# TREES AND SOLAR POWER: COEXISTING IN AN URBAN FOREST NEAR YOU

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This paper describes several innovative policies to facilitate the successful coexistence of urban trees and rooftop solar energy collection.

ABSTRACT

Solar power generation is growing rapidly across the developed world as costs to collect solar energy fall and new business models lower installation costs. But trees continue to be planted where they may eventually conflict with solar collection as they grow into a collector's access plane, lowering efficiency and affecting Return on Investment. Property owners do not need to make an all-or-nothing choice between trees or solar power. The arboriculture industry is poised to assist the solar industry to generate clean energy by contributing expertise to recommend best practices for policy and maintenance. This paper describes solutions to decrease tree and solar conflicts and increase solar collection in the urban forest. The benefits of strategically increasing tree canopy in built environments – increased shade and solar power generation, reduced stormwater peak flows, increased aesthetics, and improved environmental health - far outweigh the costs and pay dividends many times over.

## 1. INTRODUCTION

### 1.1 Urban Forests

Urban forests in North America are generally decreasing in areal extent (1). At the same time, human population is urbanizing and urban per capita land consumption is increasing (2). Eighty percent of North Americans are now living in urbanized areas, and urbanized land area is projected to increase another 50% by the year 2050 (3). Although they currently are in decline, urban forests directly positively affect quality of life for built environments via the ecosystem services and psychosocial restoration they provide.

The vast majority of formal, empirical cost-benefit analyses find that urban forest benefits exceed their costs, sometimes substantially (4). What follows is a necessarily brief and incomplete discussion of some important benefits of urban forests.

Ecologically, urban forests intercept particulate and absorb gaseous air pollution (5), cool surrounding areas by evapotranspiration and shading which reduces low level ozone and smog formation (6), intercept and slow precipitation which slows stormwater peak flow and reduces soil erosion (7), sequester carbon (8), and provide habitat for biota, among other benefits.

Economically, urban forests conserve energy by shading building envelopes and ameliorating the urban heat island (9), avoid stormwater engineering and treatment costs by intercepting and slowing precipitation (10), improve human productivity by providing greenery for psychological restoration (11), increase residential and commercial property values (12) and improve business performance in well-landscaped areas (13).

Socially, urban forests are "nearby nature" that provide several important psychosocial and wellness benefits. Urban forests improve overall quality of life, in that they appear to speed human healing (14), provide restoration from stress and urban conflict (15), are a component in increasing physical activity, provide positive environments for children (16), slow traffic thereby improving roadway safety (17), and signal desirable areas (18). Built environments would be far less desirable without urban forests.

### 1.2 Solar Power Generation

Solar power generation is increasing rapidly across the developed world as costs fall, innovation increases and acceptance grows. The solar power industry doubled its growth in 2010 and is one of the fastest growing industries in the United States and Canada (19). Projections indicate that approximately 7% of world electricity production will be from solar power generation by 2020 (20). There appears to be an analog to Moore's Law in solar power technology innovation (21), which indicates continued movement to solar power generation provided material shortages do not impede expansion.

An impediment to solar power generation in the United States is the fact that there is no legal "right to light" due to federal circuit court decisions in the 1950s (22). This lack of federal legal guidance has resulted in a hodgepodge of local laws, which has led to recent conflicts and legal decisions clarifying the boundaries between trees and Photovoltaic (PV) arrays, despite the fact that a majority of states have some form of solar easement or solar access law on record (23). As an illustration of the legal vacuum solar power generation faces, a recent California, USA legal decision was further clarified by political action that mandated clear access for solar panels between 10:00 AM and 2:00 PM after the installation of a solar collector (24).

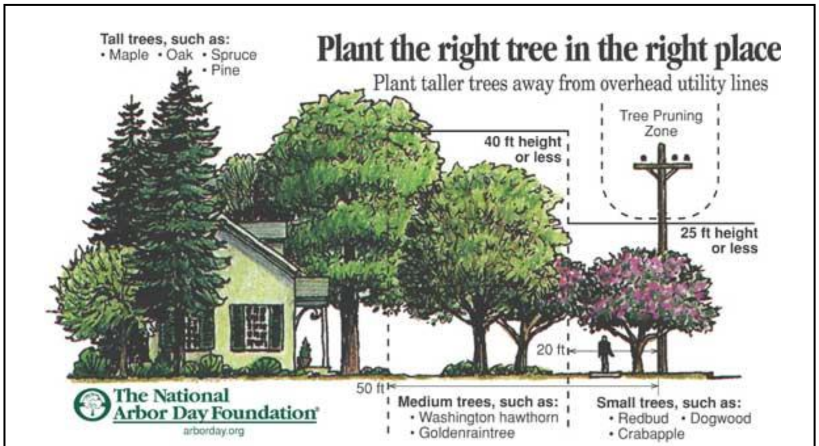


Fig 1: Traditional urban tree siting recommendations often impede solar power collection. Source: Arbor Day Foundation

In an uncertain environment, the arboriculture industry can be an effective partner with the solar industry to develop energy-efficient cities while maintaining a high quality of life. The benefits of strategically maintaining or increasing tree canopy in built environments – increased shade and solar power generation, improved property values, reduced stormwater peak flows, increased aesthetics, and improved environmental health - far outweigh the costs and pay dividends many times over. The strategic partnering of trees and solar panels will allow cities to come closer to achieving sustainability goals, and further the goals of the solar industry as well as urban forest advocates.

## 2. DISCUSSION

Urban forests can and often do conflict with rooftop solar power generation as trees grow large and interfere with sunlight falling on PV arrays. The most important reason that trees conflict with PV arrays – especially in urban residential settings – is the value of tree canopy over buildings for envelope conditioning. Much of the older building stock in North America was constructed when insulation standards were lower than today, and trees are key components in envelope moderation, mainly by casting shade but also by creating wind turbulence to lessen heat loss. Wind turbulence from trees, incidentally, is what makes wind power generation difficult in urban areas and positions solar power as a key component of renewable energy portfolios. Trees and solar collection are good partners for these reasons.

Trees planted for building envelope conditioning are less necessary in modern buildings built to higher insulation and design standards. Therefore the traditional siting of trees, such as depicted in Figure 1 can often be unnecessary in areas using higher construction standards such as the International Building Code (IBC) (25) and requiring underground utility placement. Solar-friendly recommendations for tree siting appear below.

Trees are important components of the built environment, not only for energy savings but for aesthetic purposes as well. A large healthy tree adds "curb appeal" and can increase property values of residential and commercial parcels (26), and that value spills over to adjacent properties in residential areas (27). The increase in property values and stormwater mitigation are likely sufficient reasons to assume tree planting will continue in cities. It is estimated that by 2050, approximately 50% of all buildings in North America will have been built since the year 2000 (28). That is a lot of potential trees, as well as potential rooftops available to collect solar power. Aesthetics come from not only trees, but PV arrays as well. There is a 'green premium' on real estate sales, where single-family houses with PV arrays visible from the street currently command a higher sale price than comparable houses nearby (29). The time to ensure a successful coexistence of trees and PV arrays is now.

### 2.1 Tree Placement

Traditional tree placement paradigms generally seek to use trees to assist in building conditioning and to increase the aesthetic appeal of the parcel. The dynamic nature of tree growth and the time required for tree maturity are important considerations in tree placement, as benefits of tree canopy are realized only after years of growth, as most of the benefits of tree canopy are realized only as the tree approaches maturity. Mistakes in placement take many years to correct. Fortunately, understanding of optimum tree placement for building conditioning is fairly robust, and Figure 2 depicts optimum tree placement for efficient building conditioning by selected USDA climate zone.

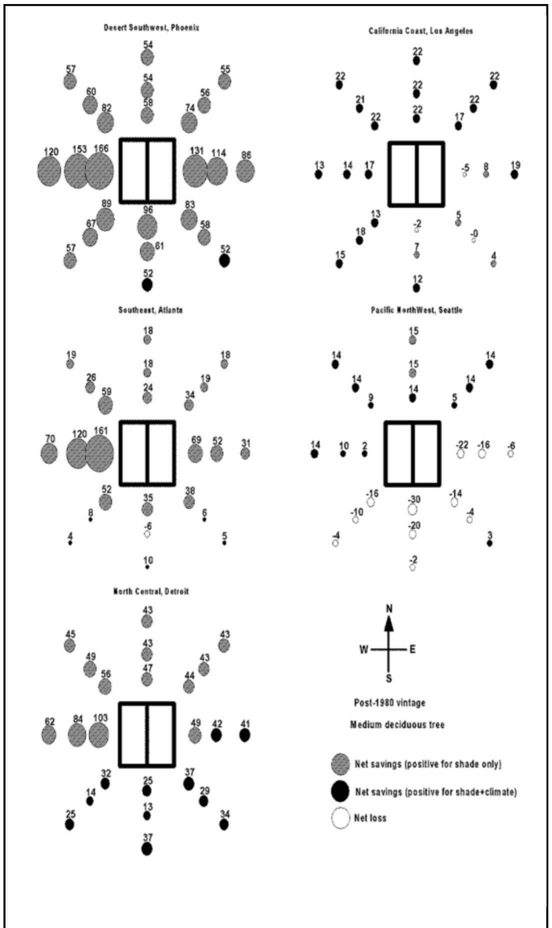


Fig. 2: Optimal tree placement for building conditioning. From Sarkovich (30).

A large tree planted on the west side of a building will deliver cooling benefits in many locations in North America (Figure 2). Even large deciduous trees cast shade in winter, lowering solar gain and raising winter conditioning costs (31). A large tree to the west of a structure also has a smaller chance of shading a PV array on the average residential roof between 9:00 AM - 3:00 PM. Modern, efficient building envelopes may not depend upon shade cast by trees for conditioning, although tree shade is still helpful.

Proper shade tree placement, therefore, is favorable for rooftop PV arrays.

2.2 <u>Photovoltaic Array Placement</u>

Most jurisdictions with solar access laws – or contemplating such laws - attempt to regulate clearance via some method of space clearance, either by clearance zones by time period or easement to allow PV arrays to collect sunlight.

This paper proposes no changes to existing PV placement paradigms. Installers, engineers, sales staff, and analysts need to make no changes to their businesses.

This paper proposes new design standards at various scales, according to plant species' mature expected sizes and PV array placement.

## 3.0 <u>PROPOSED DESIGN STANDARDS FOR SOLAR ACCESS ZONES</u>

### 3.1 <u>Solar Access Zone Introduction</u>

This paper's main proposal is for the creation of innovative "Solar Access Zones" at different scales to ensure vegetation clearance for solar arrays. Solar Access Zones are areas around 1- to 3-story buildings that restrict plant species selection to ensure clearance for current or future solar collection. This paper proposes such zones for rooftop solar power generation only – ground-mounted solar arrays and "solar gardens" are treated in a separate paper in preparation at press time. Solar Access Zones do not replace solar easements or other solar access laws, but can supplement them or in some cases serve as a bridge or temporary measure until more complete local ordinances are enacted. .

In general, developers do not need to change construction methods, techniques, or materials to adopt or incorporate Solar Access Zones into their plans. Plant material choice and plant placement in new construction and redevelopment will change.

This paper's proposed Solar Access Zones do not replace "solar subdivisions" – areas that have streets, buildings and roofs oriented to receive sunlight. Solar Access Zones can – and should - be a component of such developments.

Solar Access Zones can be a public ordinance and a private development choice, as well as a covenant in a Homeowner's Association and are not dependent upon police power or force of law for existence, although better success is expected if Solar Access Zones are implemented via ordinance or regulation.

3.2 Plans and Policies: Comprehensive Plans

Comprehensive Plans are the top-level general directive to guide specific planning policies and practices. Many communities create Comprehensive Plans to guide, clarify and enforce development of the built environment. Accepted planning principles state that all elements in Comprehensive Plans should enforce each other (32), which is called *concurrence*. For example, when a city's Economic Development Plan states that reducing dependence on foreign oil is a goal, the Land Use Plan should not state a goal that only large homes on large lots are desired – policies at cross purposes are not concurrent and are not accepted practice.

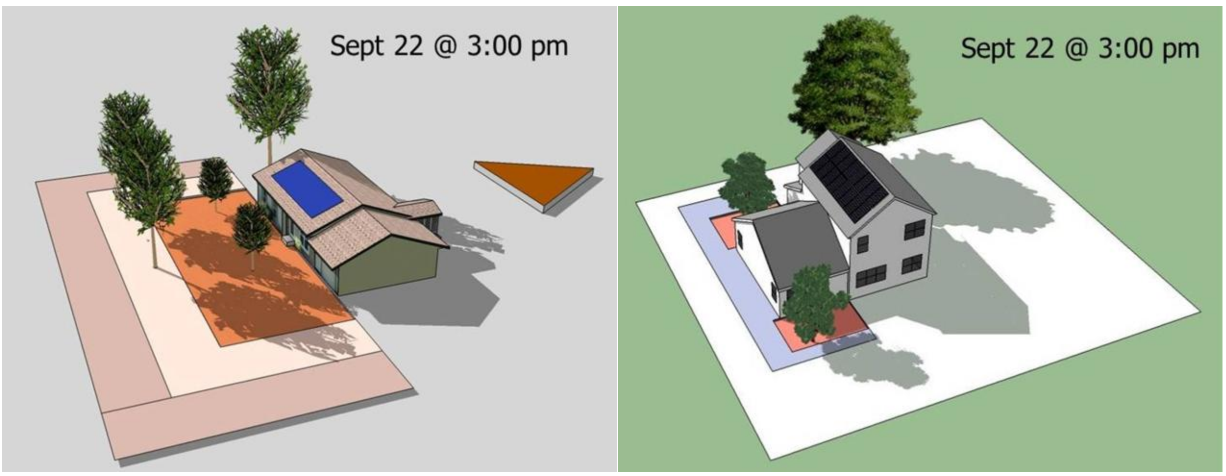


Fig. 3: Parcel-scale Solar Access Zones depicting optimum tree placement near buildings to maintain clearance for rooftop solar arrays and optimum energy efficiency. Renderings by author.

Urban forests support many elements and goals in Comprehensive Plans (33). From national requirements such as stormwater runoff (34) to local goals such as affordable housing, efficient infrastructure, or economic development, goals of urban forestry are easily integrated into several elements within Comprehensive Plans.

Communities are just beginning to include separate green infrastructure (35) or 'sustainability' (36) elements in their Comprehensive Plans, and formal plans for solar access usually fall into a sustainability or green infrastructure plan.

Although both urban forests and solar collection often appear together in such plans, they almost always are treated separately, and not considered together when planning for land use or utility placement.

Comprehensive plans should explicitly state that trees can be in conflict with solar collection and efforts *shall* be made to ensure their coexistence to receive the benefits of both and not one at the expense of the other. Such wording gives a better chance for consideration at code formulation, plan review, and in code enforcement

3.3 Plans and Policies: Design Standards

Design standards regulate the form of commercial, residential and industrial buildings as well as elements within the built environment such as signs and lighting. Design standards may also regulate road, sidewalk and pathway form and dimension. Such standards also regulate the spacing in between buildings and roads. These standards are commonly attached to land development codes and can be included in zoning, development or subdivision regulations. Many jurisdictions have design standards for signs and streets, but standards for building form are not guaranteed.

Design standards often have a purpose statement. Purpose statements signal the intent of plans, policies and code. With respect to solar collection and urban forests, an effective purpose statement should explicitly state that solar collection and urban trees should coexist, via language such as: *solar collection is valued for energy savings and improving the quality of life, and the built environment shall be harmonious with solar collection and green infrastructure. Plans* shall *include accommodation for medium and large urban tree and solar collection whenever possible.*

3.3 A Sample Design Standard at the Parcel Scale

Trees and woody plants have maximum or expected sizes (37) and therefore have optimum placement away from buildings and each other, even without considering solar collection. Existing design standards may or may not acknowledge the ultimate size of plants. Solar Access Zones specifically acknowledge and consider plant size to maintain clearance for solar collection. The needs of solar collection restrict the plant palette in many settings to small trees or large shrubs, although a small tree does not lower the aesthetic quality of the property.

Figure 3 shows sample Solar Access Zones for one- and two-story houses at 40 degrees north. Between 9:00 AM and 3:00 PM local standard time, no tree shadows impede solar collection in either scene. Note the large tree placement to the west of the houses for optimum cooling in summer and minimal shading in winter. In many residential areas in North America, these trees would not impede sunlight striking a rooftop PV array on a house located to the west of the tree; whether the tree impedes sunlight striking a rooftop PV array to the west depends upon parcel shape and side setbacks. Care should be taken to ensure ultimate tree size does not result in shading a PV array to the north. Practitioners can determine the size of these zones by direct calculation and using several free drawing programs available on the World Wide Web.

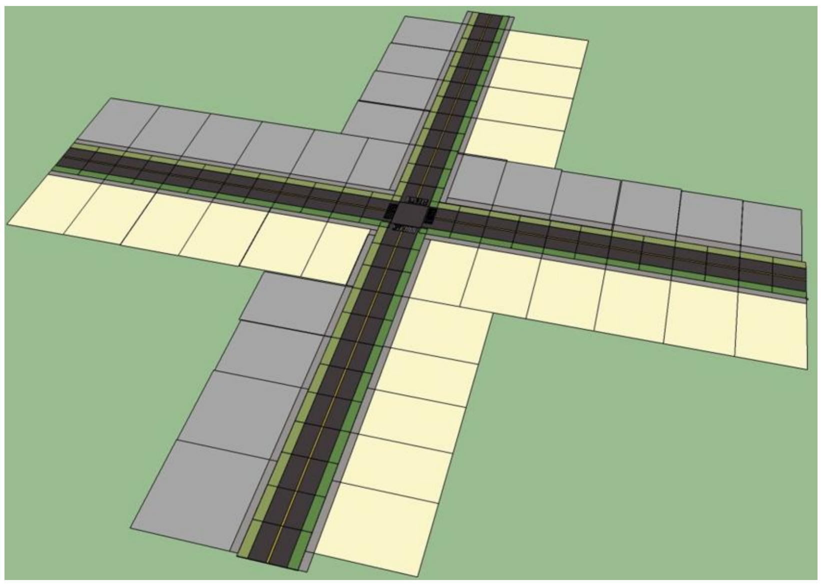

Fig. 4: Neighborhood-scale Solar Access Zones, the dark parcels having restrictive tree placement in the Right Of Way to maintain optimum clearance for rooftop solar arrays. North is up. Rendering by author.

The one-story house has a larger "solar safe zone" due to the PV arrays being closer to the ground. The inner restricted area extends twenty feet from the house (6m). Tree height in the restricted area adjacent to the house is limited to twenty feet (6m), strictly ornamental or fruit trees. The next restricted area limits tree height to a moderate-sized tree and is a distance typically associated with a treelawn (planting strip) and typical post-WWII suburban setback in much of North America.

The two-story house has a much smaller restricted area due to the height of the PV arrays. Tree height in the restricted area adjacent to the house is limited to twenty feet (6m) in this scene as well. The next restricted area limits tree height to a moderate-sized tree as in the one-story scene.

Specific tree species to site in the Solar Access Zones depends upon USDA climate zone, and professionals should seek appropriate plant lists for their climate zone.

3.4 <u>A Sample Design Standard at the Neighborhood Scale</u>

The neighborhood scale Solar Access Zone takes into consideration street trees and their potential contribution to shading rooftop solar arrays. Street trees are important to urban infrastructure, as their shade cast on streets improves pavement longevity (38), lowers ambient air temperature and slows automobile fuel volatilization,several constituents of which are important components of smog precursors (39). Street trees are also important components of stormwater infrastructure, as tree canopy slows precipitation runoff (40). Modern compact land-uses favor short setbacks – the distance to the front of the building from the public right-of-way - which increases the potential for large street trees to grow into a solar access plane.

Solar Access Zones at the neighborhood scale make a choice as to which side of a north-south running street allows tall street trees in areas with short setbacks. There is no inherent 'better' side of the street to permit tall street trees. In Figure 4, the west side of the north-south running street (dark parcels) restricts the use of tall street trees in order to allow clearance for solar access. A design standard for an area depicted in Figure 4 might read: *Street trees in Neighborhood Solar Access Zones shall not exceed thirty-five (35) feet (10m) in order to maintain clearance for solar collection. Tree species shall be restricted to the approved Solar Access Zone Plant List and may not be "topped" to* *lower height to maintain clearance. Existing trees may be pruned to maintain clearance by an approved, Certified Arborist.*

3.5 A Sample Design Standard at the City Scale Using Overlay Zoning

Solar Access Zones can be implemented at city-wide scales. *Overlay zones* can be created and implemented at the city scale, and also in areas deemed good solar collection areas to implement smaller-scale Solar Access Zones at the parcel or neighborhood scale. Overlay zoning is a type of zoning placed "on top of" – not replacing – existing zoning as a supplement to existing code. Overlay zoning often can take much less work to implement, as its implementation can have less impact on the value and use of the underlying real estate. An overlay zone can work in typical zoning schemes, in areas under contract zoning (such as Planned Unit Developments), or in areas with Codes, Covenants, and Restrictions (CC&Rs). Overlay zoning can work in states that do not allow local CC&Rs to supercede state law, such as Colorado, which does not allow CC&Rs to prohibit energy-saving devices such as clotheslines for aesthetic reasons.

New development areas are good solutions for implementing overlay zoning for Solar Access Zones, as newly-planted trees have not yet grown into solar access planes.

Areas to be redeveloped, such as commercial and industrial areas, are good areas to implement new Solar Access Zones, as often developers choose to remove trees (and ordinances allow it for economic reasons) in redevelopment projects. It is key in such areas that solar companies and arborists are part of the design or planning teams to ensure that the architecture, building placement and landscaping are optimized for solar collection.

Areas with existing buildings but not being redeveloped will be the most difficult areas to implement Solar Access Zones, as there is the chance some trees will have to be removed, requiring additional work with the public to hear and understand concerns and work through mitigation strategies.

3.6 Tree Pruning as a Design Standard

International Society of Arboriculture (ISA) Certified Arborists have the knowledge to perform proper clearance pruning to clear access planes for solar panels. ISA-Certified Arborists can determine whether a tree needs to be removed or simply pruned to ensure solar collection continues, wheras a "tree service" may or may not have this knowledge. In addition, ISA-Certified Arborists can estimate tree growth rates to determine approximately when a tree will grow into the access plane. This service can preserve the benefits of trees as well as solar collection.

Regulations on pruning private trees can be tricky in many jurisdictions due to resistance to regulation of private property. Design standards may be appropriate where permits are required to remove trees on private property, and may mitigate canopy loss by offering an alternative to removal. A sample design standard may read: *Pruning of trees on private property shall be performed by an approved and certified arborist to appropriate standards, shall not reduce aesthetic appeal, and shall at all times attempt to preserve tree canopy when practicable.*

3.7 Permitting

It is neither innovative nor new to state that solar permitting in many jurisdictions needs addressing if communities wish to become more energy-efficient. Colorado recently tackled this issue with HB 11-1199 the Colorado Fair Permit Act (41), requiring that limits be placed on permit fees for solar installations. Nevertheless, even with legislation lowering permit costs, the cost for a permit on a residential installation in Boulder, CO for projects requiring a permit can be as much as 3-5% of the total cost (42), significantly lengthening the return on investment. For jurisdictions that wish to privilege renewable energy, prioritizing permit streamlining and reform is a necessity to ensure the end-users of renewable energy gain the most return on their investment.

It is important that minimum plant spacing from infrastructure is explicitly stated, especially minimum distance from utility easements. Figure 2 is an example of a diagram depicting tree size and distance from infrastructure that should be included in a design standard. Distances from sidewalks, curbs, and utility cores are appropriate applications for such a standard. Sample code language where such a diagram is appropriate: *All tree lawns in public rights of way shall be a minimum of 6 (six) feet (2m) width.*

## 4. CONCLUSION

This paper describes several innovative and traditional land-use and design solutions to facilitate the successful coexistence of urban trees and rooftop solar energy collection. Urban forest benefits can be preserved as solar collection becomes more common in the urban forest. Proper tree placement is beneficial for rooftop solar collection, energy savings, property values, and human health and restoration. Proper tree placement includes parcel-scale zones where tree species are limited to small-statured trees, and neighborhood-scale restriction of street tree size to facilitate rooftop solar collection.

The arboriculture industry is poised to partner with the solar industry to generate clean energy by contributing expertise when recommending best practices for policy and maintenance. The benefits of strategically increasing tree canopy in built environments – increased energy savings from shade, increased solar power generation, reduced stormwater peak flows, increased aesthetics, and improved environmental health - far outweigh the costs and pay dividends many times over.

## 5. ACKNOWLEDGEMENTS

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