatures by 50 to 80Fº, thereby reducing the building heat load, lowering energy bills, and helping to cool the city. Colorwise, these would be called bright white. We understand that darker colors absorb more solar radiation than lighter colors. An aerial photo of the city will usually reveal many examples of cool roofs already in place.


Reflective roof on industrial building


Dallas Home Depot with reflective roof

There are also "green or garden roofs" that cool by shading a roof membrane (that keeps the water out) and by evaporation of moisture from plants and soil. One of the best known green roofs today is on the Chicago City Hall, but there are many others. Both reflective and green roofs are included here as "cool roofs".

Of the methods for reducing urban heat island effects, cool roofing is the most cost effective, often providing an immediate payback for the building owner or tenant. Estimated energy savings average 20 percent with roofing costs that can be comparable to conventional roofing. They are particularly effective in saving energy for older, less energy efficient buildings.


Dallas school with reflective roof

Buildings have two basic kinds of roofs and there are different products for each. "Low slope" or flat roofs are usually found on commercial and industrial buildings. These include various materials: reflective coatings, single-ply membranes, field-applied materials, and tiles. Sloped roofs, such as those found on most housing, often rely on shingle, most commonly asphalt/fiber glass.

Cool roofing is usually reported by the amount of solar radiation it reflects, called solar reflectance or *albedo*. Today's cool roofing can reflect up to 85% of solar radiation on initial installation, with some decline due to weathering over the first three years. EPA's Energy Star program and California's building code specify reflectance levels that define what is considered a cool roof. California has utilized cool roofing as a cost effective means of reducing overall and peak period electrical demand.

Green or garden roofs provide an engineered roof assembly with several components including a waterproof membrane, a drainage system, and a growing medium for plants. Planting may be relatively shallow or provide for larger plants including trees.


Green roof on apartment building serving as greenspace.

COSTS AND BENEFITS

Cool roofing technologies range widely in materials, applications, and cost. They include inexpensive surface coatings, reflective membranes, coated metal roofing, many types of tiles, and green/garden roofs. Cost differences between reflective roofing and comparable materials can range from zero to 20 percent or more (Table 2). Green roofs often have much higher costs, but are incorporated by building owners for various other reasons in addition to energy savings.

Energy savings are the most direct benefit of cool roofs. Savings can be substantial in older, less energy efficient buildings, offsetting any added roofing costs. Estimates suggest that the Dallas/Ft. Worth area would save $40 million annually with widespread use of cool roofs.[67] Energy reductions can potentially lower power plant emissions and reduce ozone formation that occurs with higher ambient temperatures. Lower roof temperatures may also reduce heat-related roof and roof-mounted equipment deterioration.

A green or garden roof can reduce building energy demand, but also help to manage stormwater runoff by slowing and retaining water. In the U.S., green roofs are sometimes used as public greenspace and a development feature. In Europe and the northwestern U.S., they are primarily used for water management.

OPTIONS FOR COOL ROOFING ACTIONS

OUTREACH

- Inform target audiences of cool roof requirements as part of Phase 1 of the Green Building Program
- Through outreach efforts, emphasize the use of cool roofing for all re-roofing of low-slope buildings
- Showcase existing green roofs for their energy and stormwater management benefits

COOL ROOF POLICIES

- Encourage other entities in the region to adopt cool roof requirements and standards
- Consider inclusion of Energy Star cool roof standards for sloped roofs (25% or greater solar reflectance)

INCENTIVES AND REGULATIONS

- Include cool roof requirements in the Green Building Program for re-roofing
- Encourage electric utilities to provide cool roof rebates as part of their energy efficiency requirements
- Create specific provisions in building codes for green roofs
- Use stormwater fees to fund demonstration projects for public sector greenroofs and porous paving
- Support explicit inclusion of cool roofs in the State's energy code

INTRODUCTION

Roofing is typically the hottest urban surface, ranging from 150 to 180º F on a clear sunny day. Rooftops comprise roughly 20% to 30% of developed areas, and in commercial and industrial areas these percentages are even higher (Table 1). Residential roofing accounts for more than half of all roof surfaces in cities. While there are more paved surfaces, rooftops are hotter and as such may play a largeer role in urban heat island effects.

A. THERMAL PROPERTIES OF ROOFING

Cool reflective roofs have high solar reflectance values, which result in temperatures that are 50 to 80º cooler. A green roof cools by shading the roof membrane and moisture evaporation from plants and soil.

B. COOL ROOFING COSTS AND BENEFITS

Highly reflective roofing costs are the same or somewhat more than conventional roofing, while green roofs cost substantially more, but provide other benefits such as water management.

Benefits include (1) reduced energy use, (2) reduced air pollution, and (3) improved human health and comfort. Reduced energy use can save citizens and businesses money at the same time reducing power plant emissions. Human health is at risk during extended heat waves, particularly in buildings that lack air conditioning. Cool roofs have also been shown to improve building comfort for occupants, residents, or customers.

C. COOL ROOFING TECHNOLOGIES

Cool roofing products are available for all conventional roofing applications whether flat or sloped roofs. Flat roofs are typically commercial or industrial, but may include some residential roofs. Flat roof technologies include built-up roofing (BUR) or a single-ply membrane. Cool roof coatings are used to extend the life of existing roofs that need relatively little repair. Cool roofing has solar reflectance values of 65% and more. Sloped roofing includes various shingles, tiles, and coated metal sheets, with solar reflectance ranging from 25 to 70% (Table 3).

D. ACTIONS FOR HEAT ISLAND REDUCTION

Cool roofing strategies and actions are outlined below. The options range from outreach and education during Phase 1 of the Green Building Program to the strengthening of various regulatory measures.

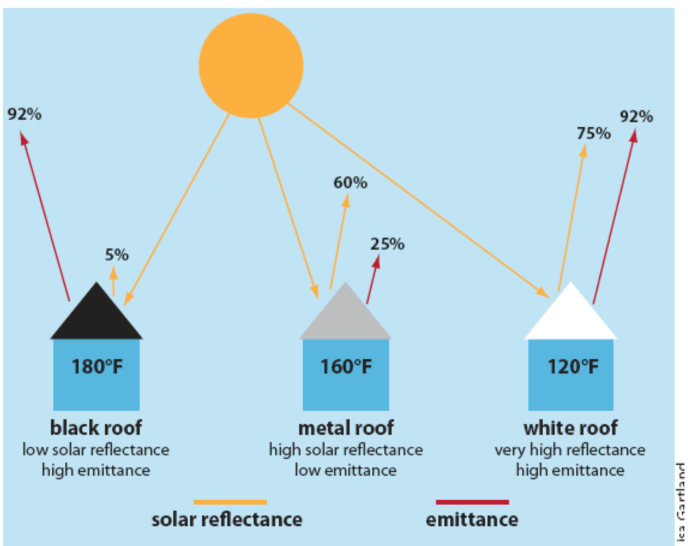
A. Thermal Effects of Roofing

Rooftops are the hottest of all urban surfaces, hot enough for third degree burns. Cool roofs reach only 100 to 115ºF by reflecting a greater portion of the sun's energy. The primary thermal properties are *solar reflectance* (or albedo), which is the fraction or percentage of solar radiation that is reflected, and *emissivity*, which is the ability of a material to release heat.

Solar reflectance is the most important thermal property of roofing since it is responsible for energy savings. EPA Energy Star uses a value of 65% or more, while California uses a higher threshold of 75% as a minimum initial level. For emissivity, California requires an initial level of 70% or more.[68]

A *green roof* has vegetation on the uppermost surface of the roof assembly. It shades the roof membrane (which prevents water entry into the building) and cools the roof through moisture evaporation from plants and soils (planting medium). Green roof soils are specifically engineered to support the desired plant growth and level of maintenance.

Figure R1: Effect of solar reflectance and emittance on roof surface temperatures



On a hot, sunny, summer day, a black roof that reflects 5 percent of the sun's energy and emits more than 90 percent of the heat it absorbs can reach 180°F (82°C). A metal roof will reflect the majority of the sun's energy while releasing about a fourth of the heat that it absorbs and can warm to 160°F (71°C). A cool roof will reflect and emit the majority of the sun's energy and reach a peak temperature of 120°F (49°C).

Albedo (also called solar reflectance) is the ability of a surface to reflect short-wave radiation from the sun, and is typically expressed as a number between 0.0 and 1.0, or as a percentage from 0% to 100%. Lighter colors generally have a higher albedo, although visible light is only a portion of solar spectrum (typically 43%).

Emissivity is the rate at which a material radiates heat from its surface. Materials with high emissivity will lose heat more quickly.

While roof insulation plays a role in saving building energy, decisions about building insulation are generally separate from roofing installation, except for new buildings. Roof insulation is less important in southern climate since it plays a larger role in wintertime heating requirements. Re-roofing an existing building does not typically involve opening the roof cavity. Insulation changes usually occur only if a building is substantially underinsulated and at the same time is being extensively renovated. Spray or rigid insulation is sometimes installed on top of an existing roof surface with a cool roof coating or single-ply membrane applied over the insulation.

Table R1

Land Cover Percentages in Four Major Cities[69]

Urban Area	Pavement	Vegetation	Roofs	Other	Total%
Sacramento	45	20	20	15	100
Chicago	37	27	25	11	100
Salt Lake City	36	33	22	9	100
Houston	29	37	21	12	100

B. COOL ROOFING COSTS AND BENEFITS

COSTS

Cool roofing options range from roof coatings to clay tiles, and cost differences of ten times or more. It may involve a simple maintenance treatment that changes the roof surface on an old building or construction of a roof on a new building. Green/garden roofs can be costly and may require structural changes for an existing building. Studies of cool roofing costs from California, with the most experience to date, indicate that a premium for cool roofs may range from zero to 20¢ per square foot (Table 2).

Roof coatings may be as little as 75¢ per square foot including materials and labor, but not including any roof repair needed for leaks and cracks. Single-ply membranes range in cost from $1.50 to $3.00, not including any extensive repairs or removal of existing roof layers. Cool roofing materials may use additional pigments or formulations needed to increase reflectivity, adding to the cost. However, it is important to understand that roofing cost is less related to the cost of the material than to other factors; local market and labor characteristics, the building itself, and the job size.

An analysis from Pacific Gas and Electric in 2002 presented the following cost premiums for low-slope roofing options. With the advent of additional cool roof products in the market over the last 5 years, these cost differentials may decline.

Table R2: Cost premiums for cool varieties of common low-sloped roofing products[70]

Roofing Product	Cool Variety	Cost Premium ($/ft²)
ballasted BUR	use white gravel	up to 0.05
BUR with smooth asphalt coating	use cementitious or other white coatings	0.10 to 0.20
BUR with aluminum coating	use cementitious or other white coatings	0.10 to 0.20
single-ply membrane (EPDM, TPO, CSPE, PVC)	choose a white color	0.00 to 0.05
modified bitumen (SBS, APP)	use a white coating over the mineral surface	up to 0.05
metal roofing (both painted and unpainted)	use a white or cool color paint	0.00 to 0.05
roof coatings (dark color, asphalt base)	use a white or cool color coating	0.00 to 0.10
concrete tile	use a white or cool color	0.00 to 0.05
cement tile (unpainted)	use a white or cool color	0.05
red clay tile	use cool red tiles	0.10

BENEFITS

Cool roofing helps mitigate the urban heat island effect, but also helps reduce energy consumption, reduce air pollution, and improve human health and comfort. In addition, green/garden roofs can reduce and help control urban stormwater runoff and water pollution.

Cool roofs reduce electricity demand from power plants at the hottest time of the day and year. The savings from reduced energy use also retains money for use in the local economy. By reducing overall demand and peak period demand, pollution from area power plants may be reduced. This includes NOx reductions contributing to ozone formation, and CO2 reductions, which are emerging as a concern in Texas. Human health can be harmed during lengthy heat waves, and cool roofs have been used to help reduce these effects. This is particularly helpful when air conditioning is unavailable or unaffordable for individuals. Building comfort levels can also improve in cool roof buildings, particularly during the hottest parts of the day, benefiting customers, employees, and residents.

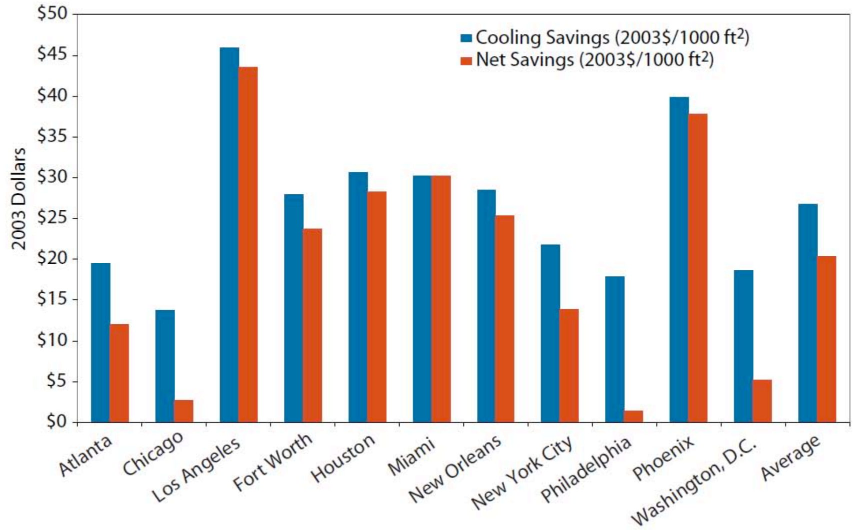
Table R3: Comparison of Traditional and Cool Roof Options[1]

Warmer Roof Options				Cooler Roof Options			
Roof Type	Reflectance	Emittance	Cost ($/ft²)	Roof Type	Reflectance	Emittance	Cost ($/ft²)
Built-up Roof With dark gravel With smooth asphalt surface With aluminum coating	 0.08-0.15 0.04-0.05 0.25-0.60	 0.80-0.90 0.85-0.95 0.20-0.50	**1.2-2.1**	**Built-up Roof** With white gravel With gravel and cementitious coating Smooth surface with white roof coating	 0.30-0.50 0.50-0.70 0.75-0.85	 0.80-0.90 0.80-0.90 0.80-0.90	**1.2-2.15**
Single-Ply Membrane Black (PVC)	 0.04-0.05	 0.80-0.90	**1.0-2.0**	**Single-Ply Membrane** White (PVC) Color with cool pigments	 0.70-0.78 0.40-0.60	 0.80-0.90 0.80-0.90	**1.0-2.05**
Modified Bitumen With mineral surface capsheet (SBS, APP)	 0.10-0.20	 0.80-0.90	**1.5-1.9**	**Modified Bitumen** White coating over a mineral surface (SBS, APP)	 0.60-0.75	 0.80-0.90	**1.5-1.95**
Metal Roof Unpainted, corrugated Dark-painted, corrugated	 0.30-0.50 0.05-0.08	 0.05-0.30 0.80-0.90	**1.8-3.7**	**Metal Roof** White painted Color with cool pigments	 0.60-0.70 0.40-0.70	 0.80-0.90 0.80-0.90	**1.8-3.75**
Asphalt Shingle Black or dark brown with conventional pigments	 0.04-0.15	 0.80-0.90	**0.5-2.0**	**Asphalt Shingle** "White" (light gray) Medium gray or brown with cool pigments	 0.25-0.27 0.25-0.27	 0.80-0.90 0.80-0.90	**0.6-2.1**
Liquid Applied Coating Smooth black	 0.04-0.05	 0.80-0.90	**0.5-0.7**	**Liquid Applied Coating** Smooth white Smooth, off-white Rough white	 0.70-0.85 0.40-0.60 0.50-0.60	 0.80-0.90 0.80-0.90 0.80-0.90	**0.6-0.8**
Concrete Tile Dark color with conventional pigments	 0.05-0.35	 0.80-0.90	**1.0-6.0**	**Concrete Tile** White Color with cool pigments	 0.70 0.40-0.50	 0.80-0.90 0.80-0.90	**1.0-6.0**
Clay Tile Dark color with conventional pigments	 0.20	 0.80-0.90	**3.0-5.0**	**Clay Tile** White Terra cotta (unglazed red tile) Color with cool pigments	 0.70 0.40 0.40-0.60	 0.80-0.90 0.80-0.90 0.80-0.90	**3.0-5.0**
Wood Shake Painted dark color with conventional pigment	 0.05-0.35	 0.80-0.90	**0.5-2.0**	**Wood Shake** Bare	 0.40-0.55	 0.80-0.90	**0.5-2.0**

Reduced energy use

A cool roof reflects solar energy that might otherwise add to a buildings heat load. Savings range widely because of varying building energy characteristics. For example, an older, less energy efficient building would benefit more than a newer, more energy efficient building. Studies have shown that savings range from 11 to 69%, while average savings equal about 20%. Figure 2 compares net annual energy savings for various U.S. cities. The Dallas/Fort Worth area savings were estimated to be approximately $23 per 1,000 square feet (2003 electricity price for commercial sector).[71] Estimated savings in 2008 would increase to $28.9 per 1,000 square feet due to higher electricity prices.

Figure R2
Modeled Net Energy Cost Savings ($/1,000 ft2) in
Various U.S. Cities from Widespread Use of Cool Roofing



Costs are based on state-specific data applied to each city, using 2003 Energy Information Administration reported prices for the commercial sector.

Dallas would also benefit from reduced peak energy demand. The thermal load on roofs occurs over the same time period as peak energy demand. Reduced thermal load means less peak energy demand from air conditioning, a primary determinant of peak electricity demand. Reducing peak demand can also reduce the need for additional power plants and transmission lines. In studies of nine buildings with cool roofs in Florida, California, and Texas, peak demand was reduced 14 to 38%. Even northern cities such as Chicago and Philadelphia would experience a net savings from cool roofs. Commercial and industrial users often pay higher rates during peak periods. Residential users are not typically charged this way, but future residential rates may rely on peak period pricing.

Reduced air pollution.

As discussed above, reduced energy demand reduces electricity demand from Texas power plants. This in turn can reduce power plant emissions and help improve air quality. In 2006, the Energy Systems Laboratory at Texas A&M estimated Texas NOx emission reductions from statewide energy codes would total 900.52 tons/year in 2009 (2.5 tons/day); and 1,167.49 tons/year in 2013 (3.2 tons/day).[72] Cool roofs are an energy efficiency measure that can help achieve these reductions.

Cool roofs are particularly effective in older, less energy efficient buildings. Often building energy codes are not applied to older buildings. However, roofing is one of the few major building elements that is partially or completely replaced over relatively short periods of time. California's building code with its cool roof provisions includes any substantial roofing replacements in air conditioned buildings. This achieves cost effective energy savings and air pollution reductions, benefits not covered if energy requirements apply only to new buildings. Like California, Houston is also requiring cool roofs with roof replacements.

Improved human health and comfort

Hot days can also mean uncomfortable temperatures in buildings during the hottest parts of the day. The added heat load is sometimes a challenge to air conditioning systems to maintain interior comfort levels during the hottest days. Cool roofs are a way of improving such conditions. In a study of a "big box" retail store in California, installation of a cool roof reduced peak indoor temperatures by 5ºF or more, providing comfortable temperatures for ten additional shopping hours per week. Similarly, a Florida school reported improved staff comfort following installation of a cool roof.[73]

Extended periods of high temperatures are another human health concern. Residents of buildings without air conditioning can be subject to heat-related illnesses and even death. Cool roofs were installed in Philadelphia following an extended heat wave, lowering daily maximum room temperature by 2.4ºF, which was a level that occupants considered to be noticeably more comfortable. In Sacramento, second floor apartment air temperatures were reduced by 4ºF after cool roof installation.

Additional benefits

Other benefits of cool roofs include cost savings from possible downsizing of air conditioning equipment and an extended roof life due to reduced temperature extremes. Air conditioning equipment may be downsized due to cooler roof surface temperatures. The reduced heat load on roof mounted units may also help prevent heat related equipment deterioration. Roof materials that reach high temperatures, but then receive colder rainfall are subject to rapid shrinkage and expansion. By reducing these effects, roof materials may achieve a longer life before replacement or before surface maintenance is needed.

C. Cool Roof Technologies

Cool roofing products are available for all conventional roofing applications whether on a flat or sloped roof. Flat roofs are generally commercial or industrial, but include some residential buildings. Flat roof (low slope) technologies are usually built-up roofing (BUR) or a single-ply membrane. Cool roof coatings are used on existing roofs that need relatively little repair. A roofing product considered to be "cool" has a solar reflectance of 65% or more under EPA EnergyStar and 75% or more under California provisions. Cool roofing products for sloped roofs include various shingles, tiles, and coated metal sheets with solar reflectance values from 25 to almost 70%.

Roofs may be either low-slope or steep-slope, each using substantially different roofing materials. Residential roofs are usually steep-slope, with a roof pitch rising more than 2 inches over a 12-inch horizontal distance (a 2:12 pitch). Low-slope roofs have a lower pitch and are typically found on offices, retail, industrial, warehousing, and apartments. The distinction between these roof types often separates the types of roofing companies into primarily residential or primarily commercial.

Steep-slope residential roofs often use some type of shingle (asphalt, shakes, or metal) or various tile products (clay, concrete or slate). Coated metal sheets are also used. Unlike low-slope roofs, steep-slope roofs are visible from ground level. As such, highly reflective roofing is not generally considered suitable. Manufacturers are producing shingles and tiles that have higher solar reflectance. Asphalt shingles, for example, are available with 25 to 65% solar reflectance. Tiles are available with solar reflectance ranging from 10 to 30%.[74] Energy Star specifies reflectance levels for both low-slope and steep-slope roofing products.

Types of Roofing Technologies

Built-up Roof

Built-up roofs (BUR) are a common field applied roofing for low slope roofs. They consist of layers of reinforced fabrics (felts) that have coal tar bitumen, asphalt, or cold applied adhesive between layers. A reflective surface or coating is needed to achieve higher reflectivity. The BUR roof surface may be aggregate, a glass-fiber or mineral cap sheet, hot asphalt, aluminum coating, or an elastomeric coating. Lighter color aggregate is also used to increase reflectance.

Single-Ply Membrane

Single-ply roofing is a manufactured flexible membrane material of rubber or plastic. It is applied in a single layer and glued or attached with fasteners with all seams and edges sealed. Single-ply roofs are used for new construction and for replacement roofing. Single ply cool roof products are available with solar reflectance ranging from 50% to over 80%.

Tiles: concrete, metal, and clay

Concrete, metal, and clay tiles are used on sloped roofs, more commonly for residential applications. Tiles are not as widely used as asphalt shingles in the residential market. Conventional tiles have reflectivity levels as high as 30%, but are more frequently at lower levels. Cool tiles are now available with reflectivity ranging from 25% to almost 70%. Due to the use of "cool colors", traditional colors have become available at an additional cost. "Cool colors" use pigments that increase reflection of infrared rays, which allows darker colors to achieve greater solar reflectance.

ASPHALT SHINGLES

The most frequently used residential roofing material is asphalt/fiberglass shingles. Conventional shingles have reflectivity levels below 20%. Newer shingles using "cool colors" are available in darker, traditional shades and achieve reflectance levels over 25%. Cool shingles currently have a cost premium that may decline as these products become a larger part of the market.

COATED METAL

Coated and uncoated metal roofing is used for sloped roofs in commercial and residential applications. Metal roofing and can be structural and self supporting, or with a non-structural covering placed on a supporting surface. Cool metal roofing is coated and available in a range of products. Reflectance levels are available up to 80% for white colors and up to 38% for darker colors.

SURFACE COATINGS

Cool roof coatings are liquids that are sprayed or rolled onto low-slope roofs. Roofs being coated need to be in good initial condition. Surface coatings can create a reflective surface (65% or more). Two primary cool roof coating materials are available; elastomeric, which is waterproof, and cementious, which is permeable.

GREEN ROOFS

Green roofs or garden roofs place vegetation on a roof assembly that includes a drainage system topped by some sort of growing medium for plants. A green roof assembly cools the roof in two ways: first, by shading the roof surface (i.e., a waterproof membrane), and through evaporation of moisture in soils and plants. Green roofs may be *extensive* systems, which are installed with a relative thin planting soil (4 to 6 inches), or *intensive* systems, which are planted with deeper soils and larger plants, including trees. Extensive systems can be placed on some sloped roofs, while intensive systems are used only on low-slope roofs. Depending on the design and landscaping, irrigation systems may or may not be installed. Structural provisions are needed to accommodate green roof assemblies, however, some existing structures can support a green roof installation without structural modifications.

Figure R3

Green roof in Webster, Texas, General Contractor, Jacob White Construction of Houston, 14,559 square feet, and the largest green roof in Texas. An estimated 73% of all rain that strikes the roof is retained in the green roof, while the excess (approximately 24,000 gallons a month) is transported to the roof drains that direct it to the underground cisterns for storage. Reclaimed water is used for many on site uses (including greenspace irrigation).

D. OPTIONS FOR COOL ROOF ACTIONS

The existing rooftops in Dallas cover an estimated 20 to 25% of the entire area within the Dallas city limits. In addition to their prominence as part of urban surfaces, rooftops typically reach higher temperatures than any other major surfaces in the city (150 to 180ºF). These high temperatures increase surrounding air temperatures as part of the urban heat island effect, but also have important impacts on building energy use and comfort. Dallas has already recognized the potential energy savings and related benefits by including cool roofing as an element in Phase 1 of the green building program, and by the use of cool roofs on city buildings. The following options can be used to further advance cool roofing. They include:

- Outreach to target audiences covered in Phase 1 of the Green Building program and for cool roofs on buildings not included in Phase 1 (primarily re-roofing)
- Actions to increase green roof awareness in relation to stormwater management
- Policies to encourage additional entities to adopt cool roof standards
- Development of incentives and regulations that more fully incorporate cool roofs in Dallas

1. INCREASING AWARENESS THROUGH OUTREACH

Target audiences need to be well informed on cool roofs as part of implementing Phase 1 of the Green Building Program. Phase 1 requires cool roofs (not green roofs, discussed separately below) for projects less than 50,000 square feet of floor area. Building regulations define cool roofs as low-slope roofs using materials that meet EPA's Energy Star performance specifications (Table 3). Buildings larger than this must meet building energy requirements, but do not require cool roofs. Cool roofs are an option for meeting these requirements that could be encouraged through these outreach efforts.

Table R3
Specifications for Energy Star Qualified Low-Slope Roofs
http://www.energystar.gov/index.cfm?c=roof_prods.pr_crit_roof_products

Characteristic	**Performance Specification**
Energy Efficiency	
Initial Solar Reflectance	Greater than or equal to 0.65.
Maintenance of Solar Reflectance	Greater than or equal to 0.50 three years after installation under normal conditions.
Reliability	
Manufacturer warranty for defects in materials and manufacturing	Each company's warranty for reflective roof products must be equal in all material respects to the product warranty offered by the same company for comparable non-reflective roof products. A company that sells only reflective roof products must offer a warranty that is equal in all material respects to the standard industry warranty for comparable non-reflective roof products.

It is important that target audiences for this outreach effort understand cool roof characteristics and the varied range of technologies that are available. Cool roofing provides a different but complementary role to roof insulation, and these differences should be clear to affected audiences. The additional benefits also need to be included in outreach; such as reduced heat load on rooftop equipment, reduced landfill from re-roofing, and the potential for an extended roof lifetime.

Target audiences affected by cool roof requirements under the Green Building Program include builders, developers, roofing companies, construction companies, architects, and building owners. These groups need greater awareness of cool roof requirements and eligible products. Experience in California, where cool roofing is being used extensively, suggests that outreach include several pathways and methods to ensure that goals are met – namely that energy savings are achieved, that building standards are met, and that installed products meet specifications. City staff and building officials will need to understand roofing technologies and applications as well.

Outreach methods include web-based information, on-line informational videos, and training workshops. These can be developed in coordination with local building and roofing organizations to ensure the provision of consistent information.

A cool roof outreach effort can reach low-slope roofs not covered in Phase 1 of the Green Building Program. In particular, this includes existing buildings, many of which have poor energy efficiency characteristics that would benefit from cool roofing. Re-roofing does not ordinarily include the addition of insulation to the roof cavity, and, as such, energy benefits from cool roofing are readily available. There is more square footage of roofing replacement and roofing maintenance every year than would be covered under Phase 1, which applies only to new construction of low-slope roof surfaces.

Re-roofing of low-slope buildings can occur over a ten to fifteen year time frame, and roof maintenance using coatings can occur over much shorter time periods (3 to 5 years). Outreach target audiences include building owners, building managers, and roofing companies. Building owners and building management organizations may be useful in this regard, as will roofing consultant organizations. While the Green Building Program does not require cool roofing for these applications, voluntary participation can be encouraged through cool roofing outreach.

Unlike urban heat island programs such as tree planting, there are no known city-based cool roof outreach and education programs, although cities such as Chicago and Portland have promoted cool and green roofs as part of related initiatives. At the state level, California's cool roof requirements have included a wide range of outreach and education activities including on-line training and training videos for code enforcement staff and building trades. The best Texas example for building code/energy changes was in 2001 as the statewide energy code was promoted. Training and outreach workshops were organized for various target audiences. Builders and trades people were given detailed training in applying new code requirements.

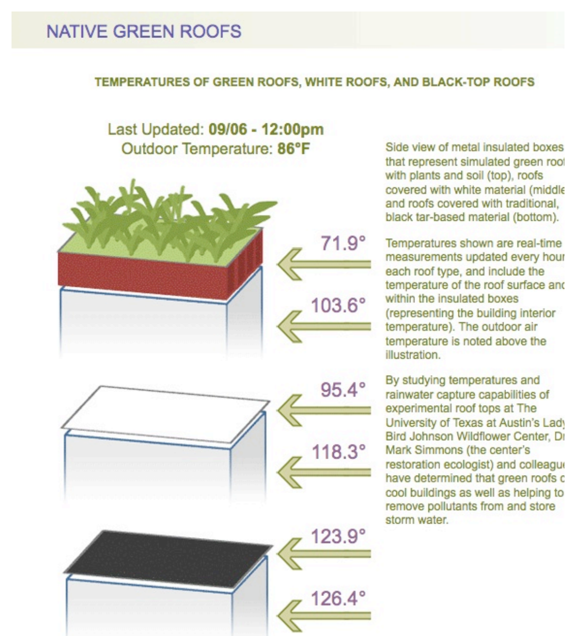
Resources: Existing materials can be adapted for cool roof outreach. There are organizational resources available that include local roofing industry expertise, builders' organizations, and national organizations with local members, such as the Cool Roof Ratings Council, National Roofing Contractors Association, and RCI, International. There are also building and roofing experts at Oakridge National Laboratory and Lawrence Berkeley National Laboratory.

Opportunities: Major roofing events provide opportunities for Dallas cool roof outreach. For example, RCI, International held its 2008 annual convention and trade show in Dallas, and the Texas Association of Roofing Contractors has its annual meeting in Grapevine in October 2009. Similar opportunities are available through target audience events and activities.

<u>Existing green/garden roofing can be showcased as a special cool roofing technology that provides energy savings as well as needed stormwater management and water quality benefits.</u> Water management has been the primary driving force for green roofs in most places where they have been emphasized and promoted (for example, Portland, several cities in Germany, and Tokyo). Green roofs in the U.S. are typically implemented as building design features apart from heat island or energy conservation. These features include aesthetic/design considerations, functional (green roof garden/green space, for example), or market-based (environmental image and attraction of a market segment). The Ford Rouge Plant has the largest expanse of green roof in the world, and was used to signify corporate commitments to environmental principles.

Existing green roof projects in the Dallas area can be identified and highlighted in cool roof outreach materials and separately reported in any web-based information on cool roofs.

Figure R4: Green Roof Test Facility
Lady Bird Johnson Wildflower Center
Temperature readings from September 6, 2008 12 p.m.
http://www.wildflower.org/greenroof/



This showcasing has been used most effectively in the Chicago City Hall building in which one green roof project has been featured again and again.

Other notable green roof examples include the Lady Bird Johnson Wildflower Center, University of Texas at Arlington, City of Atlanta City Hall, and Portland's eco-roof program.

Only nine Texas greenroof projects are listed at Greenroofs.com (not an all inclusive list but has 526 total projects listed for U.S.). Atlanta has 20 projects and 25 are listed in Oregon (primarily Portland). The City of Portland, however, includes over 120 eco-roof projects in its presentations (program described below).

Although they are often special cases, greenroof workshops and projects attract attention to heat island issues, stormwater runoff, and urban design issues. Chicago and Portland have emphasized green roofs as part of other environmental initiatives.

PORTLAND'S GREEN ROOF INITIATIVES

Portland has the most active green roof program in the U.S. and promotes green roof development through a number of policies, and requires green roofs on public buildings.

Figure R5: The Texas Instruments RFAB facility in Richardson, Texas used reflective roofing as well as reflective building and paving materials to achieve urban heat island mitigation benefits.

- All new City-owned buildings are built with a green roof that covers at least 70% of the roof, the remaining roofing being ENERGY STAR rated. When possible, roof replacements must also include a green roof. Stormwater fees are used to finance public green roofs.
- The zoning code gives floor area bonuses for various options, including green roofs; the larger the green roof, the larger the bonus.
- A stormwater management charge is levied for commercial, industrial, and institutional ratepayers based on a site's impervious surface area ($6.45 per 1,000 square feet of hard surface per month – 2006 rates).
- Education and outreach is provided by the city for green roof development through technical assistance, guided tours of green roofs, and ongoing monitoring of green roofs.
- Portland funds green roof demonstration exhibits and test sites.
- Green roofs are formally recognized in the Portland stormwater manual as a Best Management Practice.
- A citizens' group promotes green roof development for lower income areas.

2. POLICIES TO ENCOURAGE COOL ROOFS

<u>In addition to outreach activities for cool roof requirements in the Green Building Program, other entities in the region should be encouraged to adopt cool roof requirements and standards.</u> To achieve any air quality benefits from heat island mitigation as well as meeting energy efficiency goals, other entities, particularly school districts, need to adopt cool roof standards and policies. School buildings comprise the largest single public sector roofing market in the region, and as such, offer the greatest potential. Examples of schools using cool roofs include:

School Examples

- In a Georgia school district, two identical elementary schools were built with the same solar orientation, building design and insulation. A "cool color" metal roof was used on one school (29% solar reflectance) and a conventional color pigment roof (12% solar reflectance) on the other. Both roof colors are visibly similar, with the cool color roof having infrared reflecting pigments. Measured energy savings during the 2006-07 school year amounted to $15,000 on the cool roof school. This amounts to $525,000 over the 35-year life of the roof (assuming no energy cost changes).

- The Enid, Oklahoma school system installed reflective roofing on 22 of its schools as part of an overall energy savings measure. The school district received an Energy Lighthouse award in 2008 for its overall energy conservation efforts.
- A project in San Antonio used a reflective roof coating on portable classroom buildings to measure energy savings. Buildings with the coating had measured reductions of 15% to 17% in August.[75] The payback period for the coating from energy savings was estimated to be 3.6 to 4.7 years. The study did not evaluate comfort levels for students and teachers, which is another benefit in buildings such as these.

<u>Cool roof standards for sloped roofs are available today and can be adopted in future policy decisions (Table 4. Energy Star steep slope roof specifications).</u> In recent years, more cool roofing products for steep sloped roofs (typically residential) have become available. These are suitable replacements for standard asphalt shingles as well as various tiles and metal roofing products that meet EPA ENERGY STAR cool roof standards. It is important to note that solar reflectance requirements for these products are substantially lower than low-slope (flat) roofs, and that their reflectance values are achieved through changes in surface materials that provide darker, but reflective surfaces. California utilities also include provisions for steep sloped roofing in their cool roofing rebate programs (California Edison, for example, provides rebates of 10¢ to 20¢ per square foot). Unlike provisions for low-slope roofs, the California state building code has not yet been adopted provisions for steep-slope roofs, although this is being considered for near term inclusion.

Residential roofing comprises more than half of all roofing surfaces in Dallas and as such having cool roofs would provide substantial benefits for energy savings and air quality. As part of its green building program, steep slope roofing needs to be included as part of cool roof outreach and consideration for future green building requirements.

Table R4
Specifications for Steep-Slope Roof Products
http://www.energystar.gov/index.cfm?c=roof_prods.pr_crit_roof_products

Characteristic	**Performance Specification**
Energy Efficiency	
Initial Solar Reflectance	Greater than or equal to 0.25.
Maintenance of Solar Reflectance	Greater than or equal to 0.15 three years after installation under normal conditions.
Reliability	
Manufacturer warranty for defects in materials and manufacturing	Each company's warranty for ENERGY STAR qualified roof products must be equal in all material respects to the product warranty offered by the same company for comparable non-ENERGY STAR qualified roof membrane products. A company that sells only ENERGY STAR qualified roof products must offer a warranty that is equal in all material respects to the standard industry warranty for comparable non-ENERGY STAR qualified roof products..

3. INCENTIVES AND REGULATIONS

<u>Roofing replacements need to be included as a cool roof option in the Green Building Program.</u> Such a requirement would only occur at the time a building owner decides to replace an existing roof, not on an accelerated schedule. As discussed above, existing buildings are typically less energy efficient than new construction, and in the near term, this would provide much greater energy, heat island, and air quality benefits. The California and Houston building codes include roofing replacement with cool roofing. Buildings owners are given the option of achieving similar energy efficiency gains through other measures. However, in practice, roofing replacement does not typically involve other energy saving building changes, such as opening the roof cavity to add insulation.

<u>Electric utilities should be encouraged to provide cool roof rebates as part of required energy</u>

efficiency measures by utilities. Retail electric power providers might also be willing to participate on a voluntary basis in such rebate programs, apart from any requirements by the Public Utility Commission of Texas. Florida, Georgia, and California utilities have offered cool roof rebates in the past. Even though California has included cool roof provisions in the state's building code, some utilities continue to provide cool roof rebates (typically 10 to 20¢ per sq. ft.) to further accelerate use of cool roofs for energy savings.

Green roofs need separate provisions in the green building program. Unless detailed in other codes, green roofs need to be identified and defined as part of the green building program. They meet similar energy efficiency goals and provided water quality and management functions. Reduction of water use is specifically incorporated in the green building program as a goal, but it does not address lawn irrigation, one of the largest urban water uses. Green roofs are one of several ways to reduce lawn irrigation. Green roofs are also a consideration in integrated stormwater management policies and regulations.

Stormwater fees are one type of incentive that could be used in public sector greenroofs and porous paving demonstration projects. Both greenroofs and porous paving are good stormwater management technologies that accomplish multiple goals (reduced heat island effects, water quality improvements, and air quality benefits). Stormwater fees based on property runoff characteristics encourage sustainable development practices. Greenroofs and porous paving demonstration projects provide good first steps to their expanded use. Stormwater fees could be used as an incentive for offsetting potentially higher initial capital costs, future operating costs (if any), and perceived uncertainties that may exist.

The State of Texas energy code could be amended to explicitly include cool roofs. The region's building code committee has previously considered incorporating cool roofs as part of city building codes. The impact on air quality and energy use would be widened by expanding the use of cool roofs to all buildings covered by the energy code.

Other city building codes with cool roof provisions include Houston and Austin. Austin has provisions for both low slope and steep slope roofs.

> **Austin Energy Code:** 502.7 Reflective Roofing. Roof surfaces with an incline of two inches or less of rise per each 12 inches of horizontal run shall incorporate a roof material having a minimum reflectance of 0.70 or a minimum solar reflective index (SRI) of 78. Roof surfaces with an incline greater than two inches of rise per each 12 inches of horizontal run shall incorporate a roof material having a minimum reflectance of 0.35 or a minimum SRI of 29.
>
> **Houston Code: 5.4.3.5 Cool roofs.** Low slope *roofs* up to 2:12 shall be provided with a roof covering where the exterior surface has: (a) a minimum total solar reflectance of 0.70 when tested in accordance with one of the solar reflectance test methods listed below, and (b) a minimum thermal emittance of 0.75 when tested in accordance with one of the thermal emittance test methods listed below.
>
> - Solar Reflectance Test Methods: ASTM C1549, ASTM E903, ASTM E1175, or ASTM E1918.
> - Thermal Emittance Test Methods: ASTM C835, ASTM C1371, or ASTM E408.


Dallas freeway interchange


Shaded parking


Permeable brick pavers


Porous paving parking lot

EXECUTIVE SUMMARY

Paved surfaces make up 30% to 40% of developed land surface in Dallas, covering more than half of some commercial and industrial areas. Although streets and highways are what we normally think of as pavement, much of it is parking, driveways, shoulders, patios, sidewalks, and ancillary surfaces. These surfaces absorb and store solar energy, contributing to higher temperatures. Almost all are impermeable surfaces that require stormwater infrastructure to handle urban runoff. Cool pavements can help address these effects.

Cool pavements reflect solar energy or they may absorb less energy due to a lower mass and moisture characteristics. *Impervious cool pavements* reflect part of the solar radiation and thereby reduce energy absorption. *Permeable cool pavements* allow water to flow through voids in the materials with the retained moisture providing a cooling effect from evaporation. Cool pavements may include existing cement concrete and asphalt surfaces, as well as a wide range of other paving systems.

Because of their characteristics, cool pavements can make large paved areas, such as parking lots, more comfortable for users. They may add value to the quality of a retail environment. Lower pavement temperatures may also reduce heat related deterioration of paved surfaces and extend the useful life. Some of these materials may also complement the City's goal of creating more sustainable green transportation infrastructure.

COSTS AND BENEFITS

Costs for competing pavement materials cannot be meaningfully compared without considering the application and location. Although some cost data are included in this report, on-going and projected increases in paving costs, regardless of materials, introduce substantial uncertainty for such comparisons.

With some exceptions, cool paving benefits for the urban heat island are indirect, unlike the direct energy savings from cool roofing or shade trees. In addition, pavement standards and practices have not typically been linked to urban heat island concerns. Some paving requirements, such as minimum street widths or parking requirements, determine the extent of paved surfaces and, consequently the resulting heat island effects. Given these conditions, it is important to understand cool paving in the context of related goals and strategies. In Dallas, for example, cool paving benefits are reinforced by the adoption of LEED in development standards, the importance of stormwater benefits, and longer term development goals.* A summary table in the Appendix summarizes many of the cool paving issues and variables.

In addition to effects on urban temperatures, cool paving provides benefits that may well justify their use apart from any heat island benefits. These additional benefits include:

- *Water quality and* stormwater *management.* Cool pavements can reduce stormwater runoff temperature by 2 to 4ºC, a factor helping to meet stormwater quality standards.[76] Permeable cool paving materials are available which may effectively reduce the portion of land covered by impervious materials by minimizing stormwater retention facilities. By slowing the release of stormwater from a site, these materials also remove pollutants from runoff.

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* The LEED Green Building Rating System was developed by the U.S. Green Building Council.

- *Energy savings.* Cool paving and accompanying strategies can reduce urban temperatures to achieve energy savings during hot weather. The savings from cool paving have not been separately quantified, but increased reflectivity (albedo) of both paving and roofing by 0.1 is estimated to provide 5 to 7% annual savings.[77] Reflective paving also reduces nighttime lighting requirements, such as street lights, providing direct energy savings. On parking areas, these pavements may provide improved security through improved illumination.[78] Reduced lighting requirements can also reduce capital costs for lighting.
- *Air quality.* Increasing the amount of shade in parking lots, as suggested in LEED standards and the Dallas comprehensive plan can reduce emissions from parked vehicles by reducing evaporative and start-up emissions. To the extent that paved surfaces contribute to higher air temperatures, cool paving helps reduce ozone formation.
- *Quality of life.* Paved surfaces are a prominent element of the city and help shape the quality of life. Cool paving strategies can improve these features in various ways; reduced surface areas of paving, increased street trees and shaded parking, landscaped medians, vegetated berms, varied pavement textures and materials, more compact designs, and even vegetated parking surfaces. Many cool pavements are included in LEED credits that are part of Dallas development goals and standards. Inclusion of cool paving may add to a development's uniqueness and marketability.
- *Noise reduction.* A composite paving structure of rubber asphalt surface placed over conventional concrete[79] has been shown to reduce noise reduction as well as provide nighttime temperature benefits.

DALLAS COOL PAVING STRATEGIES AND ACTIONS

Five strategies that reduce urban heat island effects from paved surfaces are incorporated in LEED standards and are supported by various elements in the Dallas comprehensive plan, *forwardDallas!*

The LEED Rating System's Credits 7.1 and 7.2 specifically address heat island effects and other Credits include cool paving strategies for development design and water management. The strategies below provide a framework while placing cool paving within a forward looking development context. The five cool paving strategies include:

1. Minimize total paved surfaces in development by limiting the amount of impervious surfaces, clustering development, and replacing unnecessary paved surfaces with landscaped areas.
2. Increase pavement albedo (reflectivity) to at least 29%.
3. Increase the porosity of paved surfaces through the use of selected applications of pervious paving.
4. Shade paved surfaces to help reduce urban heat island effects.
5. Stack or shade parking areas to reduce impervious surface cover and to provide cool parking areas.

Cool Paving Definition: LEED identifies two ways of defining paved surfaces that meet LEED's urban heat island provisions: paving that is at least 50% pervious and paving that has a solar reflectance of 29 or more.

OPTIONS FOR COOL PAVING ACTIONS[1]

DEMONSTRATION AND OUTREACH

- Foster and support cool paving demonstration projects
- Create a database of existing cool paving applications to illustrate current uses
- Provide cool paving product workshops for staff, developers, and builders

POLICIES

- Create a unified cool paving policy that applies to parking, street medians, and freeways. Incorporate existing policies including:
    - Comprehensive Plan – *forwardDallas!*
    - Green Building Program
    - LEED Rating System provisions
    - Landscape Ordinance
    - Storm Water Management

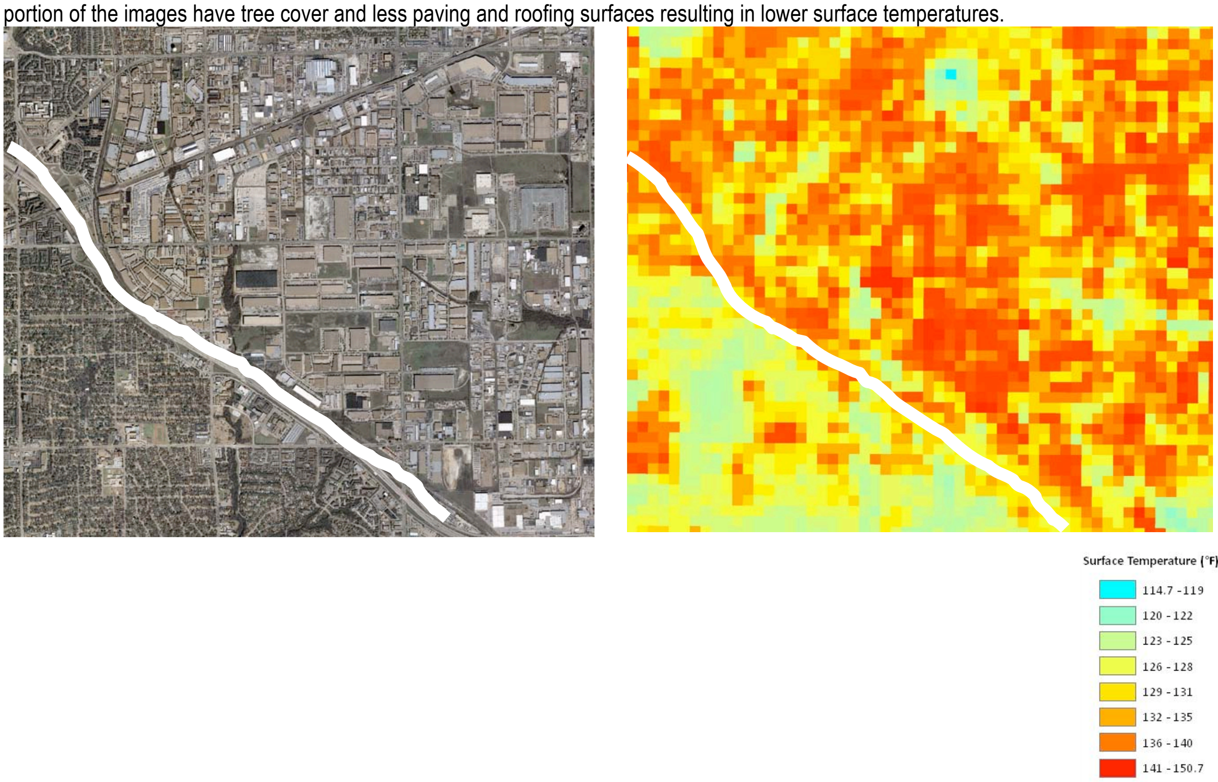
INCENTIVES AND REGULATIONS

- Provide points in the Green Building program for cool paving
- Ensure supportive provisions in stormwater management regulations
- Add provisions to the zoning ordinance to limit impervious surfaces

Figure P1.

Surface Temperatures in Northwest Dallas Industrial/Warehousing Area

This light industrial/warehouse area in the northwest portion of the image is along I-635 (white line). The residential areas in the southwest portion of the images have tree cover and less paving and roofing surfaces resulting in lower surface temperatures.



[1] See details below in Section D. Cool Paving Strategies and Actions

INTRODUCTION

Paved surfaces occupy a large portion of urban development reaching up toward 50% in some cities. They affect temperature, but stormwater runoff, water quality, and appearance of the city.

A. THERMAL EFFECTS OF PAVEMENT

The thermal properties of paving determine its impact on temperature. Pavement characteristics include solar reflectivity (albedo), porosity, thickness, and emissivity. Cooler pavements can be achieved by increasing the reflectivity to reduce the amount of absorbed solar radiation, increasing the pavement's porosity to cool the pavement through evaporation, and using pavement that emits lower levels of heat during the night.

B. COOL PAVING COSTS AND BENEFITS

Costs for competing pavement materials cannot be meaningfully compared without considering the application and location, although selected cost data are included in this report. Indirect economic costs, such as health effects from extreme heat[80] and ecosystem damage from paving runoff are not generally included in paving cost considerations. Most cool paving benefits are indirect, unlike those provided by trees for the quality of life in Dallas, or the direct energy savings from cool roofs. Thus, it is particularly important to understand cool paving in the context of several related goals and strategies. In Dallas, some of the related goals include the provision of LEED criteria in development standards, the importance of stormwater benefits in urban development, and the longer term development goals of the city.

C. COOL PAVING TECHNOLOGIES

Cool pavements reflect solar energy or they may absorb less energy due to a lower mass and moisture characteristics. *Impervious cool pavements* reflect part of the solar radiation and thereby reduce energy absorption. *Permeable cool pavements* allow water to flow through voids in the materials with the retained moisture providing a cooling effect from evaporation. Cool pavements include existing cement concrete and asphalt surfaces, as well as a wide range of other paving systems.

D. STRATEGIES AND ACTIONS FOR HEAT ISLAND REDUCTION

Cool paving strategies and actions that Dallas can take are outlined in this section. The strategies incorporate elements of LEED standards as well Dallas plans. The actions range from demonstration projects to possible modifications of regulations and standards.

A. THERMAL EFFECTS OF PAVED SURFACES

Paved surfaces are hot in the summer. Most people know this from stepping out of their air conditioned cars on a hot sunny day onto a large parking lot, both feeling and seeing the heat radiating from the surface. Surface temperatures can exceed 150ºF. in these conditions, particularly if there is little wind movement.

Since paving also occupies a large portion of urban surfaces, it plays an important role with regard to the urban heat island effect. The following table compares the relative distribution of land cover for four major cities:

Table P1
Land Cover Percentages in Four Major Cities[81]
From pre-2003 analyses

Urban Area	Pavement	Vegetation	Roofs	Other	Total%
Sacramento	45	20	20	15	100
Chicago	37	27	25	11	100
Salt Lake City	36	33	22	9	100
Houston	29	37	21	12	100

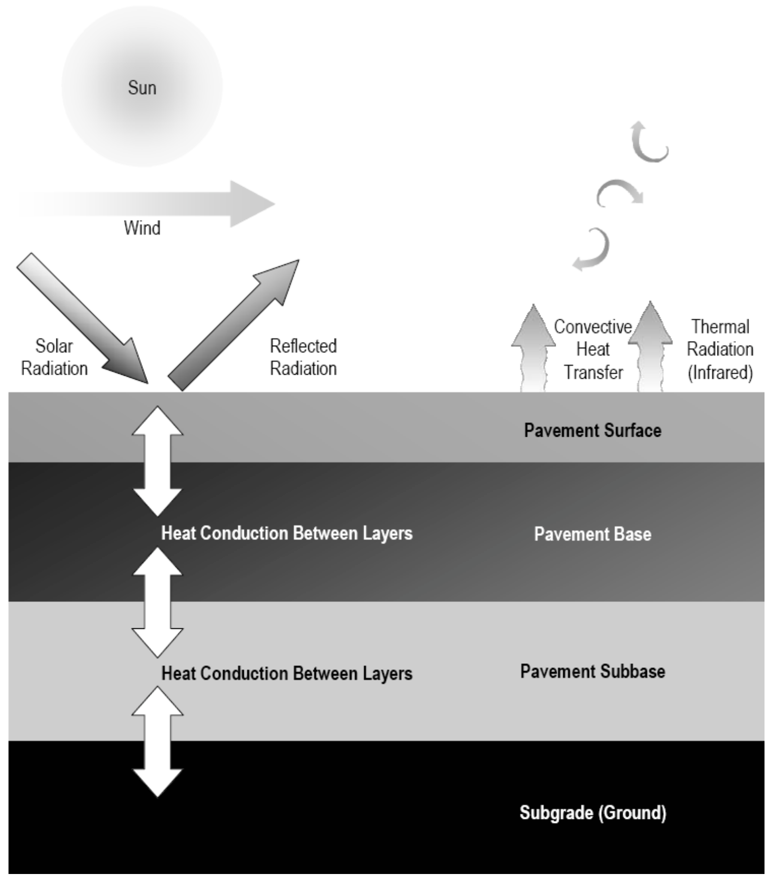
Paving materials tend to absorb and store solar energy in much larger amounts than vegetation. Paving that is impervious also means there is less moisture available for evaporative cooling than would occur with vegetation. On a sunny day, dry, barren soils will also absorb solar energy producing high daytime surface temperatures.

With the addition of paved surfaces, the surface energy characteristics of a city are changed. The "thermal" characteristics of paving materials mean they will absorb and store larger amounts of energy. The resulting higher temperatures radiate heat into the air during the day and into nighttime hours.

The physical characteristics of paving materials that affect how they behave thermally include not only the amount of energy they reflect (albedo or solar reflectance), but other properties as well. Some of these properties are illustrated in Figure 2. The following summarizes major thermal properties of paving:

- *Albedo.* Albedo (also called solar reflectance) is the ability of a surface to reflect short-wave radiation from the sun, and is typically expressed as a number between 0.0 and 1.0 or as a percentage from 0% to 100%. Lighter colors generally have a higher albedo, although visible light is only a portion of the solar spectrum (typically 43%). The albedo of paving materials typically ranges from above 5% to 40%.
- *Emissivity.* This is the rate at which a material radiates heat from its surface. Materials with high emissivity will lose heat more quickly. Paving materials have high emissivity levels that typically range from 0.90 to 0.98.
- *Permeability.* Pervious or porous paving surfaces allow water and water vapor to pass through them. Permeability (or impermeability) may be expressed as an "infiltration rate" measured in inches/hour. A permeable surface allows water to evaporate, providing a cooling effect.
- *Conductivity.* A pavement with low conductivity transfers heat slowing through it. It will heat up quickly, but does not store as much heat.
- *Thickness.* A thicker pavement is capable of storing more heat than one that is thinner. The thickness will also determine how much heat is conducted to base layers.
- *Convective airflow.* Convection is another way that heat energy is transferred. Airflow across the pavement affects the amount of energy that is transferred.[82]

Figure P2
Heat-Related Characteristics and Processes in Pavement



By changing some of the thermal properties of paved surfaces, cooling effects can be achieved. Pavement with higher albedo, for example, reflects some of the solar radiation, producing a cooler surface and a cooler pavement. Initial albedo of paving is determined to some degree by the color of aggregates and the binder materials. Use of lighter exposed aggregate results in a higher albedo. However, the albedo of paved surfaces also changes over time due to weathering and use. In the case of concrete cement, surfaces may become less reflective and in the case of asphalt surfaces, weathering produces a lighter surface.(Table 2)

As mentioned previously, porous paving cools through evaporation from moisture that may be present in the material. It may also allow more convective airflow allowing heat to dissipate more quickly. The cooling effect of permeable pavement is somewhat dependent on the presence of moisture, and a damper climate, such as Dallas, could achieve more cooling than in a very dry climate, such as West Texas.

It is also possible to change other thermal characteristics of paved surfaces to reduce heat island effects. For example, research on recycled crumb rubber pavements has shown more rapid heat loss during the night than other paving materials.

Table P2
LEED 7.1 - SOLAR REFLECTANCE INDEX (SRI) FOR STANDARD PAVING MATERIALS

Material	Emissivity	Reflectance	SRI
Typical New Gray Concrete	0.9	0.35	35
Typical Weathered* Gray Concrete	0.9	0.20	19
Typical New White Concrete	0.9	0.7	86
Typical Weathered* White Concrete	0.9	0.4	45
New Asphalt	0.9	.05	0
Weathered Asphalt	0.9	.10	6

* Reflectance of surfaces can be maintained with cleaning. Typical pressure washing of cementious materials can restore reflectance close to original value. Weathered values are based on no cleaning.

B. COSTS AND BENEFITS OF COOL PAVEMENTS

COOL PAVEMENT COSTS

Pavement costs are important in selecting a pavement material or a maintenance application. However, there are no simple comparisons among the different technologies and goals. For example, costs for a road carrying high volumes of heavy traffic will be much greater than those for a small retail parking area, regardless of heat island considerations. Some decisions are driven by life cycle costs of the paving while many are based primarily on initial costs. Similarly, costs for resurfacing, reconstruction, or maintenance vary widely. In addition, recent rises in costs of paving materials make cost comparisons particularly uncertain.

Urban heat island effects have not been a significant factor included in pavement choices, even though these effects are being included in forward looking building practices, such as LEED. This may change over time as cities come to understand these effects and ancillary benefits.

Pavement choices also depend on who is making the decision. Public agencies will consider lifecycle costs in some instances because their responsibility for maintaining that surface will continue far into the future. Financing constraints and specific projects, however, can force local governments to lend more consideration to short term costs. Private sector paving decisions can depend on such things as future ownership of that property. If the property will be sold in the near future, long term cost factors may play a lesser role. Some developers also recognize that the quality and type of pavement may affect its market value in the short term, and opt to invest more in such infrastructure.

A study by the Lawrence Berkeley National Laboratories (LBNL) examined lifecycle costs of various types of paving. Their comparison found that for streets and parking lots portland cement concrete was more cost effective than asphalt concrete over the life of the pavement, and that ultra-thin whitetopping could be an effective alternative to standard rehabilitation of asphalt concrete pavements.[83] However, chip seal treatments using lighter aggregate offered a potentially reflective cost effective pavement treatment.

The LBNL study also compared costs of porous pavement for parking lots with conventional asphalt and found lifecycle costs were higher for the porous pavement. The Federal Highway Administration has reported that porous asphalt is roughly 10% to 15% more costly than impervious asphalt while porous concrete costs are reported to be 25% more. Making these comparisons difficult is that at times reported porous pavement costs may include drainage structures that raise total costs by $50 to $75 per square yard. Any such cost comparisons would need to include porous paving's contribution to a stormwater system.[84]

The following table provides one effort to compare both construction and maintenance costs for various pavements. The cool pavements include Portland cement, whitetopping, and chip seals. It is noted in the source report for this table that the costs are a rough comparison with inherent variability due to local economics, different materials properties, and assumptions of the pavement thickness used to estimate the construction items. The data are based on 2002 construction bid costs from several states.

Table P3
Comparative Unit Costs of Selected Pavement Treatments[85]

Treatment	Unit	$/SY/in or $/SY	Years
Hot-mix asphalt	SY/in	$1.00-$1.50	7-20
Plain-jointed Portland cement concrete	SY/in	$3.00-$5.00	15-35
Reinforced concrete	SY/in	$7.00-$13.00	15-35
Whitetopping	SY/in	$3.00-$5.00	10-15
Ultrathin whitetopping (relatively new)	SY/in	$40.00-$60.00*	na
Slurry seals	SY	$0.90	2-8
Microsurfacing	SY	$1.25	5-10
Chip seals	SY	$0.85	2-8
Thin hot-mix overlay	SY	$1.75	2-12

*may include additional work with bid costs
SY/in = Square yards per inch of thickness
$/SY = Cost per square yard

Table P4
Parking Surface Initial Cost Comparison Chart[86]

Pavement Type	Cost per Ft2 (Installed)
Conventional Asphalt	$0.50 to $1.00
Permeable Concrete	$1.50 to $5.75
Grass/Gravel Pavers	$2.00 to $6.50
Interlocking Concrete Blocks	$5.00 to $10.00

Adapted from New York State, New York State Stormwater Design Manual: www.rpi.edu/~kilduff /Stormwater/ permpaving1.pdf.

BENEFITS OF COOL PAVING

Despite the prevalence of paved surfaces that contribute to the urban heat island effect, the benefits are not as compelling as for trees and cool roofs. Most of the cool paving benefits are indirect. In addition, pavement standards and practices are less connected to urban heat island concerns. Pavement selection is generally not tied to reflectivity or porosity. Some criteria for material specifications may contribute directly to urban heat island effects. For these reasons, it is important to understand cool paving in the context of related goals; for example, the role of LEED criteria, the potential for stormwater benefits, and the importance of longer term goals for the city's future.

COOL PAVING, WATER QUALITY, AND STORMWATER MANAGEMENT

Cool pavement surfaces can benefit water quality and help reduce stormwater infrastructure costs. Porous pavements, especially for parking, can improve water quality by reducing the amount of impermeable surfaces. Porous paving can be coupled with bioswales and other vegetated treatments to help filter surface runoff, increase percolation into soils, and protect groundwater. When designed as part of a drainage system, land may be used more effectively, stormwater impact fees may be lowered, and downstream stormwater infrastructure costs may be lower.

Cool pavements can improve water quality by reducing the temperature of stormwater runoff. Conventional paving produces higher temperature runoff that contributes to poor water quality. Higher temperatures in streams reduce oxygen content and create wider variations in stream temperatures.[87] The development process often involves removal of trees and vegetation which contributes to non-point thermal pollution. Cool pavements help mitigate these additional water quality impacts.

The recently published Green Parking Lot Resource Guide[88] from EPA provides many examples of water management structures that can accompany paved parking or other impervious surfaces. The Best Management Practices (BMP) listed in Table 5 can remove various pollutants from surface water runoff.

Table P5
Best Management Practices (BMP) Effectiveness

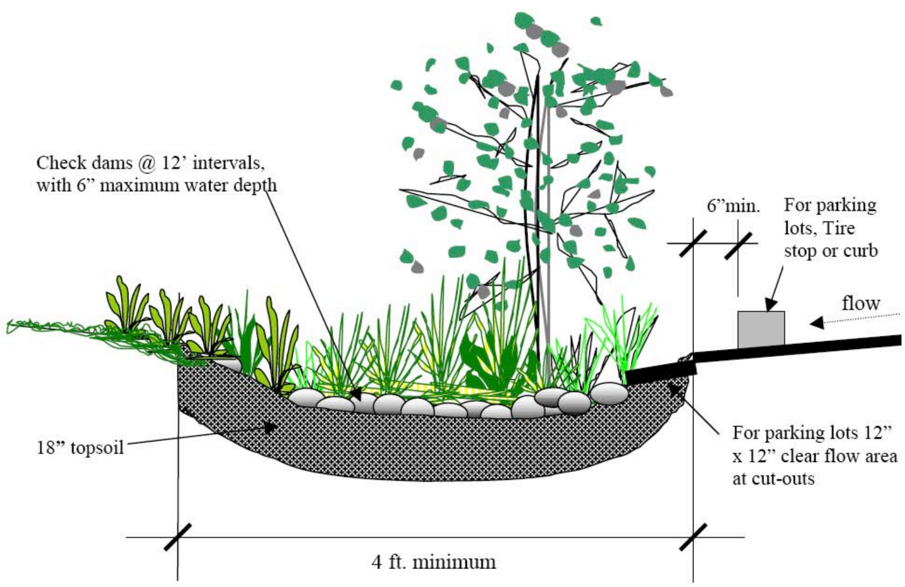
BMP Types	Typical Pollutant Removal Efficiency (percent)				
	Suspended Solids	Nitrogen	Phosphorus	Pathogens	Metals
Dry Detention Basins	30-65	13-45	15-45	<30	15-45
Retention Basins	50-80	30-65	30-65	<30	50-80
Constructed Wetlands	50-80	<30	15-45	<30	50-80
Infiltration Basins	50-80	50-80	50-80	65-100	50-80
Infiltration Trenches/ Dry Wells	50-80	50-80	15-45	65-100	50-80
Grassed Swales	30-65	15-45	15-45	<30	15-45
Vegetated Filter Strips	50-80	50-80	50-80	<30	30-65

U.S. EPA, Green Parking Lot Resource Guide, February 2008, p. 18.
Source: U.S. EPA, 1993, Handbook Urban Runoff and Pollution Prevention Planning, EPA-625-R-93-004, taken from Purdue University Engineering Department's Long-Term Hydrologic Impact Assessment (L-THIA): http://cobweb.ecn.purdue.edu/~sprawl/ LTHIA7/lthia/lthia_index.htm.

Vegetated swales illustrated below have been used in large retail developments, such as Wal-Mart's McKinney store, to help manage stormwater runoff. These designs also improve the appearance of parking areas while potentially reducing more costly stormwater infrastructure.

Swales capture pollutants as runoff is detained and absorbed in the soil, vegetation and organic matter. Using above proportions size at 0.05 x impervious area. Detention is provided for storms up to the 10-year event. Swales help mitigate runoff temperatures by retaining most of the runoff in warm seasons. Groundwater recharge occurs as check dams facilitate infiltration.

Figure P3.
Stormwater Management Function and Sizing[89]



Chicago is using porous paving to reconstruct its alleys as a way of addressing stormwater runoff. The Green Alley program is viewed as a multi-benefit stormwater and urban heat island component. The City also sees this approach as educational strategy for green building practices and for property owners who are making decisions about paving on their property.[90]

COOL PAVING AND ENERGY SAVINGS

Unlike evidence of direct energy savings from cool roofs and trees, cool paving energy benefits are not as widely researched. Since paved surfaces comprise a large portion of urban

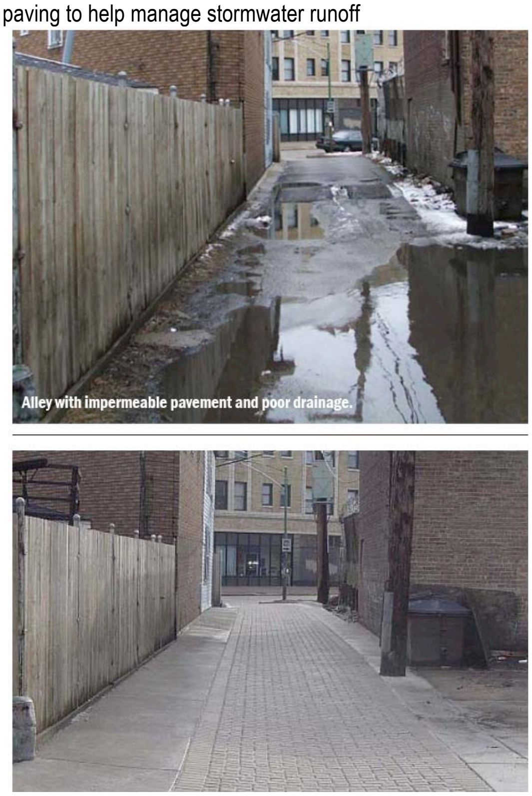

Figure P4. More reflective pavement may reduce lighting requirements and save energy.

development, it has been postulated that overall temperature impacts from paving could be considerable, and that the energy impacts might also be large. However, the thermal properties of paving materials include more than its reflective qualities. Other properties such as emissivity, heat storage capacity, density, and pavement thickness are important.[91]

Figure P5. Use of vegetation strips in parking lots collects and filters runoff, but also provides a more attractive and cooler parking surface.


In addition, paving with higher reflectivity may help improve nighttime visibility. This in turn reduces the amount of lighting needed to achieve desired illumination levels, saving energy as well as capital costs. "European road designers often take pavement color into account when planning lighting needs.[92] Nighttime illumination may be increased by 10 to 30% with more reflective surfaces.[93]

The indirect energy savings of albedo changes have been estimated in a five-city study by LBNL.[94] The indirect effects of both albedo change and forestation were combined in this analysis, but provide some relative indication of energy benefits. The combined energy savings of pavement and forestation ranged from 15% to 22% of total energy savings from heat island mitigation. In Houston, this amounted to $15.6 million in annual energy savings. Increased higher albedo pavements accounts for some portion of these savings, but the portions are not separately reported.

Figure P6. The Chicago Green Alley program uses porous paving to help manage stormwater runoff


The Mitigation Impact Screening Tool (MIST)[95] estimates energy savings from combined roof and paved surface albedo changes. For example, an albedo increase of 0.1 (albedo 0.1 above current albedo) would provide annual energy savings of 2% to 3% for office and retail development and 5% to 7% for residential structures. Since paved surfaces comprise a larger portion of urban development, cooler pavement might account for more energy savings than roofing. However, the <u>direct energy savings</u> of higher roofing albedo is considerably larger than the <u>indirect energy savings</u> from higher albedo paved surfaces.

MIST also estimates the effects of temperature change on energy savings. To some extent, cooler paving would contribute to such temperature reductions. Again, the proportional contribution of paving and roofing are not established.

COOL PAVING AND AIR POLLUTION

Cool paving strategies can provide air quality benefits by helping to reduce temperatures, and when coupled with shade in parking lots, can reduce evaporative emissions from parked vehicles.

Field studies in California measured the effect of shade tree cover in parking lots on vehicle emissions. They found that shade trees reduced ambient temperatures by 4 to 8ºF. This resulted in reduced VOC emissions that occur during various vehicle operating conditions, i.e., at rest or while the engine is still hot.[96] Newer vehicles produce lower levels of these types of emissions due to vehicle improvements. Ambient temperatures are also a factor in mobile source air quality modeling and lower temperatures do result in lower emissions. In addition, faulty vehicles with evaporative emission problems (such as leaking fuel caps) produce higher emissions at higher temperatures.

As discussed elsewhere, higher temperatures are associated with ozone formation and paving contributes to higher ambient air temperatures in cities. Although there is no definitive measure how large cool paving's impact might, these relationships suggest an indirect air quality benefit.

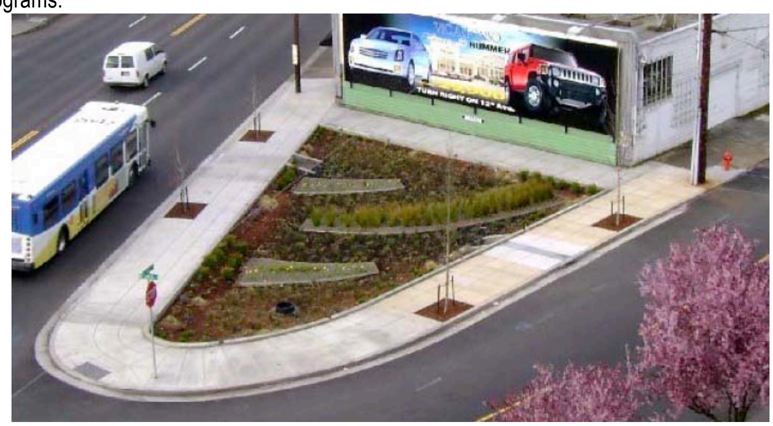
QUALITY OF LIFE BENEFITS

Paved surfaces are sometimes noted as a negative feature of cities: too much, too little, too hot, too crowded, too noisy, too rough, etc. The image of shimmering heat from a parking lot on a hot summer day is familiar to most Texans. Cool paving strategies offer the potential for lower surface temperatures and can also add to the quality of life in cities – shade trees in paved areas, landscaped medians, vegetated berms, varied textures and materials, compact designs, bioswales, and even vegetated surfaces.

Many of the LEED credits included above are intended not only to reduce heat island effects, but also to improve the quality of life through more attractive, multi-function paved surfaces.

Figure P7. Parking surface reconfigured to provide stormwater management and cooling effects for the school building. Portland Sustainable Stormwater Management Program[97]

Figure P8. Previously paved street segment converted to water infiltration planter; Portland Raingarden and Ecosroofs Programs.[98]



COMBINING COOL PAVING BENEFITS

Cool paving strategies are likely to be more effective if they take advantage of complementary benefits, some of which are described above. Other features such as safety, noise, and context sensitive designs may fit paving projects and implementation of related policies. The following table summarizes various cool paving projects that have taken advantage of combining benefits.

Table P6

Examples of Cool Pavements Complementing Other Policy Objectives[99]

Policy Objective	Location	Project
Water Quality	Ford Motor Company Rouge Center, near Detroit, MI	A 16-acre parking lot was constructed with porous pavements over large stone storage basins, as part of the facility's stormwater management system.
	Houston, TX	A 317,000 square foot Grasspave (reinforced turf structure) parking lot was constructed at Reliant Stadium, both to mitigate stormwater and "green" the stadium area. It also serves as a venue for out-door festivals and rodeos.
	Atlanta, GA	The City of Atlanta built a porous concrete parking lot at its Department of Corrections.
	Eugene, OR	The City of Eugene constructed a porous asphalt parking lot at its equipment maintenance facility, using the Oregon DOT's asphalt mix design for an open-graded friction course.
	Chicago, IL	The City of Chicago reconstructed a 10,000 square foot alley with a gravel pave system for both storm-water and heat island benefits.
Noise Reduction	Phoenix area, AZ	As part of its Quiet Pavement Pilot Program, the Arizona DOT has been experimenting with the use of asphalt rubber friction course (also called crumb-rubber) atop a concrete slab. It has plans to install these on sections of inter-states and other high-volume roadways throughout the area, with a noise-monitoring program to assess benefits over time.
Safety Improvement	San Antonio, TX	A section of I-35 was repaved with a permeable friction course (laid on top of an impermeable base) to improve traction and visibility in wet weather.
Context-Sensitive Design	Burlington, VT	The North Street Revitalization Project made use of painted, textured asphalts at crosswalks, and considered use of tinted asphalt mixes.
	Washington, D.C.	In a recent reconstruction of Pennsylvania Avenue in front of the White House, the roadway was repaved with a reddish asphalt to create a more "natural" look.

Figure P9
LOVE FIELD
Love Field aerial and surface temperature images. Both the paved surfaces and extensive unshaded grass areas contribute to higher daytime surface temperatures. The vegetated areas will cool more quickly due to moisture evaporation and surface airflow.

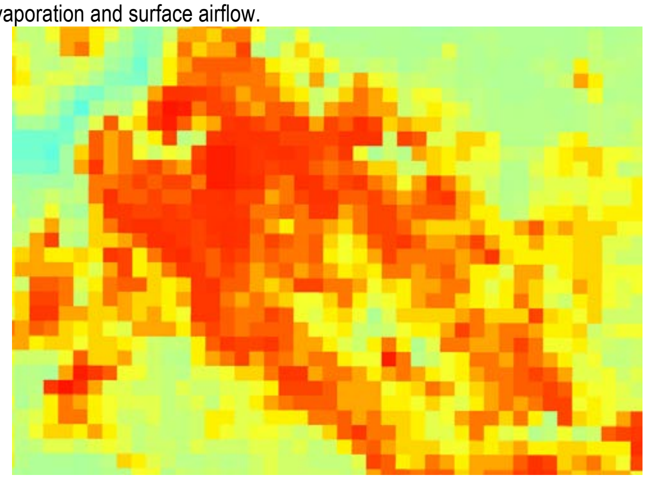


Figure P10
DOWNTOWN DALLAS
Larger paved surfaces in the west part of downtown contribute to higher surface temperatures. Building shadows from highrise structures can produce cooler surface temperatures during the day, but solar absorption contributes to the nighttime heat island effects and higher air temperatures.

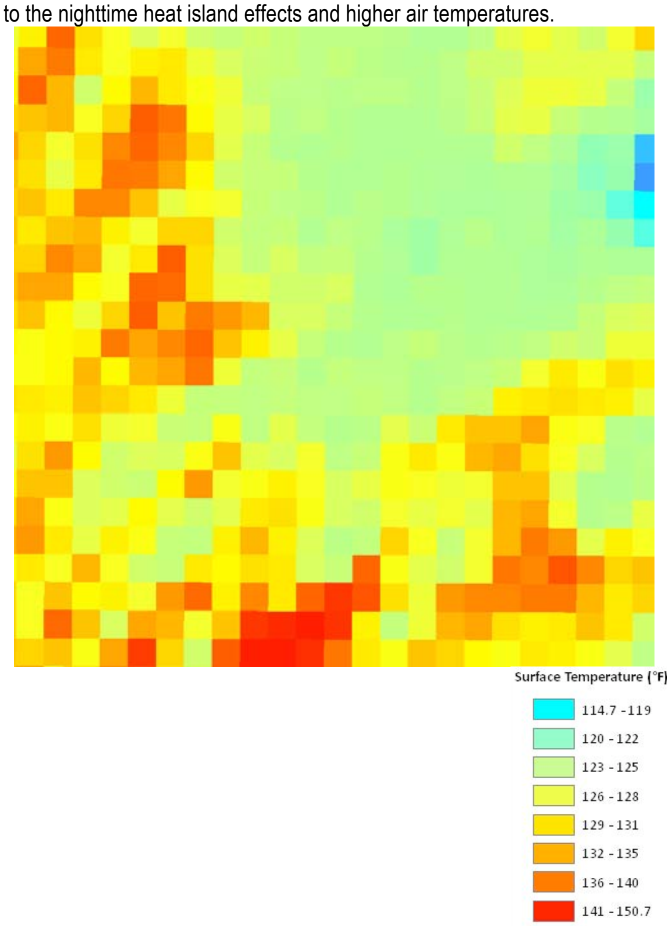
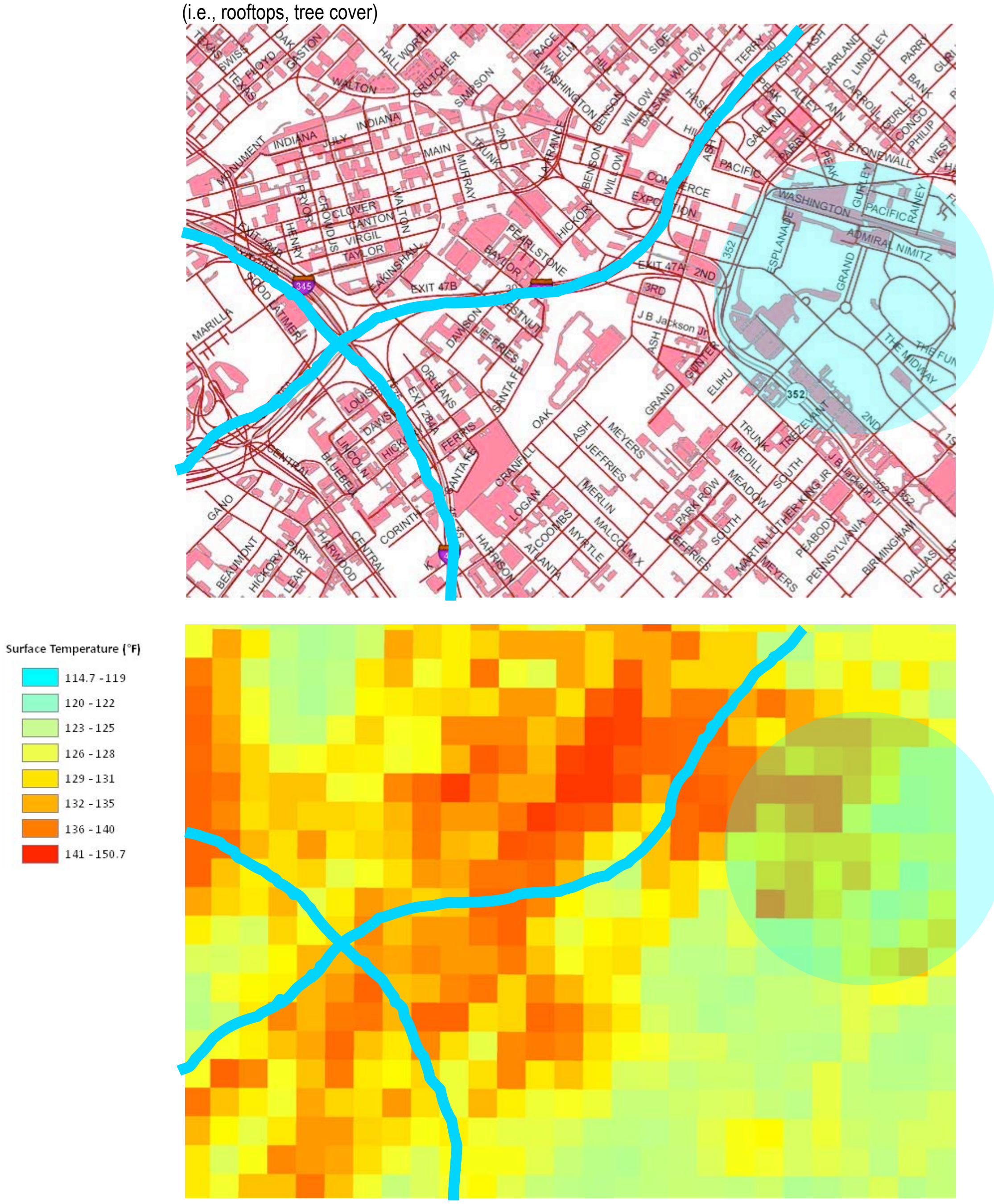


Figure P11

PARKING SURFACES IN THE FAIR PARK VICINITY

Fair Park (blue circle) is on the eastern edge of the images below (I-45 and I-30 in blue). Parking surfaces are shown in the top image and surface temperatures in the bottom. While much of the surface in the overall area is parking, surface temperatures are be more affected by other factors (i.e., rooftops, tree cover)



C. Cool Pavement Technologies

Types of Pavement Technologies

There are many types of available cool pavement technologies.[100] The use of these materials depends largely on their application and purpose. Reduction of urban heat island effects is not typically the major factor in paving choices. Rather, the decision is based on engineering practices, the particular application, and cost.

Pavements are created as new construction, reconstruction, maintenance and rehabilitation. Applications and choices will vary. For example, low volume roads are built with different specifications than freeways. Some pavement technologies would not support normal roadway traffic loads, but would be well suited for parking or sidewalks. In some instances, the choice is driven by design considerations in which a commercial or office development may want porous pavers coupled with ample landscaping. Recently, paving choices in new developments increasingly include environmental considerations and criteria.

Reflective cool pavements can have substantially lower surface temperatures and thereby have less impact on urban temperatures. In test situations, materials with lower reflectivity are found to have surface temperatures that can range above 65ºC (149ºF). Increasing the reflectivity from 0.10 to 0.25 under the same conditions can reduce surface temperatures by about 15ºC (27ºF).[101]


Porous asphalt parking lot


Pervious structure supporting growth of grass

Portland Cement Concrete

This is a conventional pavement that is considered "cool" because of its lighter color and reflectivity. The reflectivity is dependent on the cement itself and the aggregate color.[21] As it wears, the aggregate becomes exposed which changes reflectivity somewhat.

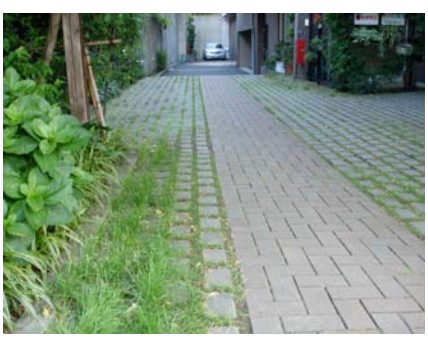

Pervious brick pavers on sidewalks and driveways

Whitetopping and Ultra-Thin Whitetopping

Whitetopping is a concrete pavement applied over asphalt pavement for maintenance or resurfacing. Ultra-Thin Whitetopping (UTW) is thinner than Whitetopping and is fiber reinforced to bond more closely with the asphalt surface. UTW can provide a lighter surface and can be used in applications such as resurfacing and parking areas.

Roller-Compacted Concrete Pavement

Roller-compacted surfaces are created with a very stiff mix of materials applied in methods similar to asphalt pavements. The surface is not finished like conventional surfaces and is used for heavy loads with slow moving vehicles, such as industrial storage and parking. Its color and reflectivity is somewhat less than conventional cement due to the surface roughness.


Pavers on driveway

Chip Seals with Light Aggregate

This surface maintenance technique is used on asphalt pavements. Light colored aggregate increases the albedo of the surface. It requires careful application to avoid excess aggregate that might damage vehicles.

Portland cement concrete freeway in Dallas
Copyright by Comstock, Inc. 2000

Porous paving highway in Japan

Seal coating as surface maintenance

Reliant stadium parking; GrassPave2

Lighter Aggregate in Asphalt Concrete Pavement
Light colored aggregate can be used in asphalt paving to produce a more reflective surface over time as the aggregate is exposed.

Porous Pavements
These include a wide variety of technologies, including both porous concrete and porous asphalt. The cooling effect of porous pavements is achieved by evaporation of water in the pavement and from convective airflow. The colors of materials vary widely from technology to technology with lighter colors being more reflectivity. The roughness of these surfaces reduces reflectivity somewhat.

Porous pavement technologies are used primarily for non-road surfaces, such as parking, driveways, emergency vehicle access to buildings, roadway shoulders, bike trails, patios, paved park areas, walkways, and for slope stabilization. Some products allow vegetation to grow through openings while others use aggregate with structural support from a plastic grid.

D. COOL PAVING STRATEGIES AND ACTIONS

Paved surfaces cover one-fourth of the area within the Dallas city limits. Over 25 square miles of paved surfaces are devoted to parking. These surfaces absorb solar radiation and contribute to urban heat island effects. In addition, paving surface characteristics, such as solar reflectance and porosity, affect water quality and stormwater runoff.

Major actions are recommended here for reducing urban heat island effects due to paving while achieving other city goals. The recommendations emphasize the need to better understand cool paving technologies through demonstration and testing. Actions are also recommended that build upon existing policies and regulations.

1. INCREASING AWARENESS THROUGH DEMONSTRATION & OUTREACH

Various actions can be taken to increase awareness of the cool paving technologies including demonstration projects, a database of local cool paving examples, and cool paving workshops.

<u>Develop reflective paving and porous paving demonstration projects.</u>
Those making decisions on pavement materials are reticent to use technologies or applications that are unfamiliar to them. More reflective pavement materials (those with lighter color aggregates, for example) are used frequently, but are not selected for their solar reflectance values. Inclusion of solar reflectance in standards such as LEED may change this. Demonstration projects are an effective technique for increasing the acceptance of alternative paving technologies.

<u>Identify a limited set of existing porous paving projects and compile information on these.</u>
Local examples provide helpful information for increasing awareness of cool paving. The data and accompanying photos can be posted to a website with other information on porous paving. Data on local examples would include location, size, observed paving materials, type of use, and estimated age. Two current examples are the McKinney Wal-Mart and the parking area at the Trinity River Audubon Center.

There are smaller paving applications in the area that have used pavers and other porous paving products. Field inventories can identify examples in commercial and office areas – several were noted in the developing area just north of downtown.

Workshops on cool paving technologies should be organized, including porous pavements and pavement reflectivity characteristics. Public works staff participates in workshops and training on relevant topics, such as these. Engineering consultants and paving product manufacturers can help organize such events. Texas companies with relevant products include TXI, Cemex, Invisible Structures, and Stoney Creek Materials. Texas is using porous asphalt overlay on highways, and these products should be part of discussions on porous paving materials.

2. POLICIES FOR PARKING, MEDIANS, AND FREEWAYS

A unified policy on cool paving should be adopted for parking areas, street medians, and freeways. Existing policies from the comprehensive plan, green building program, landscape requirements, and stormwater management would be brought together under this policy guidance statement. The policy would be based on urban heat island mitigation, air quality, and stormwater management benefits. It should address the extent of parking (i.e., reduced impervious surfaces for heat island benefits and stormwater management), pavement types (i.e., reflective and porous), and landscaping (i.e., trees in parking lots). Related policies that would be incorporated include:

a. Dallas Comprehensive Plan: forwardDallas!
Development Code Amendments III-2-5 to 18
Improving Walkability, p. III-2-8, 9
Reinforce pedestrian connections through parking lots. Solutions include painted or colored pavement, different paving material or texture, raised walkways and adding shrubs, shade trees and other landscaping.
Make parking lots cooler. Parking lots get oppressively hot in the summer. Regularly spaced trees will shade parking lots and make them more hospitable to walking.
p. III-2-11
Shade Parking Spaces with Tree Planting. Parking lots should include shade trees that are spread uniformly throughout the parking area. Trees should be set into a tree well and protected by bollards or tree guards.

Trees reduce stress, provide invaluable shade and create a sense of enclosure, producing a comfortable pedestrian environment.

Parking areas with walkways, vegetation and porous pavement contribute toward safety, climate control and on-site storm water management.

Figure P12
Example Illustrations of Shaded Parking from forwardDallas!
p. II-5-11, Parking code revisions – image on III-2-16

b. Dallas Green Building Program
Chapter 43 has provisions for the LEED building rating system as a basis for qualifying a building/development under building regulations. LEED points can be earned through paving and site design that incorporate cool paving materials and landscaping. Chapter 43 also accepts

"Green Built North Texas or an equivalent green building standard" which may lack similar guidance for use of cool paving.

c. LEED Provisions for Cool Paving

LEED provisions include the following guidance:

1. Minimize total paved surfaces in development by limiting the amount of impervious surfaces[102], clustering development[103], and replacing unnecessary paved surfaces with landscaped areas.[104]
2. Increase pavement albedo (reflectivity) to at least 29%.[105]
3. Increase the porosity of paved surfaces through the use of selected applications of pervious paving.[106]
4. Shade paved surfaces to help reduce urban heat island effects.[107]
5. Stack or shade parking areas to reduce impervious surface cover and to provide cool parking areas.[108]

d. Landscape Ordinance Provisions for Permeable Paving

Definitions

(20) PERMEABLE PAVEMENT means a paving material that permits water penetration to a soil depth of 18 inches or more. Permeable pavement may consist of nonporous surface materials poured or laid in sections not exceeding one square foot in area and collectively comprising less than two-thirds of the total surface area.

SEC. 51A-10.126. DESIGN STANDARDS.

(d) Enhanced vehicular pavement. An applicant may provide enhanced pavement. This pavement must be at least 25 percent of all outdoor vehicular pavement area on the lot. The same pavement cannot satisfy both Subsections (d) and (e). (Note: All vehicular pavement must comply with the construction and maintenance provisions for off-street parking in this chapter.)

(e) Permeable vehicular pavement. An applicant may provide permeable enhanced pavement. This pavement must be at least 25 percent of all outdoor vehicular pavement on the lot. The same pavement cannot satisfy both Subsections (d) and (e). (Note: All vehicular pavement must comply with the construction and maintenance provisions for off-street parking in this chapter.)

SEC. 51A-10.121. APPLICATION OF DIVISION.

(c) This division only becomes applicable to a lot or tract when the nonpermeable coverage on the lot or tract is increased by more than 2,000 square feet within a 24-month period, or when an application is made for a building permit for construction work that: (Note: other circumstances included following this; residential is covered separately).

e. Storm Water Management

Integrated stormwater management (iSWM) includes a goal "to minimize the discharge of pollutants from areas of new development and significant redevelopment after construction is completed." Pervious paving is a site design practice that is an option under iSWM. The iSWM™ Design Manual for Site Development (January 2006 Edition) includes porous paving and other strategies to reduce stormwater runoff from impervious paved surfaces.

The iSWM™ provides design guidance and encourages practices that achieve specified goals including actions that reduce the impact of paved surfaces. However, it does not ensure that pervious paving will be used in development or redevelopment. Other actions might be needed to achieve higher levels of use.

3. INCENTIVES AND REGULATIONS

As with water and energy efficiency, points for cool paving could be included in the Green Building Program. There are several paving options available to developers and builders to attain these points including reflective paving, pervious paving, and shade for paved surfaces. The following is example wording added to 4303.4.1:

4303.4.1 Point total. The points required by Section 4303.4 must include:

1. 1 point under the water efficiency credit titled "Water Use Reduction (20% Reduction)."
2. A minimum of 2 points (14 percent better than ASHRAE 90.1-2004) under the energy and atmosphere credit titled "Optimize Energy Performance."
3. 1 point for use of an open-grid paving system (pervious paving), reflective paving (SRI 29 or greater), and/or shaded hardscape (as set forth in Credit 7.1/LEED).

Inclusion of these provisions is consistent with development policies such as stormwater management, clean water standards, and air quality, as well as the goal of reducing urban heat island effects.

Table P7

LEED 7.1 - Solar Reflectance Index (SRI) for Standard Paving Materials

Material	Emissivity	Reflectance	SRI
Typical New Gray Concrete	0.9	0.35	35
Typical Weathered* Gray Concrete	0.9	0.20	19
Typical New White Concrete	0.9	0.7	86
Typical Weathered* White Concrete	0.9	0.4	45
New Asphalt	0.9	.05	0
Weathered Asphalt	0.9	.10	6

* Reflectance of surfaces can be maintained with cleaning. Typical pressure washing of cementious materials can restore reflectance close to original value. Weathered values are based on no cleaning.

Stormwater management regulations should be supportive of urban heat island mitigation goals relevant to paved surfaces. Many stormwater management principles are consistent with cool paving goals, including the reduction of impermeable surfaces, the effective use of natural and landscape features, and use of various permeable surfaces, such as green roofs and pervious paving. For example, integrated stormwater site design considers the following methods for reducing impervious surfaces:

- Reduce roadway lengths and widths
- Reduce building footprints
- Reduce parking footprint
- Reduce setbacks and frontages
- Use fewer or alternative cul-de-sacs
- Create parking lot storm water "islands"

Integrated stormwater management principles are site specific (one size does not fit all). This principle applies to cool paving technologies. Their use must take into consideration site specific features and any operational costs that may be incurred for different paving systems.

Limitations on impervious surfaces can be specified within the zoning ordinance, including provisions for existing development to limit expansion of impervious surfaces. Current zoning regulations do not explicitly restrict impervious surfaces. For example, "Lot Coverage" specifies a maximum percentage of an area that may be covered by the building, roof area and/or other structures. Parking areas are not included under lot coverage. However, there are off-street parking and off-street loading requirements that are generally met with impervious paving.

Stormwater management and landscape requirements partially dictate the resulting amount of impervious surface cover. As an additional consideration, lot-by-lot requirements for pervious surfaces do not necessarily recognize the overall surface characteristics a development, such as any included open space or parkland.

Example of Zoning Provision for Impervious Surfaces
Village of Arlington Heights, Illinois

Impervious Surfaces are any hard-surfaced, man-made areas that do not readily absorb or retain water, including but not limited to buildings, patios, paved parking and driveway areas, walkways, sidewalks and paved recreation areas (e.g. basketball court, tennis court, swimming pools). This would exclude public sidewalks on private property. The Impervious Surface Coverage is the area of the lot occupied by impervious surfaces. In the single-family residential districts, the allowable impervious surface coverage for the entire lot is calculated based on zoning district and lot size:

R-E thru R-3 Districts:	Lots greater than 6,600 Square Feet:	Lot Area x 0.50
	Lots less than or equal to 6,600 Square Feet:	Lot Area x 0.55

Front Yard/Exterior Side Yard Maximum: As part of the permitted total Impervious Surface Coverage for the lot, no more than 50% of the front yard, plus, if it is a corner lot, the exterior side yard, shall be impervious. (Area of the front yard x 0.50)

ENDNOTES

[1] p. I-17, Dallas Comprehensive Plan, Vision, June 2006.

[2] From EPA UHI website heat island website, http://www.epa.gov/heatisland

[3] Darby, L. and Senff, C. J. Comparison of the Urban Heat Island Signatures of Two Texas Cities: Dallas and Houston. Seventh Symposium on the Urban Environment (Expanded View), 2007.

[4] Streutker, D. R.. 2003. Satellite-measured growth of the urban heat island of Houston, Texas. Remote Sensing of Environment

[5] Based on per capita energy savings for Houston, Sacramento and Baton Rouge from heat island mitigation measures, ranging from $15 to $20 per capita per year. Total heat island effects on energy would be several times this amount since measures in this report affected only part of the building inventory and the measures could reduce temperatures no more than 2ºF. Konopacki, S. and H. Akbari. 2002. Energy Savings for Heat Island Reduction Strategies in Chicago and Houston (Including Updates for Baton Rouge, Sacramento, and Salt Lake City). Paper LBNL-49638. Lawrence Berkeley National Laboratory, Berkeley, CA.

[6] Based on annual kWh savings per capita for Houston, Sacramento and Baton Rouge from Konapaki and Akbari; 295 to 328 kWh savings per capita @ 12¢/kWh for 1.2 million people in Dallas in 2006. Estimates for residential, commercial and office with reflective roofing and added shade trees.

[7] Walcek, C. J. and Yuan, H. Calculated Influence of Temperature-Related Factors on Ozone Formation Rates in the Lower Troposphere. 1995. Journal of Applied Meteorology. Vol. 34, pp 1054-1069.

[8] Scott, Klaus.; Simpson, James R.; McPherson, E. Gregory. 1999. *Effects of tree cover on parking lot microclimate and vehicle emissions.* Journal Arboriculture 25: 129-141.

[9] Emergency Response and Research Institute, http://www.emergency.com/htwave98.htm; 4/22/08 accessed/

[10] Charles Piety. 2007. The Relationship between Urban Tree Cover and Ground Level Ozone, Baltimore SIP submittal weight of evidence report. p. 6.

[11] Akbari, H., Shade trees reduce building energy use and CO2 emissions from power plants. Environmental Pollution, 2002. 116(Supplement 1): p. S119-S126. Estimate from p. S122, Table 1. Ft. Worth, 2.8 million trees for 1.6ºK reduction in hottest simulation cell.

[12] Melissa Hart* and David J. Sailor. Assessing Causes in Spatial Variability in Urban Heat Island Magnitude, Seventh Symposium on the Urban Environment (Expanded View), 2007.

[13] "Residents strongly value the area's natural assets and want to protect air quality, water quality and trees." ForwardDallas Comprehensive Plan, Core Values, p. I-8

[14] "Trees play an important role in maintaining quality of life within the city.", ForwardDallas Comprehensive Plan, 2006. p. III-19

[15] McPherson, E.G., J. R. Simpson, P. J. Peper, S. E. Maco, and Q. Xiao. 2005. Municipal Forest Benefits and Costs in Five US Cities. Journal of Forestry. 103(8):411-416.

[16] See section xxx of report.

[1717] Akbari, H., D. Kurn, S. Bretz, and J. Hanford. 1997. Peak power and cooling energy savings of shade trees. Energy and Buildings. 25:139-148.

[18] Scott, K., J.R. Simpson, and E. G. McPherson. 1999. Effects of Tree Cover on Parking Lot Microclimate and Vehicle Emissions. Journal of Arboriculture. 25(3).

[19] D. Hitchcock and R. Brahme, Analysis of Energy Savings from Shade Trees. 2006.

[20] Sacramento Municipal Utility District. 2008. Shade Tree Benefit Estimator, high cooling load, near house, west location, 15¢/kWh, American Elm, 2008.

[21] http://www.heatislandmitigationtool.com/

[22] Konopacki, S. and H. Akbari. 2002. Energy Savings for Heat Island Reduction Strategies in Chicago and Houston (Including Updates for Baton Rouge, Sacramento, and Salt Lake City). Paper LBNL-49638. Lawrence Berkeley National Laboratory, Berkeley, CA.

[23] Peter Smith, Michael Merritt, Dave Nowak, and David Hitchcock, Houston's Regional Forest: Structure, Functions, Values. September 2005. Texas Forest Service, U.S. Forest Service, and Houston Advanced

Research Center, p. 14.

[24] From EPA Compendium on urban heat island mitigation, http://www.epa.gov/heatisland

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[26] Akbari, H., D. Kurn, S. Bretz, and J. Hanford. 1997. Peak power and cooling energy savings of shade trees. Energy and Buildings. 25:139-148.

[27] Simpson, J.R. and E.G. McPherson. 1998. Simulation of Tree Shade Impacts on Residential Energy Use for Space Conditioning in Sacramento. Atmospheric Environment. 32(1):69-74.

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