CHAPTER TWO

Boulder's Urban Forest Provides Energy Savings

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The large, mature shade tree on the south side of this home prevents solar energy from reaching the roof, windows, and walls of the structure, therefore making the air inside and surrounding it cooler and reducing (and sometimes eliminating) the need for air conditioning.

The net cooling effect of a young, healthy tree is equivalent to ten room-size air conditioners operating 20 hours a day. (U.S. Department of Agriculture)

In cities with populations of more than 100,000, peak utility cooling demand increases 1.5% to 2% for every 0.6°C (1°F) the temperature rises.[20]

Evapotranspiration:
Vegetation draws moisture from the ground through roots and releases it into the atmosphere during transpiration.

Introduction

The expansion of populated areas within the U.S. has traditionally been coupled with an increased demand for electricity. Often, more power is required than can be generated by existing power plants, and the most common method of dealing with the increase in demand is to build additional power generation facilities. A high percentage of existing, as well as new power plants burn fossil fuels to generate electricity. Historical focus has been on increasing energy supplies while somewhat overlooking ways to reduce demand; however, current fuel reserves, prices, and carbon emissions from power generation suggest taking a closer look at ways to increase efficiency as well. This chapter will explore how trees can help us to conserve energy on many levels - offsetting, or working in concert with, more traditional ways to address energy needs.

Trees can play a significant role in reducing energy demands. They provide shade to buildings and windows in summer, directly reducing the need for energy-intensive air conditioning. Trees help to cool the surrounding air though **evapotranspiration**. They also help to reduce the effects of urban heat islands. Perhaps more importantly, trees reduce power plant emissions and help moderate consumer costs by decreasing the overall demand for power.

The Urban Heat Island Effect: Why Urban Summers Keep Getting Hotter

Typical urban surfaces, comprised mostly of concrete and asphalt, get much hotter throughout the day than do vegetated surfaces. These man-made surfaces are very efficient at storing incoming solar energy, converting it to thermal energy, and releasing it again at night, creating areas of warm air over the city known as heat islands. This effect can compound over several hot days; as the city does not cool off each night, each subsequent day gets hotter.

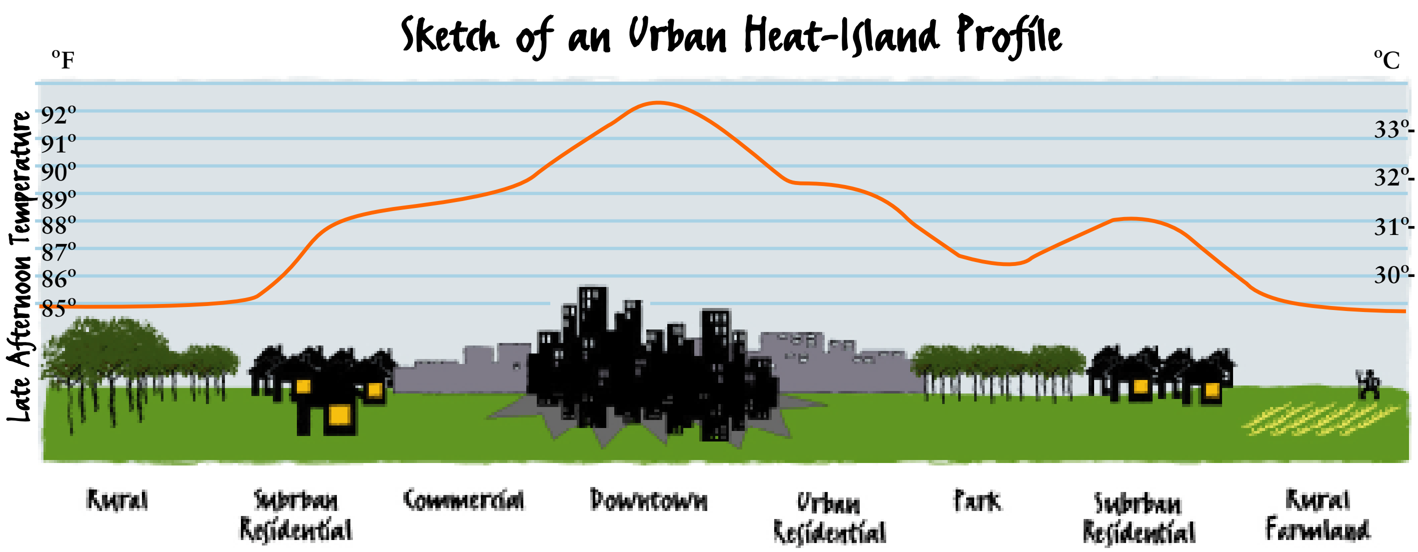
The ambient air temperature difference between an urban heat island and a vegetated area can be as much as 2-10 degrees F,[21,22] a phenomenon that meteorologists noted and named over 100 years ago. The temperature measured directly above man-made surfaces can be as much as 25 degrees F hotter than the air temperature beneath a forested area.[23]

Increased Urban Temperatures Affect Air Quality

Aside from the discomfort of rising urban temperatures, urban heat islands pose other environmental problems such as increased smog production. Unacceptable levels of ozone and other volatile organic chemicals (VOCs) can be frequently reached at 94° F and above.[21] High temperatures accelerate the formation of harmful smog, as ozone precursors such as nitrous oxides (NO_x) and VOCs combine photochemically to produce ground level ozone.[24,25] This process compounds the heat island problem by creating a heat-trapping cloud of pollution over urban areas.

Increased power generation, used to supply the increased demand for energy to cool buildings during hot summer months, is also responsible for additional CO_2 emissions, since the burning of fossil fuels is the primary source of energy in the U.S. and this practice releases tremendous amounts of greenhouse gases into the atmosphere. Colorado's energy generation comes primarily from burning coal; in 1996 coal accounted for 83% of energy production in Colorado.[26]

"Increased need for air conditioning could cost ratepayers more than a million dollars per hour or possibly over one billion dollars per year nationwide."[21]



Sketch of a typical heat island profile. Summer temperatures in urban areas are now typically 2°F to 8°F higher than in their rural surroundings due to a phenomenon know as the 'heat island effect'.[21]

Since 1990, only about one new barrel of oil has been found for every four produced. [28]

"At the national scale UHI [urban heat island] mitigation could reduce energy demand by $10-billion and health care costs by $5-billion dollars annually; reduce Global Greenhouse Gas emissions of CO_2 by 45-million tons; and eliminate $100-billion of storm water management costs." [29]

The Energy Crisis?

The National Energy Policy, released in May 2001, addressed America's need to increase energy conservation and efficiency in order to prevent possible energy shortages. "America in the year 2001 faces the most serious energy shortage since the oil embargoes of the 1970s. The effects are already being felt nationwide. Many families face energy bills two to three times higher than they were a year ago. Millions of Americans find themselves dealing with rolling blackouts or brownouts; some employers must lay off workers or curtail production to absorb the rising cost of energy."[27]

Researchers at Lawrence Berkeley Laboratory have estimated that the cost of reducing peak-load energy demand by 1 kilowatt-hour (kWh) by improving the efficiency of electrical appliances is about $0.025, while the cost of saving the same kWh by planting trees is only $0.01. The cost of generating one kWh at a new power plant costs $0.10.[20] Not only is tree planting a more cost-effective method of reducing energy use, but because electric power plants are the country's largest industrial source of the pollutants that cause acid rain, mercury poisoning in lakes and rivers, and global warming,[30] the additional environmental benefits of decreased power generation through maintenance of a healthy urban forest are many-fold.

Trees: Mother Nature's Air Conditioners

Trees directly affect indoor ambient temperatures by providing shade. When direct sun strikes building surfaces such as roofs and walls, these surfaces absorb solar energy and can transfer heat to the inside of the building, raising indoor air temperatures. Preventing sunlight from shining in southern and western facing windows also helps to directly reduce the indoor temperature, and can control the heat inside a home better than indoor window coverings such as blinds. Direct shading of air conditioning units also increases their efficiency by up to 10%.[23]

Direct shading of pavement is also important in reducing outdoor ambient air temperatures. Through direct shading, trees prevent the initial heating and storage of solar energy. The benefits of shading parking lots and other impervious surfaces are many, aside from aesthetics. Trees provide a cooler place under which to park a car in hot summer months, reducing the air temperatures of the interior of the vehicle, and the need to run air conditioning. It has also been proven that high ambient temperatures in parking lots cause the evaporation of volatile substances from vehicles, contributing to the air pollution problem.[31]

The well-shaded, mature neighborhood of Mapleton Avenue. Although having trees shade buildings is especially important, other trees are also indirectly responsible for cooling the surrounding air during the hot summer months. Through the process of evapotranspiration, trees add moisture to the air, which physically removes heat and makes it feel cooler.

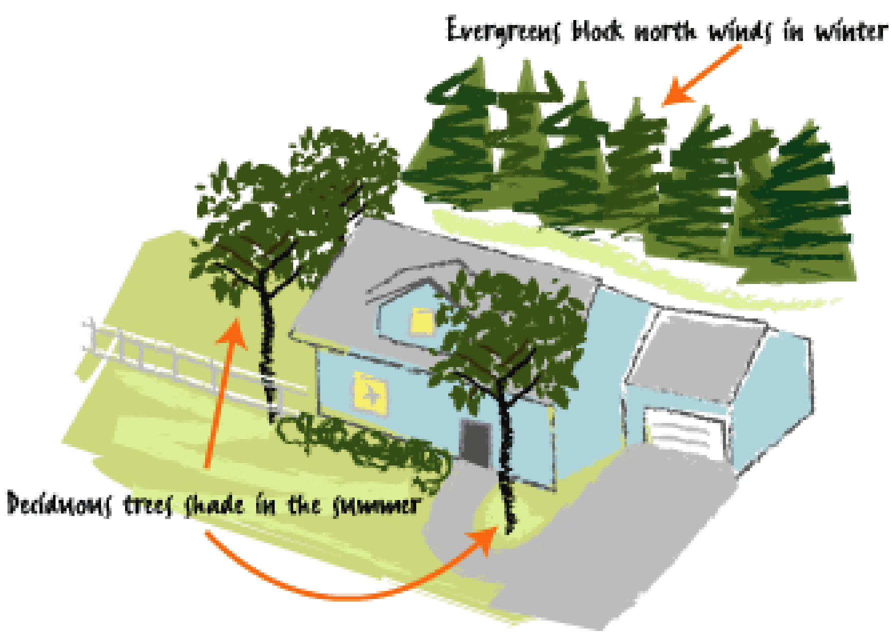
Trees cool indirectly through evapotranspiration, the process of drawing moisture from the ground through roots and releasing it to the atmosphere as the tree transpires, or breathes. The released water draws heat as it evaporates, cooling the air in the process. The climate must be relatively dry for this to occur, as evaporation rates decline as humidity rises. Because Boulder has a consistently low humidity, evapotranspiration is quite efficient at cooling the air.

These three effects provide not only a measurable amount of cooling to the City, but also a significant amount of monetary savings through reduced energy bills. In addition, trees are also responsible for improving air quality by reducing temperature-dependent production of air pollutants. As previously mentioned, VOCs, precursors to ozone, can reach unacceptable levels as temperatures rise, so trees play another important role in preventing the production of these pollutants.[32]

By directly reducing summer cooling demands, urban trees actually help to avoid the release of more CO_2 into the atmosphere during the energy generation process.[35] This prevention of carbon release is commonly referred to as avoided carbon; in most cases, the volume of avoided carbon is on the order of several times that of the volume of carbon stored and sequestered by the same trees.

"Evapotranspiration occurs when plants secrete or "transpire" water through pores in their leaves – in a way, plants sweat like people do. The water draws heat as it evaporates, cooling the air in the process. A single mature, properly watered tree with a crown of 30 feet can "evapotranspire" up to 40 gallons of water in a day, which is like removing all the heat produced in four hours by a small electric space heater." [33]

The U.S. uses 200 billion kWh annually for air conditioning. By strategically planting trees throughout the country to shade buildings and cool the air through evapotranspiration, researchers estimate that we could save approximately 25 billion kWh per year.[21,34]



Trees have been called the "low-tech" solution to energy conservation. This illustration shows proper placement of trees to maximize energy saving benefits.[42]

An example of shading trees in a residential neighborhood, as modeled in CITYgreen's Energy module. Trees on west, south, and east sides of buildings provide energy savings through shade.

Example: Site 5 Energy Statistics

Area	2.48 acres
Land Use	Residential
Number of Homes	12
Tree Canopy	48%
Number of Trees	151
Annual $ Saved (site)	$867.71
Annual $ Saved (home)	$72.28
Annual kWh Saved (site)	14224.8
Annual kWh Saved (home)	1185
Annual "avoided carbon" (site)	8122 lbs
Annual "avoided carbon" (home)	677 lbs

Modeling Urban Forest Energy Savings

The CITYgreen model for calculating energy savings was formulated by American Forests interpolated from research by Dr. Greg McPherson of the US Forest Service.[36] It was designed to determine only the savings provided by trees in residential areas with buildings having a maximum of two stories.

Data collected specifically for this model included the location of windows and air conditioning (AC) units, and number of stories for each building. These were observed in the field, drawn onto aerial photo maps, and then digitized into a GIS layer. This was used in conjunction with other GIS data, including the building footprints, to determine whether trees on each site were both close enough and tall enough to provide shade to the windows, roofs, and AC units. Since trees are most effective at reducing energy use when located on the sides of a home receiving the most solar exposure, CITYgreen's energy model also determines whether each tree's placement is appropriate to provide shade to the site's buildings.

The model assigns an energy rating of 0-5 (where 0 equals no savings and 5 signifies maximum savings) to each tree based on the following criteria:[36]

- Distance from residential building structure
- Location relative to the building
- Height and canopy spread of the tree

Once energy ratings have been assigned to each tree, the regional cooling cost associated with running an air conditioner during the summer is used to calculate the monetary and kWh savings provided by tree shade.

Using CITYgreen's avoided carbon model, the volume of carbon that Boulder's trees prevent from being released into the atmosphere is calculated. These carbon volumes are also specific to the region, and take into account the different fuel mix profile used to generate power in the area. For instance, in Colorado, where power generation comes primarily from burning coal,[26] trees help to avoid more carbon release than in regions using alternative energy sources such as nuclear or hydroelectric power.

Methods

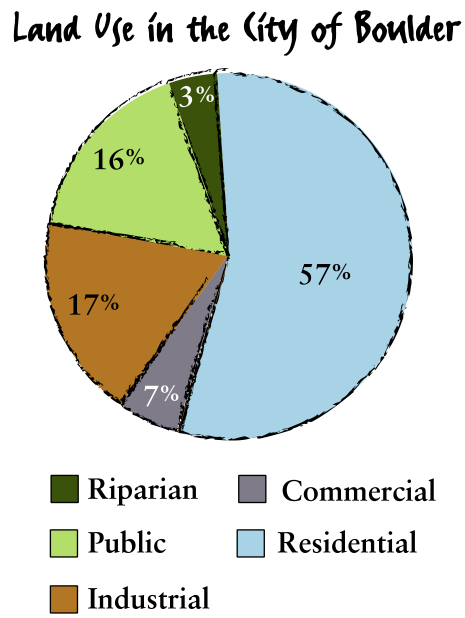
Only the 16 residential sites (of the overall 32 sites) covering 52 acres were used to calculate energy savings. These values were then extrapolated to determine the overall energy savings provided by Boulder's residential urban forest. Residentially-zoned areas cover approximately 57% of the City of Boulder.

CITYgreen contains climate and energy modeling data specific to Denver, and this was used to calculate energy savings in kWh. However, more recent and accurate figures for the carbon emission factor and cost of a kWh were acquired during the study, so these benefits were calculated manually.

For each of the residential sites, the following were calculated:

1. KWh hours of energy saved annually
2. Dollars saved annually
3. Annual avoided carbon

The figures were then analyzed to determine the three mentioned benefits on a per home, per acre and city-wide residential area basis. Cost per kWh reported by XCEL Energies[37] in 2001 was \$0.061. Reduction of energy consumption regionally saves 0.57 lbs of carbon emissions per kWh,[38] or 2.1 lbs of CO_2.



Results

CITYgreen calculations show an annual average energy savings per household of approximately 950 kWh, which equates to an annual average savings of \$57.92 attributed to tree shade. The average summer cooling cost for the Denver Metro region is \$260 per year per home,[39] so the reduction equates to a 22% overall savings in cooling costs. Per acre of residential area, Boulder's trees provided an annual average savings of 3500 kWh, or \$213.50. City-wide, this annual energy saving amounts to approximately 27 million kWh, or \$1.65 million. The 161 homes surveyed had an average of 12.3 trees per home, for an annual summertime energy savings of approximately \$4.69 and 77 kWh per residential tree.

By shading homes and reducing the demand for air conditioning power, and therefore the emissions created when burning fossil fuels, trees in residential areas of Boulder are responsible for preventing 15.7 million lbs, or approximately 7,860 tons of carbon from entering the atmosphere each year.

A megawatt hour, equal to 1000 kWh, is enough energy to completely power the typical home for two months. Therefore, the energy saved annually by Boulder's tree shade is enough to power 4500 typical homes for an entire year.

Energy Statistics	Annual \$ Saved	Annual kWh Saved	Annual Avoided Carbon (tons)
Per tree avg.	\$4.69	77	44
Per home avg.	\$57.92	950	542
Per acre avg.	\$213.50	3553	2029
All Residential Areas	\$1.65 million	27.54 million	15.73 million

"Well-placed vegetation around residences and small commercial buildings can reduce energy consumption typically by 15 to 35 percent". [21]

A newer residential site in Gunbarrel with smaller trees between the setback sidewalk and the street, and in the yard. Trees on this younger site provide only $7.50 in annual energy savings per home.

Discussion

The overall city-wide savings of more than $1.6 million may be an overestimate that could be attributed to the fact that 10 of 16 sites that had greater canopy cover than the average of 16 sites (30% canopy cover). Newly developed areas do not have mature shade trees, observed in several newer home developments sites east of 28th Street; this may be either because the trees are not fully developed or because the trees planted are not intended to grow large. Smaller non-shade tree species were observed (aspen and flowering fruit trees, for example) planted in the area between setback sidewalks and the street as well as near the homes; even at maturity these small trees will never provide much shade to either parked cars or the home. If this apparent trend in newer developments continues, overall average residential energy savings will be reduced.

The ratio of avoided carbon to carbon sequestered by Boulder's trees is roughly 4:1, consistent with ratios reported by others for national urban tree planting programs.[40] Variations in this ratio have to do with the regional fuel mix.[43] Because in Colorado energy generation uses such a high percentage of coal, the fossil fuel that generates the most CO_2 when burned, our trees play a more prominent role in reducing the release of CO_2 into the atmosphere by reducing demand for additional power to cool buildings in summertime.

Conclusion

Energy needs can be met in two ways: by increasing energy production or reducing its consumption. However, simply increasing production without considering environmental side effects is not practically feasible. On the other hand, increasing the efficiency of power facilities, automobiles, appliances, and other energy consumers can help to balance the energy equation while simultaneously limiting emissions and other forms of pollution. In reality, all of these approaches are being practiced in varying degrees around the world and will continue to be as earth's population grows.

Clearly though, one of the most economically feasible and aesthetically pleasing is the simple act of planting trees. Trees shade buildings, provide energy savings to consumers through the hot months of summer, and reduce emissions further by minimizing the fossil fuels burned for power generation. Urban forests are also responsible for reducing temperature-related smog formation. Additionally, reducing residential energy demands by planting shade trees is more cost effective than other measures such as increasing the efficiency of household appliances.

Although the City of Boulder has strict growth control measures in place, energy demands and prices are still driven by regional growth patterns in the Front Range. As the population of this region continues to grow, alternatives will have to be considered and implemented. Trees are responsible, in part, for mitigating the effect of urban growth on regional energy demands, and an ongoing urban forestry program should be considered a valuable tool for dealing with this issue.

"Fossil fuel power plants in the United States account for about two-thirds of the major acid rain precursor—SO_2; one-third of the major smog precursor—NO_2; and a variety of toxic pollutants."[41]

These students, participating in an Arbor Day tree planting at Crest View Elementary School, chose the location of tree planting in order to provide shade to their playground.

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