

Properly Placed Shade Trees Reduce Summertime Electricity Bills in Sacramento, California

By Geoffrey H. Donovan and David T. Butry

The discovery that shade trees can reduce home cooling costs is hardly surprising. Anybody who has sat under a tree on a warm summer day understands the shade benefit of trees. However, quantifying the effect a shade tree has on home energy use and carbon footprint, and identifying the optimal location for a shade tree, is less straightforward. Past studies that have looked at the effect of trees on energy use have either taken a modeling approach or have been small-scale field experiments [see Akbari et al. (1997); Simpson and McPherson (1996)]. In this article, we summarize the results of our recent study on shade trees (Donovan and Butry, *in press*) that used actual utility billing data from 460 houses in Sacramento, California, to quantify the effect of shade trees on summertime¹ electricity use.

Data and Study Area

Sacramento has a Mediterranean climate: mild winters and hot, dry summers. The mean high temperature is 54°F (12°C) in January, and 93°F (34°C) in July. On average, Sacramento has 73 days a year over 93°F.

Our sample consisted of 460 single-family homes in the Southland Park neighborhood. The crown area of trees in 12 buffers around each house were measured (Figure 1). If the crown of a tree spread over multiple buffers, we attributed the crown area to the buffer with the tree stem.

Using regression analysis, we statistically estimated the effect shade trees had on summertime electricity use, while controlling for other confounding factors, including wintertime electricity use, the presence of air conditioning, the presence of a swimming pool, house size, and lot size. The study period ran May 15, 2007 - September 15, 2007.

Study Results

Analysis showed that trees do affect summertime electricity use. Specifically each m² of canopy cover within 12 m (39 ft) of the south side of a house reduced summertime electricity use by 1.68 kWh, and each m² of canopy cover within 18 m (59 ft) of the west side of a house reduced summertime electricity use by 1.71 kWh. Trees on the east side of a house had no effect on electricity use, whereas each m² of canopy cover within 6 m (20 ft) of the north side of a house increased summertime electricity use by 1.59 kWh. These results are summarized in Figure 3. We also found that the presence of a pool or an air conditioner increased summertime electricity use as did increases in wintertime electricity use.

To understand the shade tree results, consider how the direction of shadows changes during the course of a day. When the sun rises, long shadows are cast to the west by trees. However, even in the summer, morning temperatures in Sacramento are moderate, and the demand for air conditioning is low. Therefore, it is not surprising that trees on the east side of houses had no effect on summertime electricity use. As midday approaches and temperatures rise, shadows shorten and point to the north. By the time tempera-

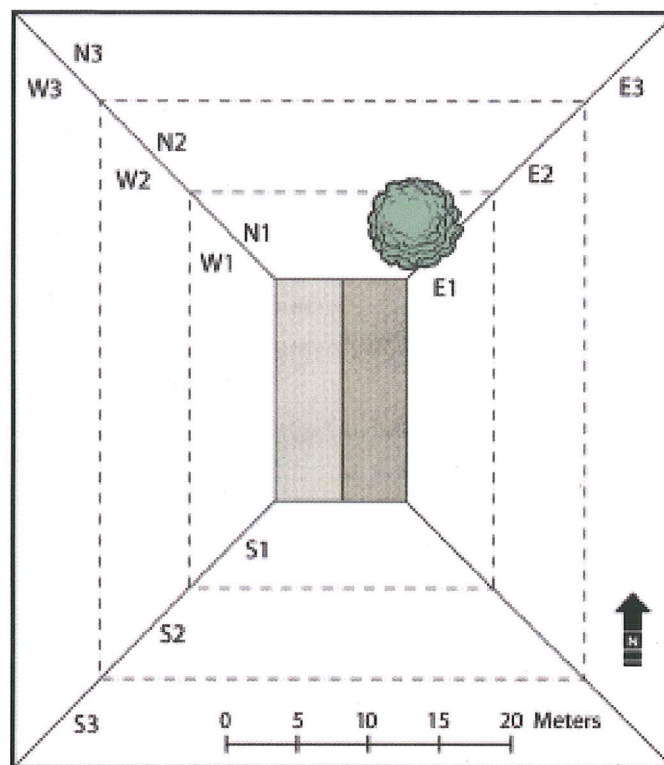


Figure 1. The twelve tree measurement buffers around a house.

tures reach their peak in the late afternoon, tree shadows lengthen and point to the east. This explains why trees up to 18 m from the west side of a house reduce electricity use, whereas trees within 12 m of the south side of a house had an effect.

The finding that trees within 6 m of the north side of a house increase electricity use was surprising. It is possible that this result was a statistical anomaly. However, there are other plausible expla-

Properly Placed Shade Trees (continued)

nations. Perhaps trees close to a house reduce the cooling effect of wind, slow the release of heat at night, or cause more lighting to be used in the house. This may be true of trees on all sides of a house, but on the east side the positive and negative effects of trees on energy use cancel out, whereas on the south and west sides the energy-saving effects of trees dominate.

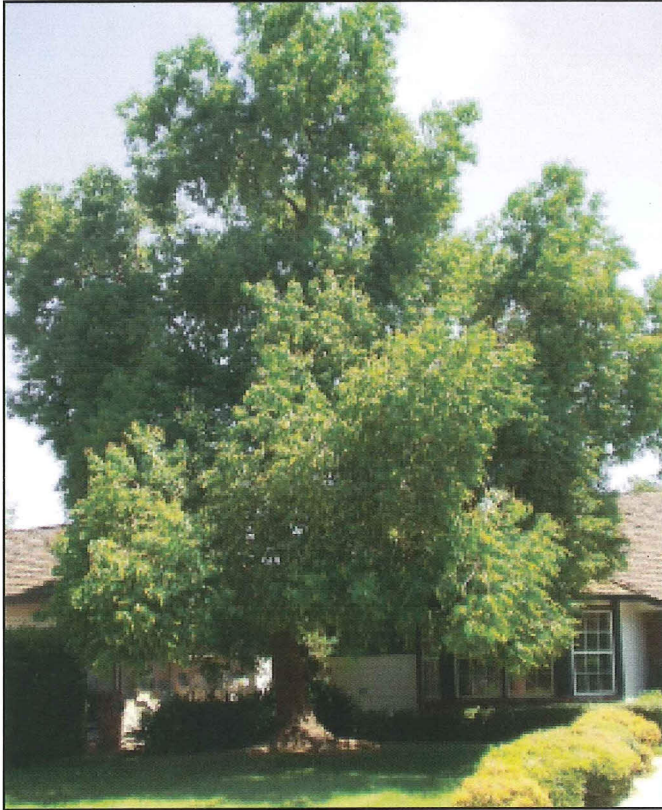


Figure 2. To understand the shade tree results, consider how the direction of shadows changes during the course of a day.

but on the east side the positive and negative effects of trees on energy use cancel out, whereas on the south and west sides the energy-saving effects of trees dominate.

Assuming the average crown area for the sample, we calculated the total effect of trees on summertime electricity use. Combined, west- and south-side trees reduce summertime electricity bills by \$25.16 (5.2 percent), whereas north-side trees increase summertime electricity bills by \$7.48 (1.5 percent).

We also used our results to estimate the benefits of planting trees. For example, the average, annual energy-conservation benefits of planting a single London plane tree (the most common tree species in Sacramento) on the west side of a house was estimated to be \$15.40 a year (assuming a 4 percent discount rate and a 50-year time horizon).

Benefits to the Utility

As in most of the United States, residential electricity customers in Sacramento face a tiered pricing system, based on monthly usage rather than time of the day. In contrast, the Sacramento Municipal Utility District (SMUD) faces generation costs that vary greatly depending on the time of day. For example, during our study period, the wholesale price of electricity in Sacramento varied between 4.3 cents per kWh at 4:00am and 28.8 cents per kWh at 6:00pm. Between approximately 3:00pm and 7:00pm, SMUD sells electricity at a per-unit loss

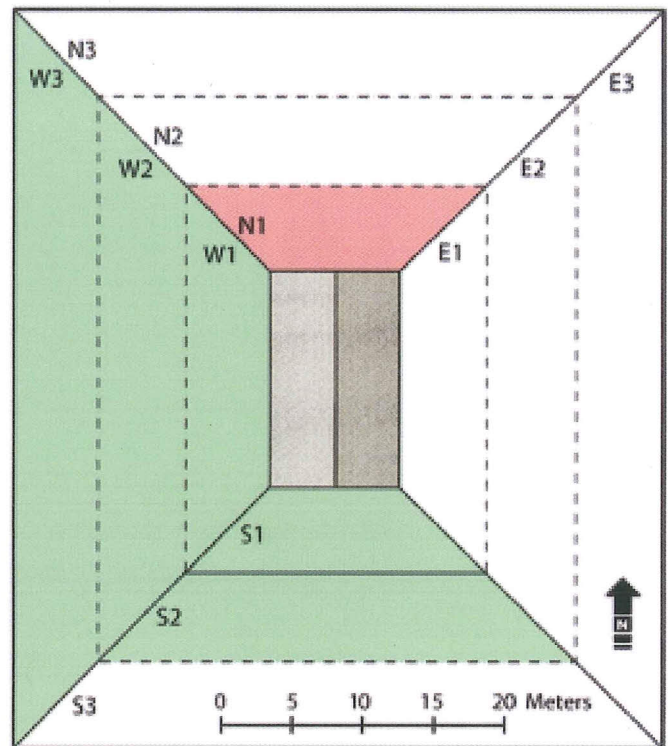


Figure 3. Canopy cover in green buffers decreased, and in red buffers increased, summertime electricity use.

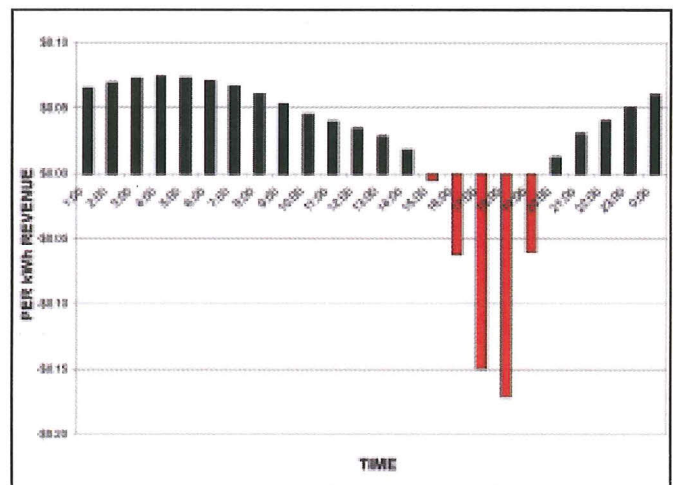


Figure 4. Utility's per kWh net revenue by hour for the period May 15 through September 15, 2007.

(Figure 4). In consequence, west-side trees generate greater benefits for the utility than south-side trees, as they shade houses during hours of peak demand.

West-side trees could soon become more important to residential customers too, as many utilities are moving toward time-of-use pricing. For example, in Sacramento, SMUD hopes to implement time-of-use pricing within 5 years (they currently offer optional time-of-use pricing). When this happens, west-side trees will generate even greater benefits for consumers than will south-side trees, because of their effect on peak demand.

Carbon Benefits

It is well established that trees directly sequester carbon. However, shade trees can generate additional benefits by reducing carbon



Figure 5. Assuming the average crown area for the sample, we calculated the total effect of trees on summertime electricity use.

emissions from electricity generation. We calculated that the direct (via sequestration) and indirect (via reducing electricity demand) carbon benefits of a london plane tree planted on the west side of a house are approximately equal-carbon benefits from a well-placed shade tree are roughly double those from a tree of the same size that does not shade a house. This is based on the fact that in California 0.274 kg of carbon dioxide is produced for every 1 kWh of electricity generated, on average (Energy Information Administration, 2006). Over 100 years, we estimated that a london plane tree, planted on the west side of a house in Sacramento, would reduce net carbon emissions from summertime electricity use by 31 percent.

Discussion

Our (Donovan and Butry, *in press*) study was the first to use utility billing data to estimate the energy-conservation benefits of shade trees. We found that trees within 12 m of the south side of a house and within 18 m of the west side of a house decreased summertime electricity use, whereas trees within 6 m feet of the north side of a house were associated with an increase in summertime electricity use.

As with any study; care should be taken when extrapolating our results to other parts of the United States. However, some of our findings are consistent with other studies conducted in other regions. For example, it is likely that in most areas of the country, planting trees on the west and south sides of a house will generate the greatest energy-conservation benefits. However, as utilities move toward time-of-use pricing, the benefits of west-side trees will likely exceed the benefits of south-side trees, all else equal. Past studies have found that planting trees on the north side of a house generates the least energy-conservation benefits. Our results go one step farther, and raise the possibility that north-side trees may increase summertime electricity use.

In summary; our study demonstrates that properly placed trees can significantly reduce a house's summertime electricity use and its carbon footprint.

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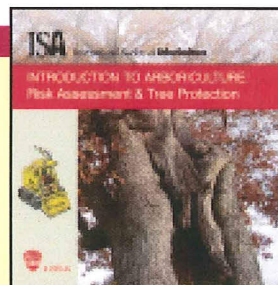
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The study was limited to summertime electricity use, because the authors were unable to obtain natural gas billing data. This was not a problem in the summer, as air conditioners are almost exclusively electric. However, because the majority of houses in Sacramento are heated with natural gas, there was not the necessary data to determine if trees affect wintertime energy use.

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