

Hedonic Valuation of Residential Resource Efficiency Variables

A Review of the Literature

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Executive Summary

California has led the nation in creating ambitious goals to reduce greenhouse gas (GHG) emissions and combat global climate change. The Governor's Executive Order S-3-05[1] establishes targets to lower emissions to 1990 levels by 2020 and to 80% below 1990 levels by 2050. Assembly Bill (AB) 32 (the Global Warming Solutions Act)[2] enshrines the 2020 targets in law, and the Air Resources Board is now working to meet these targets using a variety of policy mechanisms, including emissions trading markets, vehicle fuel efficiency and building energy efficiency standards, and increased renewable energy generation. Senate Bill (SB) 375 (the Sustainable Communities and Climate Protection Act)[3] requires that communities account for the impact of urban planning decisions on transportation-sector GHG emissions and that they reduce emissions by providing better transportation options and designing more compact, mixed-use communities. Over a quarter of California's cities are also in the process of drafting climate action plans and policies that address GHG emissions from a broad variety of sources, including building energy use, transportation, and industry.[4]

“Cool community” design strategies aim to reduce urban temperatures through a variety of measures, including:

- providing new urban parks and open spaces,
- planting new trees and vegetation, and
- using light-colored roofing and paving materials that reflect heat

These strategies have the potential to combat global warming in three ways. First, reducing ambient temperatures can lower the amount of energy needed to cool buildings, particularly in the inland areas where the majority of California's growth is projected to occur over the next several decades. Second, milder temperatures make walking and bicycling, which are the most energy-efficient forms of transportation, more appealing, facilitating a shift away from GHG-intensive automobile use. Finally, cool community strategies have the potential to mitigate some of the projected increase in temperatures due to climate change.

Though engineers and designers have extolled the benefits of cool community strategies, few local governments have implemented these strategies on a widespread basis, and the potential benefits of these strategies are often overlooked in local climate policies. One potential explanation for this is that cool community strategies are difficult to finance, since some of the strategies (e.g., light-colored roofs) are viewed as creating strictly private benefits and are thus undervalued by the public sector, while other strategies (e.g., street trees) are viewed as creating mostly public benefits and are thus undervalued by the private sector.

- This document is a literature review of articles using hedonic modeling techniques to assess the value of cool community features in residential settings. Hedonic analysis involves comparing the cost of heterogeneous goods in order to determine

the value of the various attributes that make up these goods. In the case of cool communities, hedonic analyses examine the sale prices of homes in a given area to determine how the presence of or proximity to street trees, open space, or cool roofs and pavements affect the value of homes, while controlling for other attributes such as amenities, neighborhood characteristics, and location. In addition to cool community strategies, we also considered related resource efficiency variables and concerns, such as the amenity values of climate and energy efficiency and policy mechanisms that implement land use or resource efficiency measures. This research is an initial step in a larger research project that the Center for Resource Efficient Communities (CREC) and the Fisher Center for Real Estate and Urban Economics are undertaking to develop financing and policy mechanisms for the widespread implementation of cool community strategies throughout California.

In this review, we employed a broad-based research methodology to identify relevant sources, drawing from several research databases and consulting with more than a dozen experts in economics, resource efficiency, and other relevant fields. We identified hundreds of potentially relevant articles from peer-reviewed journals and other sources and categorized them by scale of inquiry, variables studied, study location, econometric models employed, and study results.

Overall, we found a body of literature with abundant coverage of some resource efficiency features and scarce coverage of others, a shortage of California-related research, numerous and diverse methodological approaches, and limited meta-analysis potential. Features such as residence-adjacent open space and

vegetation were well covered in the literature, while features such as light-colored roofs and pavement were barely covered, if at all. In general, studies found open space and vegetation to have a positive effect on property values, but they noted several factors that could increase or mitigate this effect, including viewshed, land scarcity, buffer effects, land use diversity, homeowner type, vegetation density, and regional variation.

Among the potentially relevant articles with study areas in California, only two examine factors related to cool community design using a hedonic model of sales price. The first is limited by its concentration on a specific tree type and its specialized model structure, while the second (though perhaps the article most relevant to the consideration of cool community design value in California) cannot be easily generalized due to its use of a measurement technique and definition of green space that are unique to the study and its geographic location.

Regarding methodology, we noted substantial variation in approach to hedonic price modeling as well as in the definition and measurement of environmental factors. Some studies employed basic ordinary least squares regression equations, while others used sophisticated weighting techniques and 2-stage specifications to overcome perceived problems with spatial autocorrelation and endogeneity. Also, some studies simply used the presence of variables adjacent to homes to calculate price effects, while others used complex estimates of densities and distances derived from a number of software programs and indices.

Given the scarcity of studies involving key resource efficiency variables, the shortage of relevant California-related research, the variability of research methodologies, and other concerns, it is clear that a meta-analysis alone could not sufficiently demonstrate the property value impacts of all cool commu-

nity features on California homes. With around 70 studies addressing open space, vegetation, or both, a meta-analysis involving these specific features may be feasible, but such an approach should supplement new hedonic research (including further study within California) rather than serve as the primary research technique for valuing these variables.

The next research task will entail developing a set of hedonic studies that will contribute to understanding the benefit-cost framework of cool community investments at the individual, neighborhood, and community scales. Based on our findings, we submit the following recommendations (all of which we outline in greater detail in Section V(C) below) regarding completion of this and other research tasks:

- **Select Study Areas Carefully.** Identify study areas that are representative of many other California communities, particularly in terms of climate, socio-economic makeup, and level of urban development.
- **Specify a Standard Regression Model.** Develop a standardized hedonic regression model for use in all of the selected study areas, and use meta-analysis to assess sensitivity to location and climate variations, among other factors. When creating the standardized model, pay special attention to feature definition and methodology, both of which should be applied consistently across study areas.
- **Apply the Model and Interpret Results Carefully.** When applying the regression model to the chosen study areas and interpreting results, consider the following common causes of variation in coefficient values (for hedonic regressions valuing environmental variables): proximity, recreational benefits, aesthetic value, characteristics of adjacent land, characteristics of the homeowners in question, and buffer effects.
- **Incorporate Related Issues into the Study Framework.** In assessing the value of cool community features using regression analysis, consider incorporating the amenity values of both climate and energy efficiency into the model specification or creating complementary models that focus on these factors (e.g., via interaction effects). Also, consider accounting for the effects of policy mechanisms on feature value estimates and on the overall benefit-cost structure of cool communities implementation.



Source: CREC

I. Review Purpose and Scope

With the Governor’s Executive Order S-3-05[5] and Assembly Bill (AB) (the Global Warming Solutions Act),[6] California has established ambitious targets to reduce greenhouse gas (GHG) emissions to 1990 levels by 2020, and to 80% below 1990 levels by 2050. Senate Bill (SB) 375 (the Sustainable Communities and Climate Protection Act)[7] requires that communities account for transportation-sector GHG emissions due to urban planning decisions and produce long-term plans that reduce these emissions. In addition, over a quarter of California’s cities are currently in the process of drafting climate action plans and policies that address GHG emissions from a broad variety of sources, including building energy use, transportation, and industry.[8]

To support the implementation of AB 32 and SB 375, the California Energy Commission founded the Center for Resource Efficient Communities (CREC) at UC Berkeley to study the link between community design and energy efficiency and to identify ways of accelerating the implementation of energy-efficient communities through the planning and development professions. Part of this mission is to advance the implementation of “cool community” strategies, such as:

- providing new urban parks and green spaces,
- planting new trees and vegetation, and
- using light-colored roofing and paving materials that reflect heat.

These strategies all have been shown to reduce urban temperatures, lowering building energy consumption, creating more comfortable outdoor environments for pedestrians and cyclists in order to facilitate a shift away from automobiles toward more energy-efficient modes of transportation, and offsetting the increased temperatures caused by global warming.

Faced with rethinking building and neighborhood design in the context of state goals to drastically reduce GHG emissions, communities must consider not only the measures that could be used to meet these new goals but also the costs associated with those measures, and who will bear such costs. These are the subjects of a potential multi-year research project by CREC and the Fisher Center for Real Estate and Urban Economics, of which this literature review is the first product. The project will provide the tools for developing financial mechanisms to facilitate creation of cool communities by local governments and developers, a task that involves understanding:

- how the factors that contribute to cool communities, such as building characteristics, neighborhood landscaping and paving, and energy and transportation systems, create private real estate value;
- existing financial and institutional factors encouraging or impeding investment in the elements that create cool communities; and
- potential ways that incentive systems, lending institutions, public sector authorities, and private companies can be used to encourage investment in cool communities.

This literature review addresses the first of these research goals by examining existing research that identifies the ancillary benefits to homeowners produced by residential resource efficiency variables. We limit the review to hedonic property valuation literature, with the primary aim of identifying studies addressing the effects of cool community features on home values. As a secondary goal, we review studies on related resource efficiency variables and concerns, such as the amenity values of climate and energy

efficiency and the financial impacts of land use and resource efficiency policies. With this approach, we hope to identify key areas of focus for our future research endeavors.

Accordingly, after discussing background issues and its own methodological approach, this review surveys the hedonic valuation methodologies employed in the residential context, identifies the scope of existing research (including the range of variables addressed), summarizes research conclusions (including the range of price effects realized), and discusses major research gaps and opportunities for further study. The review also assesses the feasibility of conducting meta-analyses of the studies identified and recommends research alternatives and next steps.



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II. Background: Cool Communities and the Hedonic Method

As previously discussed, our review focuses primarily on studies involving cool community features, residential design elements that directly or indirectly reduce urban heat island effects.[9] Major cool community features include:

- urban vegetation such as street-side trees and shrubs, which can reduce urban surface temperatures by 20 to 45°F via shading and evapotranspiration;
- light-colored roofs, which can reduce peak roof surface temperatures by 55 to 70°F and have been shown to reduce overall cooling energy consumption for structures by as much as 34%; and
- light-colored pavement, which can reduce peak street temperatures by at least 10°F.

While the effects of these features on local temperatures and energy consumption can be demonstrated easily, determining how residents might value these features is a bit more difficult. One approach to assessing the property owner or tenant's "willingness to pay" for cool-community-related features is to examine the extent to which particular aspects of the property and surrounding neighborhood are capitalized into home values.

The hedonic method has been widely used to estimate value in this way.[10] Hedonic analysis is a revealed preference methodology that uses statistical analysis of market transactions involving heterogeneous goods, such as houses, to determine consumers' willingness to pay for (and hence the implied market value of) the attributes that make up those

goods.[11] In the residential property valuation context, this involves gathering sale price data from a large sample of properties in a specific geographical area and using a regression model to compare the differences in price that occur based on the presence of or proximity to a particular attribute (such as light-colored roofs or street trees) after accounting for other attributes (such as house amenities, neighborhood characteristics, and location attributes).



Source: iStockphoto

III. Review Methodology

In our search for relevant literature, we consulted two distinct source types: research databases and other researchers. The research databases contained articles published in trade journals and refereed academic journals alike, as well as unpublished working papers, book chapters, and other sources.[12] We began our search by compiling lists of queries to submit to the three most promising databases: Business Source Complete, Social Science Citation Index, and Social Science Research Network. These lists, which include over thirty separate queries for each database, are attached as Appendix A.

After submitting the queries to each of the three databases and sorting through over 4,000 results,[13] we compiled a master list of nearly 200 relevant articles. Next, we categorized these articles by scale of inquiry (i.e., structure, yard, neighborhood, and community), variables studied (e.g., street trees or open space), study location, econometric models employed, and study results. We then critically reviewed this list, compiling descriptive statistics and charts and taking note of significant trends and gaps in the literature. Finally, after reviewing the most promising articles, we submitted a number of targeted queries to two additional databases—the Environmental Valuation Reference Inventory (EVRI)[14] and Google Scholar—in hopes of filling the research gaps from the initial set of queries.

Throughout the review process, we also consulted more than a dozen other researchers. Specifically, we communicated with business, economics, public policy, and urban planning professors at various universities; research scientists at Lawrence Berkeley National Laboratory; officials at the US Environmental Protection Agency; utility company research

analysts; and private sector green building consultants. These individuals provided valuable advice regarding research design, potential sources, theoretical trends, and study limitations.

For detailed review, we narrowed down the list of close to two hundred articles in several ways. First, we concentrated primarily on articles related to communities in the United States, drawing from articles set in other countries mostly to enhance our understanding of methodology and to provide coverage of issues that were not discussed in most US studies (e.g., the amenity value of climate). Second, we focused largely on hedonic models of sales price, touching only briefly on other types of studies (e.g., those using alternative research methods or models with other dependent variables such as time-on-the market) where the approach or results helped to inform the analysis of our target models. Finally, in order to assess the feasibility of meta-analysis, we focused on large groups of articles examining the same feature (e.g., open space or trees).



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IV. Review Findings

Overall, our review shows a body of literature with numerous and diverse methodological approaches, abundant coverage of some resource efficiency features and scarce coverage of others, and a shortage of California-related research. In this section, we first describe the methodologies commonly used to study cool community features and other residential resource efficiency variables. Next, we identify the scope and summarize the conclusions of existing studies, concentrating on extensively researched factors such as open space and vegetation. Finally, we discuss features that have not been examined well in the hedonics literature, such as roofs and paving, and also identify opportunities for further study.

A. Hedonic Valuation Methodologies

Before discussing the specific cool community features covered in the articles under review, we briefly examine the methodologies that those articles applied. The approaches vary substantially from one study to the next and over time. These variations are likely to affect the level, degree of significance, and transferability of study results.

Differences between studies involving overall model structure and the complexity of analytic techniques were particularly pronounced. Kim and Wells 2005 used an ordinary least squares, single-stage regression with sales price as the dependent variable. Mansfield *et al* 2005 used the same model structure but then tested its results for several different measures and forms of tree coverage and forest location. Many other studies used a semi-log form of the model, with the dependent variable being the natural log of sales price and the independent variables often taking the form of dummies (i.e., displaying a value of 0 or 1, as in the Donovan and Butry 2010 street tree study),

percent coverage (e.g., the Netusil *et al* 2010 study of tree canopy), or the log of distance (e.g., the Mahan *et al* 2000 study of urban wetlands). Other studies used a log-log model (e.g., Irwin 2002 and Geoghegan *et al* 2003) with all variables except dummies in natural log form, while still others used a Box-Cox Transformation[15] (e.g., Standiford and Scott 2001).

A number of technical issues led researchers to supplement their ordinary least squares analysis with a variety of more complex approaches. For example, two-stage regressions were used to address concerns with endogeneity[16] of variables. Cho *et al* 2008 used a two-stage specification to eliminate endogeneity in a study of the value of green open space. In addition to this two-stage approach, other studies used instrumental variables[17] to address the endogeneity problem (as described in Geoghegan *et al* 2003, a study of agricultural easement programs).

Many studies also raised the possibility of spatial autocorrelation,[18] but the techniques used to address this issue vary widely. Bin *et al* 2009 used a quasi-experimental framework with a difference-in-difference measure to evaluate the effects of a buffer requirement in riparian settings.[19] Geoghegan *et al* 2003 used spatial weight matrices[20] based on inverse distance from other parcels. Payton *et al* 2008 used a spatial lag model with a price weight matrix for neighboring observations.[21] Conway *et al* constructed a Thiessen Polygon[22] around each house location and created a 0/1 weight matrix to identify interactions with neighboring homes. Finally, Irwin 2002 addressed the issue by drawing a subset sample that excluded the nearest neighbors (properties within a 100-yard radius) and examining how results were affected.

Also, not all studies that recognized the existence of spatial autocorrelation adjusted for it. In Donovan and Butry 2010, for example, researchers made no adjustment because the estimated coefficients of the unadjusted model were significant despite potential efficiency problems and because spatial autocorrelation was not expected to bias the results. Some articles comparing results for different types of adjustments support this conclusion. Mueller and Loomis 2008, for instance, found that the results of nonspatial hedonic property models are often sufficient for analyzing policy variables even if spatial autocorrelation exists among the observations. On the other hand, Redfearn 2009 found that attribute prices related to distance from transit facilities vary widely depending on spatial and temporal characteristics and thus recommended a model using locally weighted regressions.

Like model structure, definition and measurement of environmental variables also takes multiple forms. The impact of trees, for example, can be based on presence or absence in a particular area, proximity to structure, count or canopy cover, or percentage of “green” on the property or in the surrounding area. With the expansion of geographic information systems (GIS), data possibilities have expanded widely in the past two decades (Taylor 2003). Many studies now use GIS data to estimate the amount and even the type of green cover (See e.g., Cho et al 2008, Geoghegan *et al* 2003, Irwin 2002, and Kim and Wells 2005). Some also make use of previously developed indices such as the Normalized Difference Vegetation Index^[23] (including MacDonald *et al* 2010 and Payton et al 2008). The availability of these technical methods allows researchers to tailor the measure to the exact issues addressed by the study. From the point of view of a literature review, however, it makes study results comparable only in a general way, as vegetation and open space metrics in different studies are actually measuring different

combinations of factors. This concern is discussed further as we address specific cool community features.

B. Scope and Conclusions of Existing Studies

A little less than half of the 200 sources we flagged in our initial search were methodologically relevant but did not involve direct application of hedonic models to the variables of interest. These included literature reviews without modeling (e.g., Jim and Chen 2009a), methodological discussions (e.g., Meese and Wallace 1997 and Timmins and Schlenker 2009), and articles with relevant methodological approaches on environmental factors not directly under examination in this review (e.g., the study on transportation nodes described in Redfearn 2009). Of the remaining articles, the largest shares were focused on some type of open space feature, some type of vegetation-related feature, or both. We also noted a significant number of articles on water-related features, which we discuss briefly in Section IV(B)(2) below. Finally, 24 remaining articles covering roofing, pavement, climate, energy efficiency, and policy mechanisms round out our list of relevant sources.

As noted above, the most frequently used cool community variables involved open space, vegetation, or wetlands. These categories included a variety of features measured and means of measurement—from 1/0 variables indicating the presence or absence of features like wetlands, to counts of trees in a particular area, to measures of area such as acres of park space. There were no articles addressing cool roof features,^[24] and the small number of articles on pavement focused primarily on access, noise, and aesthetic issues related to public roads (e.g., Boarnet and Chalermpong 2001 valued toll road access in Orange County, California).

In terms of geographic distribution, very few articles focused on California. Only three of the 75 articles analyzing cool community features were set in California, while an additional five involving related resource efficiency variables (i.e., climate, energy efficiency, and policy mechanisms) were based on California data. About two-thirds of all relevant articles discussed study areas in the United States, while around one-third of these focused solely on study areas abroad.

Table 1 describes this entire breakdown in greater detail.

Table 1. Distribution of Hedonic Property Valuation Articles on Cool Community and Related Variables*

Feature	US, Including California	US, Excluding California	Non-US	Total
Open Space	0	22	6	28
Open Space and Vegetation	2	9	9	20
Water and Wetlands	0	16	8	24
Roofing	0	0	0	0
Pavement	1	1	5	7
Climate	1	0	4	5
Energy Efficiency	3	3	1	7
Policy Mechanisms	1	3	1	5
	8	63	45	116

* This table is not meant to be an exhaustive accounting of all studies using a hedonic framework to value residential resource efficiency variables; rather, it is meant to illustrate the relative distribution of the articles that our initial searches uncovered and that we further determined to be relevant to hedonic valuation of cool community features. As noted in Section I above, our primary focus throughout this review is on cool community features, and thus we limited our selection of articles related to climate, energy efficiency, and policy mechanisms to those germane to that primary focus.

1. Cool Community Features Well Covered in the Literature

As previously discussed, the literature covers both open space and vegetation quite well. Our queries uncovered more than 70 articles employing hedonic models to estimate the property value implications of open space, vegetation, or both.

a. Open Space

Of these two well-covered features, open space was the most researched, with nearly 50 of the relevant articles using some form of open space as an independent variable. This included significant coverage of urban parks and open green space as well as less urban features such as hiking trails, greenbelts, golf courses, farmland, and prairies. In general, these studies found that open space had positive value implications but that these positive effects varied significantly based on issues like view (e.g., Luttik 2000), scarcity of land (e.g., Jim and Chen 2010), and even ownership of the open space (e.g., Geoghegan 2002). For a snapshot of the geographic distribution, variable coverage, and findings of the articles we found, see Appendix B.

i. Research Scope

The lion's share of these open space studies were conducted in urban areas and focused on urban parks or other types of urban green space. For example, Jim and Chen 2010 calculated the value of park views to Hong Kong high-rise residents, Conway *et al* 2010 estimated the effects of various types of green space (including lawns, sports fields, and landscaped areas) on home values near downtown Los Angeles, and Lutzenhiser and Netusil 2001 valued various types of parks in the Portland, Oregon area.

Several other articles dealt with suburban and rural areas, while a few focused on the urban-rural interface. The suburban articles dealt mostly with

quintessentially suburban amenities like undeveloped subdivision land, hiking trails, greenbelts, and golf courses. To illustrate, Asabere and Huffman 2009 valued trails, greenbelts, and golf courses in the San Antonio, Texas suburbs; Bowman *et al* 2009 calculated the value of embedded open space in a Cedar Rapids, Iowa “conservation subdivision;”[25] and Peiser and Schwann 1993 estimated the value of greenbelts and subdivision open space in suburban Dallas, Texas. The rural and urban-rural interface articles focused on many of the same amenities, but they also tended to address the effects of agricultural uses and wide-open spaces. Some representative studies include Joly *et al* 2009 (“farmland”), Loomis *et al* 2004 (“range” land), Geoghegan *et al* 2003 (“agricultural easements”), and Lake and Easter 2002 (“public lands,” “prairies,” and “farmland”).

ii. Research Conclusions

The conclusions of these studies were generally consistent, showing that open space has a significant, positive effect on residential property values—but that this effect is heavily dependent upon some important variables. As for this general positive effect, Sander and Polasky 2009 found that “sale prices increase with closer proximity to parks [and] trails;” while Tajima 2003 noted, “proximity to urban open space has positive impacts on property values;” and Morancho 2003 found an “inverse relationship” between “the selling price of [a] dwelling and its distance from a green urban area.” Studies quantified these positive effects by showing home value increases of between 2 and 17 percent. For example, Asabere and Huffman 2009 found that “trails, greenbelts, and trails with greenbelts...are associated with roughly 2, 4, and 5%, price premiums, respectively;” Luttik 2000 reported that a “pleasant view” of open space can increase house prices by 6 to 12%; and Jim and Chen 2010 noted that urban park views can increase residential values by nearly 17%.

The studies also identified several variables that can have a significant impact on the generally high value of open space, in some cases causing this value to be low or even negative. These variables include viewshed, land scarcity, buffer effects, land use diversity, and homeowner type. The conclusions involving the first three variables were quite predictable, while those involving last two were a bit more novel.[26] Cavailhes *et al* 2009a, Joly *et al* 2009, and Paterson 2002 all emphasized the importance of proximity to unobstructed and aesthetically pleasing views when valuing open space. Reginster and Goffette-Nagot 2005, Cho *et al* 2008, and Anderson and West 2006 addressed the issue of land scarcity by noting that the value of open space increases as land becomes more scarce; for instance, Cho explained that “amenities of different features of open space vary according to the degree of urbanization.” Finally, articles such as Geoghegan 2002 and Irwin 2002 discussed the fact that, particularly in a suburban setting, open space is valued as much as a buffer between homeowners and their neighbors as it is valued for its aesthetic qualities. Accordingly, Geoghegan *et al* 2003 found that permanent open space was valued more highly than developable space.

The studies involving land use diversity and homeowner type present some less “predictable” conclusions. Sander and Polasky 2009 and Poudyal, Hodges, Tonn, and Cho 2009 both addressed the issue of land use diversity, finding that more viewer-perceived “diversity” or “richness” of land use actually reduced home values. Sander and Polasky found that “increased view richness in terms of the number of different land cover types in a view reduced home sale prices.” Similarly, Poudal *et al* found that “open space plots with square shape and smooth, straight edges were preferred to those with more complex shapes and irregular edges” and that “residents preferred open spaces in few larger plots

to many smaller pieces that are scattered throughout the neighborhood.”[27]

On the issue of homeowner type, a few studies explored the interaction between open space amenities and the homeowners experiencing them. For example, Rouwendal and Van Der Straaten 2008 concluded that “willingness to pay for parks and public gardens increases with [homeowner] income,” while Des Rosiers *et al* 2007 explained that, “household profile and structure do shape landscaping preferences” and that “utility patterns of homeowners may be best understood by looking at interactions between the two sets of variables.”

b. Trees and Other Vegetation

With 40 of the relevant articles addressing trees and other vegetation, these variables also seem well covered by the hedonic property valuation literature. Most of the literature focuses on urban and rural forests, while the balance deals primarily with landscaping elements such as street and yard trees. Most articles found vegetation to have a generally positive effect on home value, though several strains of the literature identified issues that could intensify or reduce this effect, such as vegetation density and homeowner preferences. Again, for a snapshot of the geographic distribution, variable coverage, and findings of the articles we found, see Appendix B.

i. Research Scope

In terms of scope, the literature on trees and other vegetation can be broken into two broad categories: (1) forests and other large areas of high vegetation density and (2) neighborhood and yard landscaping elements.[28] Forests and similar areas comprise the largest subset of vegetation-related hedonic property valuation studies, accounting for about two-thirds of the relevant articles. About half of these articles dealt with forests and large stands of trees in urban,

suburban, and peri-urban areas, while the other half focused on rural forests and woodlands. Articles addressing the amenity value of densely treed urban areas include Netusil *et al* 2010 (“large patches of tree canopy” in Portland, Oregon), Payton *et al* 2008 (“urban forests” in Indianapolis, Indiana), Mansfield *et al* 2005 (“large, unbroken parcels of forest” in Durham and Chapel Hill, North Carolina), and Tyrvaiven and Miettinen 2000 (“urban forests” in Salo, Finland).[29] Equally as many articles address dense, rural tree cover, including Cho, Kim, Roberts, and Jung 2009 (“forest landscapes” in the “Southern Appalachian Highlands”), White and Leefers 2007 (“forested land” in a “rural county in Michigan”), Sinden 2003 (“woodland in New South Wales”), and Kim and Johnson 2002 (“McDonald-Dunn Research Forest near Corvallis, Oregon”).

The remaining third of vegetation-related studies addressed the value associated with trees and other landscaping in neighborhoods, yards, or both. For example, Donovan and Butry 2010 estimated “the effects of street trees on...sales price,” Bourassa *et al* 2004 calculated value based on the “average quality of landscaping in the neighborhood,” Cavailhes *et al* 2009a valued “trees...in the immediate vicinity of houses,” and Mansfield *et al* 2005 focused on “trees growing around a house or in the neighborhood surrounding the house.” Also, Des Rosiers *et al* 2002 & 2007 both examined the value created by general “landscaping features” in yards and neighborhoods in Quebec City, Quebec.

ii. Research Conclusions

As with open space, the studies dealing with trees and other vegetation generally concluded—with a few key caveats—that these variables had a positive impact on residential property values. For example, Payton *et al* 2008 found that “greener vegetation” had a “positive, significant effect on housing price;” Anthon *et al* 2005 noted that “afforestation” led to

a “significant increase in house prices;” and Willis and Garrod 1993 concluded that “trees... added a statistically significant amount to house prices.” To quantify these effects, Sander *et al* 2010 calculated that a 10% increase in tree cover within 100 meters could produce as much as a .5% increase in house value. Similarly, Donovan and Butry 2010 concluded that street trees added an additional \$8,870 to the sales prices of homes in one Portland, Oregon neighborhood, while Luttik 2000 identified a 5 to 10% premium for “attractive landscape types.” Other key studies placing a positive value on vegetation-related amenities include, Kim and Johnson 2002, Lake and Easter 2002, Standiford and Scott 2001, and Tyrvaiven 1997 (all of which focused on forests and large stands of trees).

The primary caveats to this generally positive valuation involve viewshed, vegetation density, regional variation, and homeowner profile. As with open space, the value of vegetation seems to depend heavily upon its contribution to pleasant views. Paterson and Boyle 2002 framed this issue well, asserting that “visibility measures are important determinants of prices” and that “their exclusion [from the relevant hedonic valuation studies] may lead to incorrect conclusions regarding the significance and signs of other environmental variables.” Several studies emphasized the importance of view in the valuation context and many of these—including Cavailhes *et al* 2009a & b as well as Sander *et al* 2010—found that value estimates of landscaping features at distances beyond a 200- to 300-meter viewshed became statistically insignificant. Much like land use diversity was found to affect open space valuation, a few studies found that vegetated viewshed diversity affected the hedonic value of vegetation. For example, Cavailhes *et al* 2009b concluded that “arrangement of [vegetation] in complex or fragmented landscapes commands a positive hedonic price.” Cho, Jung, and Kim 2009 presented a more nuanced opinion, finding that

“visible landscape complexity is highly valued for deciduous and evergreen forest patches, whereas lower visible landscape complexity...is highly valued for mixed forest patches.”

Judging from the literature, vegetation’s density is yet another factor affecting its hedonic value. Several studies have discussed the diminishing marginal value of vegetation density, while a few have identified and quantified the effects of density levels that actually reduce home values. For example, Des Rosiers 2002 found positive returns to yard tree cover “provided it is not excessive,” while Netusil *et al* 2010 found “diminishing returns from increasing tree canopy past a certain level.” Kim and Wells 2005 went one step further, asserting that reducing dense tree canopy in suburban Flagstaff, Arizona “would increase property values significantly.” Finally, Sander *et al* 2010 identified a point of density beyond which “tree cover contributes to lower price.”

The literature also suggests considerable variation in vegetation value estimates based on regional differences. While some studies attribute this variation to the distinction between rural and urbanized environments, others suggest alternative sources of variation. For example, White and Leefers 2007 found that “proximity to forested land...did not have a positive influence [on home value]” (emphasis added) in a rural setting and noted that these results “contrast with the results of other studies completed in suburban and urban settings.” Similarly, Cho, Kim, Roberts, and Jung 2009 found that homeowners in rural Appalachia preferred smaller, less dense patches of forest than expected. The high values placed on vegetation in more urban areas—and thus the relatively lower values observed in more rural areas—may simply reflect the premium placed on these amenities due to scarcity in urban environments. As Reginster and Goffette-Nagot 2005 aptly observed, “[T]he impact of environmental quality

components” depends heavily upon their “relative scarcity.” However, studies like Cho, Jung, and Kim 2009 seem to suggest that valuation differences exist even when comparing areas with similar levels of urbanization: “[S]maller patches of deciduous forest are more highly valued in the urban and sprawling areas of Greensboro, North Carolina, whereas larger patches of deciduous forest are more highly valued in the urban and sprawling areas of Greenville, South Carolina.”

Finally, one line of research seems to suggest that regional differences in vegetation values may signal important interactions between vegetation-related variables and homeowner preferences. As discussed in the open space context, Des Rosiers *et al* 2007 asserted that homeowners’ utility patterns may be best understood by looking at interactions between household and landscaping variables. For example, Jim and Chen 2006 attributed the low value of coefficients observed for a wooded urban area to the fact that the active local residents could not use the space for recreation, while Des Rosiers 2002 surmised that estimated coefficients on “good tree cover” were particularly high due to the “high proportion of retired persons” living in the study area.

2. Other Variables of Interest: Water-Related Features

In addition to the articles on cool community features mentioned above, we noted a significant body of work—nearly 25 articles—concerned with hedonic valuation of water-related variables in the residential context. As these articles could be informative from both topical and methodological standpoints,[30] we address them here briefly.

The articles on water-related features are best described in terms of their great variety—of locations, of features studied, of estimated effects, and of caveats. Study locations vary a great deal in terms of both global location and urban development levels.

We found articles with study areas in ten US states and nearly as many foreign countries and territories. However, California was conspicuously absent from the list of states covered in the literature, which instead included: Arizona, Florida, Michigan, Minnesota, Missouri, North Carolina, Oregon, South Carolina, Tennessee, and Texas. Additionally, these articles address all levels of urban development—from “harbor views” in Hong Kong and “urban beaches” in Pensacola (Jim and Chen 2009b and Hamilton and Morgan 2010), to remote streams in “a rural county in Michigan” (White and Leefers 2007), and everything in between (e.g., the “urban-rural interface,” Espey *et al* 2007).

The articles also focus on a wide range of water-related features, including: lakes and ponds (e.g., Espey *et al* 2007 and Lansford and Jones 1995); wetlands and marshes (e.g., Tapsuwan *et al* 2009, Bin 2005, and Mahan *et al* 2000); canals, rivers, and streams (e.g., White and Leefers 2007, Anderson and West 2006, and Nelson *et al* 2005); ocean beaches and harbors (e.g., Taylor and Smith 2000 and Jim and Chen 2009b); riparian buffers^[31] (e.g., Bark *et al* 2009, Bin *et al* 2009, and Qiu *et al* 2006); and many combinations thereof (e.g., Lake and Easter 2002, Jim and Chen 2007, and Cho *et al* 2006). Moreover, each of these features carries its own distinct set of effects and caveats.

Most of the articles reported positive price effects of between 2 and 60%, while a few reported negative effects. Articles reporting positive effects include: Jim and Chen 2009b (2.18% for “harbor views” in Hong Kong), Luttik 2000 (8-10% for “pleasant view[s]” of water in Finland), Nelson *et al* 2005 (11% for “waterways or canals” in Texas), Jim and Chen 2006 (13.2% for “proximity to water” in China), and Bourassa *et al* 2004 (59% for “waterfront property” in New Zealand). As for negative effects, Bin 2005 found that some wetlands had “either a negative

or insignificant” effect on property values, while Mooney and Eisgruber 2001 found that riparian buffers “reduce[d] the market value” of stream-front property.

These articles also identified several caveats to be considered when valuing a particular water-related feature, thus helping to explain negative price effects (including those noted above). In general, these caveats are related to land and feature type, proximity to feature, and the aesthetic and recreational value of features. With regard to land type, some articles explained price variation as a function of parcel-level characteristics (e.g., White and Leefers 2007), while others framed the issue in terms of neighborhood-level characteristics (e.g., Cho *et al* 2006, Lake and Easter 2006, and Bin and Polasky 2005). For example, White and Leefers found that proximity to lakes only “affected the values of some parcel types” (emphasis added), while Lake and Easter found varying price effects in urban areas versus the urban-rural fringe. As for feature type and proximity, a few articles (e.g., Bin 2005 and Doss and Taff 1996) found that variations in price were correlated with variations in type of feature (e.g., wetland type),^[32] while most articles (including Jim and Chen 2007, Jim and Chen 2006, Mahan *et al* 2000, and Lansford and Jones 1995) described price as a function of residential proximity to feature. Finally, the following representative articles stressed the price effects of water’s aesthetic and recreational value: Espey *et al* 2007 (“view of a lake” and “lake access”), Luttik 2000 (“a pleasant view” of water), and Lansford and Jones 1995 (“recreational and aesthetic characteristics” of lakes).

C. Major Research Gaps and Opportunities for Further Study

There are several gaps in the literature and under-researched issues that limit our understanding of the financial implications of cool community design and

suggest topics for further study. First, there are no articles on roof color and very few on paving. Second, there are a few articles on the amenity values of climate and energy efficiency and on the financial impacts of policy mechanisms, all of which warrant additional attention. Finally, very little of the research of interest has been centered in California.

1. Cool Community Features Poorly Covered in the Literature

Relevant articles on cool roofs and pavement are largely absent from the literature. As noted in Table 1 above, our queries identified no hedonic property valuation articles addressing roof characteristics and only seven articles addressing pavement, none of which focused on pavement attributes relevant to cool community design. For example, Calvailhes *et al* 2009a & 2009b and Joly *et al* 2009 each described the results of a single study on the value of landscape characteristics in France's urban-rural fringe; these articles included the view of roadways as a variable incidental to their analysis. Similarly, Boarnet and Chalermpong 2001 assessed the value of access to toll roads in Orange County, California.

Two other studies examined the property value impacts of removing a highway. Kang and Cervero 2009 found that the replacement of an elevated highway in Seoul with a greenway reversed the property value effect of proximity to the structure from negative to positive. Also, Tajima 2003 compared the values of proximity to parks and highways in Boston and concluded that relocating an elevated highway, replacing it with parks, would improve property values (but possibly displace tenants). Both studies are closer to the open space studies described earlier than to the type of site-specific analysis that would be helpful in determining potential impacts of paving and other design features on property values.

Finally, Lake *et al* 2000 used property database and GIS data in a detailed analysis of site and neighborhood effects on property values in the United Kingdom. The study demonstrated that lot and block layout, orientation of the lot to the east, and some walkability characteristics affected property values. The methodology and findings are of interest in broad scope but are of limited transferability to California, as they are drawn from a single study in a very different climate, time period, and country.

2. Other Resource Efficiency Variables and Issues

Other types of studies offer some insights into how cool community design could affect property values. A small number of studies have addressed the effects of climate on property values. A few other studies have examined the property value effects of energy efficiency measures on residential and commercial properties. Finally, some studies have examined how policy mechanisms (e.g., zoning related to environmental features) might affect property values. Viewed broadly, the studies in each of these categories suggest innovative ways to supplement hedonic models valuing cool community features.

a. Climate

As the purpose of cool community design is to moderate warm climates and reduce warming effects, we searched for articles that addressed how temperature or other climate features affect home prices. We found a small number of hedonic studies addressing these effects in foreign housing markets and agricultural settings, the results of which were not particularly applicable to cool communities in California. Their very existence, however, points to alternative methods for valuing cool community features.

Three of the studies examined climate change in the context of home prices in foreign countries. Rehdanz 2006 found a positive link between January temperature and home prices in Britain, and a negative link

with January precipitation. Rehdanz and Maddison 2009 found similar results for Germany. Maddison and Bigano 2003 used after-tax labor income, net of housing costs, instead of housing prices as the dependent variable to study climate impacts in Italy; the authors found high temperatures in July and high precipitation in January (both likely to be increased by global warming) to be disamenities.

Two papers addressed the impacts of global warming on agricultural land. Lang 2007 found a positive effect of global warming on agricultural land prices in Germany. Similarly, Deschenes and Greenstone 2007 found a positive effect of global warming on agricultural profits in the US and argued that profits, not land prices, are best used to evaluate climate impacts in agriculture. Both studies noted, however, that impacts varied widely—with parts of southern Germany, as well as California, Nebraska, and North Carolina in the US predicted to have significant losses from warming.

While these results tell us little about the preferences of California homeowners and renters, they suggest that determining the amenity value of climate—particularly consumers' willingness to pay for increases or reductions in temperature—represents another way to value cool community features. Conducting direct hedonic studies to value specific cool community features (e.g., studying the value of street trees) is a way to determine how consumers currently value the aggregate of temperature reduction and other benefits related to cool communities. However, including the amenity value of temperature in these regressions (e.g., via an examination of interaction effects) would allow researchers to (1) determine what consumers would pay for features' temperature reduction benefits if they had perfect information about those benefits and (2) distinguish features' temperature reduction benefits from their other benefits (e.g., their aesthetic value). That is, if we know the

value consumers place on a one-degree reduction in temperature and the average number of degrees by which a particular feature reduces temperature,[33] then we can determine both the amount consumers would pay for the feature given knowledge about its temperature reduction benefits and the proportion of the feature's overall hedonic value attributable to those benefits. This information would be particularly useful where features are difficult to value due to their undercapitalization in land prices (e.g., light-colored roofs and pavement), as it would provide at least some basis for estimating hedonic value.

b. Energy Efficiency and Related Certifications

As with climate, the studies involving energy efficiency are valuable less for their specific findings and more for what they suggest about supplementing further hedonic research. We found three articles, published in the 1980s, that examined how energy efficiency investments were capitalized into home prices and a few others, published in the past few years, that have explored the effects of energy efficiency certifications on rents and sale prices of commercial properties. The three residential studies were each conducted in the Midwest and focused on reduction in heating bill costs. Consequently, few of their findings are particularly relevant for our purposes. Johnson and Kaserman 1983 used a predicted fuel bill as the dependent variable in a two-stage least squares study of sales in Knoxville, Tennessee, concluding that a \$1 reduction in a home's annual fuel bill could increase its market value by over \$20. Longstreth *et al* 1984 examined the effects of specific conservation measures and found that wall and ceiling insulation combined with wood or vinyl frame windows added approximately 7% to a home's value. More than half of this value came from the window quality, however, which is not necessarily equated to energy efficiency (e.g., storm windows did not significantly affect price). Finally, Dinan and Miranowski 1989 found that a \$1 decrease in fuel cost increased

the expected selling price of a home by \$11.63 in a Des Moines, Iowa sample. While Johnson and Kaserman and Dinan and Miranowski found positive effects, these effects were small relative to the mean values of the homes studied. Accordingly, Johnson and Kaserman concluded that high discount rates or lack of full information might lead to less than complete capitalization of energy savings.

A few papers have also addressed the effects of LEED and Energy Star ratings on rental rates and sale prices in office buildings. However, due to complications involving lease structure characteristics, varying definitions of comparable market areas, and tenant variations in energy demand, the results of these studies are not closely transferable to the residential real estate market. Miller *et al* 2008 found that LEED impact on sales price was on the order of 10% and that an Energy Star rating raised price by approximately 6%. The statistical significance of the study's estimated coefficients was weak, however. Moreover, Muldavin 2008 critiqued an earlier draft of the paper for a lack of detail regarding building characteristics, questionable building selection details for comparison buildings, and dubious interpretation of results. Eichholtz *et al* 2009 (a working paper forthcoming in a refereed journal) reported the results of a recent hedonic analysis using CoStar data.[34] After analyzing both sales and rents, the authors found that the presence of energy efficiency certifications increased rental rates by 3% (6% when effective rent was used) and sales price by as much as 16%. Fuerst and McAllister 2008 & 2009 reported a similar set of regressions, showing somewhat higher impacts. Unfortunately, as previously mentioned, none of these results are applicable to the residential case.

Nonetheless, studying the amenity value of energy efficiency could yield important information for researchers. For reasons similar to those cited in the above discussion of climate, adding the amenity value

of energy efficiency to hedonic studies of cool community features would allow researchers to (1) determine consumers' potential willingness to pay for the energy efficiency benefits of cool community features, given perfect information, and (2) distinguish the value of energy cost savings (i.e., observed willingness to pay for \$1 of energy savings) from the other factors contributing to features' overall hedonic value.

c. Policy Mechanisms

A few studies explicitly addressed the property value effects of policy mechanisms related to environmental quality, thus identifying issues that should be considered when specifying regressions to value cool communities. These mechanisms ranged from national conservation laws to local zoning regulations to subdivision deed restrictions. At the national level, Sinden 2003 found that a recently passed vegetation conservation act in the UK had imposed disproportionately high costs on farmers. Netusil 2005 examined the price effects of local conservation zones in Portland, Oregon and found that the effects varied by zone type and location and that, where a zone was successful in preserving tree canopy coverage, the positive effects of the canopy could mitigate the negative effects of the restrictions. Also at the local level, Newburn *et al* 2006 developed a methodology—using Sonoma County, California as a case study—for estimating conservation easement costs and the probability of land use conversion, while Bin *et al* 2009 found “no evidence” that a mandatory riparian buffer rule had a significant impact on property values when compared with a control group. Finally, Bowman *et al* 2009 studied “conservation-oriented subdivisions” in Iowa and found that “consumer demand and willingness to pay for conservation subdivision design are positive and should not be considered a barrier to implementation.” These studies emphasize the importance of considering policy mechanisms at all levels of government, including neighborhood deed restrictions. Account-

Table 2. California Hedonic Studies Valuing Environmental Features*

Citation	Title	Factors Studied	Location
Banzhaf 2005	"Green Price Indices"	Green Cost of Living Index	Los Angeles, CA
Boarnet and Chalermpong 2001	"New Highways, House Prices, and Urban Development"	Transportation	Orange County, CA
Conway et al 2010	"A Spatial Autocorrelation Approach for Examining the Effects of Urban Greenspace on Residential Property Values"	Green Space	Los Angeles, CA
Deschenes and Greenstone 2007	"The Economic Impacts of Climate Change"	Agricultural Output	US, including estimates for California
Kuminoff 2009	"Using a Bundled Amenity Model to Estimate the Value of Cropland Open Space and Determine an Optimal Buffer Zone"	Cropland	San Joaquin County, CA
Meese and Wallace 1997	"The Construction of Residential Housing Price Indices"	Housing Price Index	Alameda County, CA
Newburn et al 2006	"Habitat and Open Space at Risk of Land-Use Conversion"	Probability of Land Use Conversion	Sonoma County, C
Redfearn 2009	"How Informative Are Average Effects?"	Transportation	Los Angeles, CA
Roe et al 2001	"US Consumer's Willingness to Pay for Green Electricity"	Energy Rates	US, including California utilities
Sieg et al 2004	"Estimating the General Equilibrium Benefits of Large Changes in Spatially Delineated Public Goods"	Ozone Concentration	Southern California (multiple sites)
Standiford and Scott 2001	"Value of Oak Woodlands and Open Space on Private Property Values in Southern California"	Oak Trees	Riverside, CA

* In contrast to Table 1, this table includes hedonic studies that are not directly related to residential resource efficiency variables (and instead consider other environmental factors such as air quality). In addition to the studies listed in Table 2, McPherson et al 2005, McPherson et al 1999, and McPherson and Simpson 2002 discuss property value impacts, among other things, in California cities, but these studies do not use hedonic analysis directly, and the hedonic-based estimates they do cite are in fact drawn from Anderson and Cordell 1988, which estimates property value impacts in Georgia.

ing for these mechanisms in hedonic studies of cool community and related features could help researchers control for their effects on feature value estimates and could provide policymakers with a more complete picture of the benefits and costs associated with cool community implementation.

3. California Studies

California is not well covered in the literature addressing cool-community-related features. Table 2 lists eleven published studies that include hedonic analyses (but not necessarily of specific residential resource efficiency variables) and use California as the analytic site or as one of several analytic sites within the United States.

Two of the studies (Banzhaf 2005 and Meese and Wallace 1997) developed price indices, using hedonics incidentally to this exercise and not as a means of evaluating environmental factors. Two more (Deschenes and Greenstone 2007 and Kuminoff 2009) are related to agricultural production, while three others (Boarnet and Chalermpong 2001, Redfearn 2009, and Sieg *et al* 2004) all address transportation or air quality. In Roe *et al* 2001, which addresses willingness to pay for renewable energy, utility rates are the dependent variable, while Newburn *et al* 2006, which addresses land conversion issues, uses land value as the dependent variable. None of the results from these studies are comparable with those from hedonic house price models in other studies.

Only two studies, Standiford and Scott 2001 and Conway *et al* 2010, examined factors related to cool community design using a hedonic model of sales price. Standiford and Scott used a less common model structure[35] and found an approximate 11% price advantage for homes directly adjacent to an oak grove. The study's comparability to the broader

research on trees is somewhat limited by its concentration on a specific tree type and its specialized model structure.

Conway *et al* 2010 is the article in this review that is perhaps the most relevant to the consideration of cool community design value in California. It considered the impacts of "greenspace" (e.g., the comparison between "barren urban alleys" and "a greened alley with native trees and permeable surfaces") on residential sale prices in Los Angeles.[36] In the study, "greenspace" was an aggregate measure of "tree canopy, parkways, lawns, landscaped areas, sports fields, and even cemeteries," digitized into the ArcView GIS software.[37] The study used a log-log model, used green concentration in concentric rings as the measure of the effects of greenspace (as well as distance from a recreation area), and used an alternative specification with spatial weights to address spatial autocorrelation concerns. The results for the two different model specifications were similar, with the latter showing "that increasing greenspace by 1% in [the inner] ring can increase the property value by 0.076%, which is lower than the impact of proximity to parks and recreational facility (0.128%)."[38] This study is useful as a California case but also illustrates the limits of trying to extend conclusions from existing research to the resource efficiency case, as the measurement technique and definition of green space is unique to the study and to the geographic area.



Source: iStockphoto

V. Summary, Meta-Analysis Feasibility, and Recommendations

This section contains a brief summary of our findings thus far, our evaluation regarding meta-analysis feasibility, and our recommendations with respect to research alternatives and next steps.

A. Summary of Review Findings

As explained at the beginning of Section IV, our review shows a body of literature with numerous and diverse methodological approaches, abundant coverage of some resource efficiency features and scarce coverage of others, and a shortage of California-related research. Moreover, we found some studies that suggest innovative ways to supplement hedonic models attempting to value cool community features. Regarding methodology, we observed a great deal of variation among the methodological approaches employed in the relevant studies, particularly in the areas of model structure and variable definition. As for model structure, some studies employed very basic OLS models in single-stage regressions, while others employed sophisticated techniques such as Box-Cox Transformations, instrumental variables, spatial weight matrices, and two-stage regressions. Using many of the techniques just mentioned, some studies corrected for endogeneity and spatial autocorrelation, while others either ignored or dismissed these issues. Dependent variable types in the studies ranged from simple sales price functions to several sophisticated logarithmic forms. Similarly, independent variables were measured in multiple ways, including presence or absence in a particular area, proximity to other features and structures, and percent coverage.

Features relevant to cool community design such as open space, vegetation, and water-related elements were well covered in the literature, while features

like light-colored roofs and pavement were not. The studies we reviewed found that the well-covered features have positive impacts on home value, generally in the range of .5 to 60 percent, but that these values come with significant caveats. Specifically, the values appear heavily dependent on the aesthetic and recreational benefits that these features generate as well as on the characteristics of adjacent land and of the homeowners in question. Among other attributes, quality of views, possibility of recreational use, scarcity of land in the surrounding area, buffer effects generated, and homeowner profile all appear to be important determinants of value.

Most of these caveats are intuitive and self-explanatory, while a few bear further discussion. It should come as no surprise that homeowners value pleasant views of trees and oceans, recreational access to parks and lakes, more space in densely populated cities, or neatly trimmed hedges in suburbia. However, some studies identify less obvious issues like “richness” of views (i.e., diversity of parcel shape or fragmentation of features) and homeowner profile as crucial determinates of value. The studies involving homeowner profile are particularly important, as they point to differences in consumers’ willingness to pay depending on knowledge regarding the feature in question as well as individual socio-economic characteristics such as income, education level, and employment status.

The literature has gaps in geographic coverage and all but ignores some cool community features. Few relevant studies were set in California, and cool community features like light-colored roofs and pavement were covered sparsely, if at all. Our queries uncovered only two California studies examining cool community features with a hedonic model of sales

price, both of which would be difficult to generalize. Likewise, we found no hedonic studies valuing roofs (light-colored or otherwise) and less than ten studies dealing with pavement, none of which were particularly relevant.

While the reasons for the dearth of California-related research are unclear, the lack of studies involving roofs and pavement may be explained in part by the findings above related to well-covered features. Unlike open space, vegetation, and water, light-colored roofs and pavement provide little or no aesthetic or recreational benefits. Moreover, many homeowners are likely to know very little about the economic benefits associated with these features.

Finally, as discussed in Section IV(C)(2) above, including the amenity values of temperature and energy savings in hedonic models attempting to value cool community features would (1) allow disaggregation of value estimates, (2) show maximum consumer willingness to pay for reductions in both temperature and energy costs in the presence of perfect information, and (3) offer an alternative for assessing the value of cool community features, such as light roofs and pavement, which (due to lack of aesthetic and recreational benefits and limited consumer knowledge of temperature reduction and energy efficiency benefits) may not be capitalized into property values. Also, considering the effects of policy mechanisms on cool community feature values will allow researchers to control for these effects and provide policymakers with a more complete benefit-cost picture.

B. Meta-Analysis Feasibility

One goal of this literature review is to determine if a meta-analysis would be feasible and useful for assessing the value to residents of cool community features and other resource efficiency variables, as a prelude to determining financing options. Given the foregoing findings (in particular, the scarcity of studies

involving key resource efficiency variables and the shortage of relevant California-related research), it is clear that a meta-analysis alone could not sufficiently demonstrate the property value impacts of all the relevant variables on California homes. However, with about 70 studies addressing open space, vegetation, or both, it is worth exploring further the possibility of conducting meta-analyses of the studies involving these two variables. The following includes a general overview of meta-analysis and a brief discussion of issues affecting the feasibility of its application, all of which raise serious doubts regarding application of the technique to the studies in question.

Although meta-analysis techniques were initially applied in the field of medical research, several published hedonic housing price studies have used the technique.[39] Most meta-analyses of real estate hedonic studies use the technique to identify factors that cause variation in estimated coefficients. Sirmans *et al* 2006, for instance, used meta-analysis to compare results on the single-family housing characteristics that appear most often in hedonic regressions, examining how estimated coefficients vary with geographic location of the study, time, and model specification, among other characteristics. In medical studies, the technique may be used to summarize effect size (Smith and Huang 1995); Nelson 2004 uses it for this purpose. However, Smith and Huang 1995 caution that other factors may lead to a wide range of variations in coefficients between studies, making use of an aggregate effect problematic.

These studies are informative in a number of ways for analyzing the cool-community-related studies and suggest some possible directions going forward. First, some of the meta-analyses suggest that both geographic location and time period of the research matter for many coefficients related to housing values. For example, Sirmans *et al* found that coefficients for square footage, lot size, age of structure, number of

bathrooms, swimming pool, and air conditioning varied significantly by geographic area. Similarly, Smith and Huang found that variations in the impact of air quality across space can vary substantially due to local conditions, while Daniel *et al* 2009 found that both space and time features affected the impact of flood risk on home prices. Kiel and Williams 2007 created a set of regressions to analyze sensitivity to superfund sites across the US and found that coefficients ranged from negative and significant to positive and significant, influenced by a range of factors, including size of the site and number of sales in the study region around the site.

Second, to maintain the validity of the comparison, meta-analysis requires careful consideration of the features that distinguish each study—particularly with respect to model specification and variable definition. Sirmans *et al* 2006 included only studies using ordinary least squares regressions in a semi-log model specification, while Kiel and Williams 2007 maintained consistency by basing their meta-analysis on their own set of regressions in a standardized format, which included minimal variation in the explanatory variables.[40] Other authors included the model structure as an explanatory variable in the meta-analysis.

Third, socio-economic characteristics may also affect the level or significance of a coefficient, especially where environmental factors are concerned. For example, Kiel and Williams 2007 found less sensitivity to superfund sites in predominately blue-collar communities, perhaps indicating less awareness of the issue or a different tradeoff between environmental quality and job opportunities.

Finally, a sufficient number of studies and model estimates are required. Most meta-analyses were based on a minimum of 20 separate studies, with 30 or more versions of the models tested (as some studies reported more than one model). Sirmans *et al* used over 80

studies, although for some coefficients the sample was as small as 28 or 29, and little significant variation was found for the coefficients based on variables with smaller samples.

Existing studies on factors related to vegetation and open space could provide some basis for meta-analysis, but the apparently large number of studies on each topic is likely to shrink due to the general lack of consistency in model specification and variable definition. Even if there were enough similar studies, the small count of studies conducted in California would render dubious the application of any of these coefficients to California communities, especially in light of the concerns cited above regarding the sensitivity of meta-analysis to geography and socio-economic conditions. As a result, a meta-analysis of existing studies should supplement new research (including further study within California) rather than serve as the primary research technique for valuing the subject variables.

C. Recommendations

Based on earlier planning and in light of this literature review, CREC and the Fisher Center have identified on three prospective research tasks related to the valuation of cool community features in California:

- developing a set of hedonic studies that will contribute to understanding the benefit-cost framework of cool community investments at the individual, neighborhood, and community scales;
- creating an institutional framework and financing mechanisms that support cool communities implementation and describing how these financing mechanisms would interact with other more general financing products and how they may be expected to change energy investment decisions; and

- applying these tools to at least one prototype community to illustrate benefits, costs, and financing structures within a real-world situation.

This literature review has helped illuminate the path to achieving all of the research tasks cited above, particularly the first. Based on the findings of this review, we recommend the following regarding completion of these tasks:

- *Select Study Areas Carefully.* Identify study areas that are representative of many other California communities, particularly in terms of climate, socio-economic makeup, and level of urban development.

- *Specify a Standard Regression Model.* Develop a standardized hedonic regression model for use in all of the selected study areas, and use meta-analysis to assess sensitivity to location and climate variations, among other factors. When creating the standardized model, consider the following:

- *Feature Definition.* Carefully define the cool community features studied, distinguishing between features directly affecting the property (e.g., roof color or yard trees) and features affecting community-wide conditions (e.g., neighborhood open space or water bodies). Also, consider overlap between features (e.g., between neighborhood trees and neighborhood open space when valuing an urban park).
- *Methodology.* Create and consistently apply a standardized OLS model specification that is empirically rigorous yet widely applicable and easily applied:

- Utilize independent variable definitions (described above) and metrics both of which are standard across study areas. Develop appropriate metrics (e.g., percentage of tree coverage within a given area) contemporaneously with selection of data sources and study areas.

- Create a similarly standardized dependent variable and metric. Natural log of sale price, for example, would make an excellent definition/metric combination.

- Test for spatial autocorrelation and apply techniques to compensate for it (e.g., a spatially weighted regression specification) as necessary.

- *Apply the Model and Interpret Results Carefully.* When applying the regression model to the chosen study areas and interpreting results, consider the following common causes of variation in coefficient values (for hedonic regressions valuing environmental variables):

- proximity,
- recreational benefits,
- aesthetic value (including less obvious factors like “richness” of view[41]),
- characteristics of adjacent land (e.g., utilization and scarcity),
- characteristics of the homeowners in question (e.g., age and socio-economic status), and
- buffer effects (i.e., the extent to which variables separate homes from neighbors or other neighborhood features).

- *Incorporate Related Issues into the Study Framework.*

In assessing the value of cool community features using regression analysis, consider incorporating the following related factors into the model specification or creating complementary models that focus on these factors (e.g., via interaction effects):

- *Climate.* Determining the amenity value of climate, particularly consumers' willingness to pay for increases or reductions in temperature, represents another way to value cool community features, as it would allow researchers to (1) determine what consumers would pay for features' temperature reduction benefits if they had perfect information about those benefits and (2) distinguish features' temperature reduction benefits from their other benefits (e.g., aesthetic value and energy cost savings).[42]
- *Energy Efficiency.* Similarly, studying the amenity value of energy efficiency would yield consumers' current willingness to pay for a dollar of energy savings and thus would allow researchers to (1) determine consumers' potential willingness to pay for the energy efficiency benefits of cool community features, given perfect information, and (2) further distinguish between energy cost savings, temperature reduction benefits, and other benefits.
- *Policy Mechanisms.* Finally, considering the effect of policy mechanisms on cool community feature values would allow researchers to control for these effects and would provide policymakers with a more complete benefit-cost picture.



Source: CREC

Notes

- [1] Office of the Governor of the State of California. 2005. Executive Order S-3-05. Text available at <http://gov.ca.gov/executive-order/1861/>.
- [2] Chapter 488, Statutes of 2006.
- [3] Chapter 728, Statutes of 2008.
- [4] California Governor's Office of Planning and Research. 2010. The California Planners' Book of Lists.
- [5] Office of the Governor of the State of California. 2005. Executive Order S-3-05. Text available at <http://gov.ca.gov/executive-order/1861/>.
- [6] Chapter 488, Statutes of 2006.
- [7] Chapter 728, Statutes of 2008.
- [8] California Governor's Office of Planning and Research. 2010. The California Planners' Book of Lists.
- [9] The term "urban heat island effect" refers to the increase in surface and air temperatures caused by surfaces prevalent in urban areas such as dark-colored roofs and asphalt streets, which absorb and re-radiate much more heat than light-colored and vegetated surfaces. This effect is described in greater detail in *Building Energy Efficient Communities: A Research Agenda for California* (Eisenstein 2010). All of the technical figures contained in this paragraph are drawn from pages 34 through 39 of that publication.
- [10] Rosen 1974 is frequently cited as a seminal paper on this methodology. Timmins and Schlenker 2009 placed the methodology in the broader context of environmental and resource economics studies.
- [11] Taylor 331-2.
- [12] As the great majority of the sources we discuss are studies found in journal articles, however, we refer to our collective sources as "studies" or "articles" throughout this review.
- [13] By design, several of our queries returned overlapping results; consequently, the number of unique results is significantly smaller.
- [14] EVRI (<https://www.evri.ca>) is a database containing, among other things, articles relevant to estimating the value of environmental amenities. Because the database's initial focus was on valuation of water-related amenities in the Americas, most of its articles focus on that topic. Nonetheless, it is becoming an increasingly useful repository for environmental valuation articles of all kinds.
- [15] A Box-Cox model is a special non-linear generalized model that allows more flexibility in model specification than either the basic linear regression model or the log-linear model. A Box-Cox approach can be used with maximum likelihood estimation to determine optimal model specification for a regression.
- [16] In a regression equation, endogeneity occurs when an explanatory variable is correlated with the error term (i.e., the term representing all unexplained variables), thus leading to the possibility that the derived value associated with the variable (i.e., its "regression coefficient") has been significantly under- or overestimated. For example, a regression including as an explanatory variable the density of trees in a yard but not including yard size may suffer from endogeneity due the correlation between tree density and yard size (i.e., the larger the yard, the more trees required to increase tree density); thus the absence of yard size as an explanatory variable

may cause the equation to misestimate the effect of tree density.

- [17] An instrumental variable replaces an endogenous explanatory variable in a regression; the instrumental variable is chosen to be correlated with the endogenous explanatory variable but not with the error term.
- [18] In its simplest exposition, spatial autocorrelation in this context occurs when the characteristics of one property are affected by the characteristics of adjacent properties. For example, the value of a person's yard may increase due to the well-manicured trees in a neighbor's yard. Spatial autocorrelation may or may not lead to endogeneity.
- [19] A quasi-experimental analysis uses a unique event or condition (in this case the imposition of a buffer zone) to set up an experiment-like comparison of sales with and sales without the unique event or condition (similar to an experiment, but absent random selection). Difference-in-difference refers to the comparison (or second difference) of price changes (or differences) in the groups with and the groups without the unique event or condition.
- [20] A spatial weight matrix is used to address spatial autocorrelation. The matrix may be based on (1) a decay function of distance to other properties, (2) the distinction between adjacent and non-adjacent properties, or (3) classification of other properties as nearby/distant (determined by a band of distance from the subject property).
- [21] Spatial lag is similar to spatial weight and spatial autocorrelation, referring to the relationship between a parcel and neighboring parcels.
- [22] For a set of Thiessen Polygons, each polygon contains one observation (e.g., a residential parcel), and every point within the polygon is closer to the observation within it than to any other observation.
- [23] The Normalized Difference Vegetation Index is a -1.0 to 1.0 index of green vegetation level based on satellite imagery.
- [24] The roof-related queries submitted to the primary databases can be found in [Appendix A](#).
- [25] Unless otherwise noted, direct quotations from articles cited in this review can be found in the cited article's abstract.
- [26] i.e., these factors were not frequently addressed in the literature, and we did not include them in our initial queries
- [27] Contrast these conclusions with those of Cavailles et al 2009b, which found, "The arrangement of features in complex or fragmented landscapes commands a positive hedonic price."
- [28] While these categories are meant to convey the general focus of the studies cited, many studies (e.g., Mansfield et al 2005, which is cited twice in this section) examine multiple features, from large forest patches to sparsely distributed yard trees; this overlap is especially evident in studies like Netusil et al 2010 that use percentage of tree cover as an independent variable and thus study a wide range of tree densities.
- [29] See also Konijnendijk et al 2007, a paper discussing multiple forest-related hedonic property valuation studies.
- [30] First, proximity to water may exhibit cooling effects similar to typical cool community features. Second, land use restrictions and other policy

mechanisms associated with water regulation (e.g., policies regarding mandatory riparian buffers) may be illustrative of the types of policies that could be employed in the cool communities context. Finally, the hedonic valuation methodologies employed in these studies are quite similar to those employed in the cool communities context and thus are likely to inform the discussion of hedonic valuation best practices.

- [31] A riparian buffer is “a complex assemblage of plants and other organisms in an environment adjacent to water. Without definitive boundaries, it may include stream banks, floodplain, and wetlands, as well as sub-irrigated sites forming a transitional zone between upland and aquatic habitat. Mainly linear in shape and extent, they are characterized by laterally flowing water that rises and falls at least once within a growing season.” (Lowrance et al 1985)
- [32] Contrast these studies with Mahan et al 2009, which found, “Home values were not influenced by wetland type.”
- [33] i.e., based on existing information regarding the average temperature reduction effects of cool community features.
- [34] CoStar Group, Inc. describes itself as “the number one provider of information, marketing and analytic services to commercial real estate professionals in the United States as well as the United Kingdom.” (<http://www.costar.com/about/>)
- [35] a Box-Cox Transformation
- [36] p. 151
- [37] p. 154
- [38] p. 161
- [39] See e.g., Nelson 2004, Sirmans et al 2006, and Kiel and Williams 2006.
- [40] e.g., excluding swimming pools if sample size and character warranted it
- [41] See Section IV(B)(1)(a)(ii).
- [42] See Section C(2)(a) for a more detailed discussion of including the amenity value of climate in the proposed hedonic studies.

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Appendix A: Queries Submitted to the Primary Databases

Business Source Complete ("BSC")	Social Science Citation Index ("SSCI")	Social Science Research Network ("SSRN")
hedonic* AND albedo*	hedonic* albedo*	hedonic albedo (albedos)
hedonic* AND asphalt*	hedonic* asphalt*	hedonic asphalt
hedonic* AND buffer*	hedonic* buffer*	hedonic buffer (buffers)
hedonic* AND california*	hedonic* california*	hedonic california
hedonic* AND climat*	hedonic* climat*	hedonic climate (climates)
hedonic* AND conserv*	hedonic* conserv*	hedonic conservation
hedonic* AND cool*	hedonic* cool*	hedonic cool (cooling)
hedonic* AND energ*	hedonic* energ*	hedonic energy
hedonic* AND energy star*	hedonic* energy star*	hedonic energy star
hedonic* AND environment* AND amenit*	hedonic* environment* amenit*	hedonic environmental amenity (amenities)
hedonic* AND environment* AND resource*	hedonic* environment* resource*	hedonic environmental resource (resources)
hedonic* AND evapotranspiration*	hedonic* evapotranspiration*	hedonic evapotranspiration
hedonic* AND green*	hedonic* green*	hedonic green
hedonic* AND green-e*	hedonic* green-e*	hedonic green-e
hedonic* AND heat AND island*	hedonic* heat*	hedonic heat
hedonic* AND heat*	hedonic* heat* island*	hedonic heat island (islands)
hedonic* AND home*	hedonic* home*	hedonic home (homes)
hedonic* AND hous*	hedonic* hous*	hedonic house (houses)
hedonic* AND landscap*	hedonic* landscap*	hedonic landscape (landscapes, landscaping)
hedonic* AND leed*	hedonic* leed*	hedonic leed
hedonic* AND meta*	hedonic* meta*	hedonic meta-analysis
hedonic* AND pav*	hedonic* pav*	hedonic pave (pavement)
hedonic* AND propert* AND valu*	hedonic* propert* valu*	hedonic property value (values, valuation)
hedonic* AND riparian*	hedonic* riparian*	hedonic riparian
hedonic* AND roof*	hedonic* roof*	hedonic roof (roofs)
hedonic* AND solar*	hedonic* solar*	hedonic solar
hedonic* AND space*	hedonic* space*	hedonic space (spaces)
hedonic* AND spatial*	hedonic* spatial*	hedonic spatial
hedonic* AND street*	hedonic* street*	hedonic street (streets)
hedonic* AND sustain*	hedonic* sustain*	hedonic sustainable (sustainability)
hedonic* AND temperature*	hedonic* temperature*	hedonic temperature (temperatures)
hedonic* AND tree*	hedonic* tree*	hedonic tree (trees)
hedonic* AND weather*	hedonic* weather*	hedonic weather

Appendix B: Snapshot of Articles on Open Space and Vegetation[§]

Type [§]	Citation	Location	Scope ^a	Indep. Variables	Representative Results/Conclusion(s) [©]
S	Acharya and Bennett 2001	New Haven County, CT	Y N	“open space” “land-use diversity” “other environmental variables”	“[I]n addition to structural characteristics, variables describing neighborhood socioeconomic characteristics and variables describing land use and environmental quality are influential in determining human values.” “[T]he scale at which we measure these spatially defined environmental variables is important.” “A unit increase in the richness of land use...results in a lower house price of \$85.” (p. 234)
S	Anderson and West 2006	Minneapolis-St. Paul, MN	N	“open space” (also discusses lakes and rivers)	“[T]he value of proximity to open space is higher in neighborhoods that are dense.” “Using the metropolitan area’s average value may substantially overestimate or underestimate the value of open space in particular neighborhoods.”
V	Anthon et al 2005	Denmark (two sites)	N I	“urban-fringe afforestation”	There is a “significant increase in house prices in the time of afforestation” which becomes “larger the closer the house is to the new forest.” “[I]ncreased annual property tax...has to be included in the analysis to avoid serious misestimation.”
S	Asabere and Huffman 2009	San Antonio, TX	N	“trails and greenbelts”	“[T]rails, greenbelts, and trails with greenbelts (or greenways) are associated with roughly 2, 4, and 5%, price premiums, respectively.” Also, “proximity to golf course, neighborhood playground, tennis court, neighborhood pool, view, and cul-de-sac, all add significantly to home value.”

[§] This table includes all of the articles we found that use hedonic models to assess the effect of open space and/or vegetation on residential values. Unless otherwise noted, direct quotations are drawn from the cited article’s abstract.

[§] This indicates whether the article focuses on Open Space, Vegetation, or Both. As many articles include both types of features, we attempt to categorize articles by the components that appear to be the authors’ primary focus.

^a This indicates whether the article focuses on Yards, Neighborhoods, or Institutions (e.g., deed restrictions or zoning issues).

[©] As most studies report the results of multiple specifications and offer several conclusions, we provide the results and/or conclusions most representative of the study’s overall findings and most relevant to hedonic valuation of cool communities.

Type§	Citation	Location	Scope ^a	Indep. Variables	Representative Results/Conclusion(s)©
V	Bourassa et al 2004	Auckland, New Zealand	N	"landscaping" (also discusses "waterfront property")	"[P]roperties in neighborhoods with only poor-quality landscaping...experience a -51% impact on price."
S	Bowman et al 2009	Cedar Rapids, IA	N I	"conservation subdivision design"	They found "higher 5-year appreciation rates for conservation versus standard Subdivision design." "[W]ell-integrated conservation features...have a positive effect on... prices." "[C]onsumer demand and willingness to pay...should not be considered a barrier to implementation."
B	Cavailhes et al 2009a	Dijon, France	Y N	"landscape"	"[W]hen in the line of sight, trees and farmland...command positive prices and roads negative prices; if out of sight, their prices are markedly lower or insignificant." "[L]ayout of features in fragmented landscapes commands positive hedonic prices." "Landscapes and features in sight but more than 100-300...m away all have insignificant prices."
B	Cavailhes et al 2009b	Dijon, France	Y N I	"landscape attributes" (including "forests and farmland")	"[L]andscapes and visible features more than 100-200m away all have insignificant...prices." "[F]orests...in the immediate vicinity of houses have positive prices and roads a negative price when these features can be seen, while their prices are lower when they cannot be seen." "The arrangement of features in complex or fragmented landscapes commands a positive hedonic price." "[T]he productive function of...forestry is in contradiction with its scenic function." "[P]ublic policies directed at landscape maintenance should take the precise location into account with reference to the urban system."
B	Cho et al 2008	Knox Co., TN	N	"green open space" "evergreen trees" "forests"	"[A]menities of different features of open space vary according to the degree of urbanization." "[E]vergreen trees, a diverse landscape with fragmented forest patches, and more complex and natural forest edges are more highly valued in Rural-Urban interfaces." "[D]eciduous and mixed forests, larger forest blocks, and smoothly trimmed and man-made forest patch boundaries are more highly valued in urban core areas."

Type§	Citation	Location	Scope ^a	Indep. Variables	Representative Results/Conclusion(s)©
S	Cho et al 2006	Knox County, TN	N	“park amenities” (and “water bodies”)	They found “important local differences in the effects of proximity to water bodies and parks on housing price.”
V	Cho, Jung, and Kim 2009	Greenville, NC Greensboro, SC	Y N	“forest composition”	“Amenity values of forest patches are found to vary the most by urban and sprawling development patterns of specific areas and forest types.” “[V]isible landscape complexity is highly valued for deciduous and evergreen forest patches, whereas lower visible landscape complexity...is highly valued for mixed forest patches.”
V	Cho, Kim, Roberts, and Jung 2009	Southern Appalachian Highlands, USA	N	“forest-patch size and forest-patch density”	Homeowners preferred smaller, less dense patches of forest. (p. 2651) “[H]ousing-price response to mean forest-patch size and forest-patch density increased substantially between 1990 and 2000 in a few specific areas with economically significant amenity values.”
B	Conway et al 2010	Los Angeles, CA	Y N	“greenspace”	“[I]ncreasing greenspace by 1%...can increase the property value by 0.076%, which is lower than the impact of proximity to parks and recreational facility (0.128).” (p. 161)
V	Des Rosiers et al 2002	Quebec City, Canada	Y N	“landscaping”	“[C]ottages experience a rise in their market value (0.1%) for each additional positive departure-from-mean percentage point of ground cover on the property, and a drop if the departure is negative.” (p. 152) “[T]he density of the vegetation visible from the property...impacts negatively on prices, each rank unit resulting in a loss of roughly 2.2% of value.” (Id.) “[A] landscaped patio, a hedge as well as landscaped curbs add respectively 12.4%, 3.6% and 4.4% to the market value of a house...” (Id.)
V	Des Rosiers et al 2007	Quebec City, Canada	Y N	“landscaping attributes”	“[H]ousehold profile and structure do shape landscaping preferences and... utility patterns of homeowners may be best understood by looking at interactions between the two sets of variables.”
V	Donovan and Butry 2010	Portland, OR	N	“street trees”	Trees “add \$8870 to sales price and reduce [time on market] by 1.7 days.” “[B]enefits of street trees spill over to neighboring houses.” “[I]f...left solely to homeowners, then there will be too few street trees.”

Type§	Citation	Location	Scope ^a	Indep. Variables	Representative Results/Conclusion(s)©
V	Gao and Asami 2007	Tokyo & Kitakyushu, Japan	Y N	"greenery"	"[T]he compatibility of the buildings and the greenery of the neighborhood were distinctively perceived, these factors significantly influenced land prices, and the marginal effects were similar for both cities."
S	Geoghegan 2002	Howard Co., MD	N	"open spaces"	"[P]ermanent open space increases... values over three times as much as... 'developable' open space."
S	Geoghegan et al 2003	Maryland, USA (3 counties)	N I	"open spaces"	"[P]reserved open space does increase property values on adjacent residential parcels in two of the three examined counties in Maryland. Assuming the existing open space increases by 1%, using simulations based on the spatial econometric model, the increased property tax from these agricultural easements could generate enough revenue to purchase a significant portion of the 1% more open space acres, especially if one considers that the increases in tax revenue go on in perpetuity..." (p. 44)
S	Hite et al 2006	Delaware County, OH	N	"agricultural, residential, park and golf course uses"	"The percentages of golf course area and park area within a distance of 0.50 miles from the undeveloped land... have a positive impact on its price, while the percentage of residential land has a negative impact..." (pp. 11-12) "[O]nly the percentage of residential land within 0.25 miles from the property has a negative impact on the price of undeveloped land transactions..." (p. 12)
S	Hoshino and Kuriyama 2010	Tokyo, Japan	N	Parks	"[T]he effect of parks on property values varied with the buffer distance and park size."
S	Irwin 2002	Maryland, USA (3 counties)	N	"open space"	There is "a premium associated with permanently preserved open space relative to developable agricultural and forested lands." "[O]pen space is most valued for providing an absence of development, rather than for providing a particular bundle of... amenities."
S	Jim and Chen 2010	Hong Kong	N	"parks"	"Neighbourhood parks could lift price by 16.88%, including 14.93% for availability and 1.95% for view."
S	Jim and Chen 2007	Guangzhou, China	N Y	"green space" "parks" (and "water")	"[G]reen space provision, proximity to parks, and views of green space and water carried significant hedonic values." "Differences between the submarkets of old and new towns were found."

Type§	Citation	Location	Scope ^a	Indep. Variables	Representative Results/Conclusion(s)©
B	Jim and Chen 2006	Guangzhou, China	N Y	"urban green spaces"	"View of green spaces and proximity to water bodies raised housing price, contributing notably at 7.1% and 13.2%, respectively." "Proximity to nearby wooded area without public access was not significant, expressing the pragmatic mindset in the hedonic behavior."
B	Joly et al 2009	Dijon, France	N	"landscape" "forests"	"Landscapes and visible features more than 100 to 200 m away all have insignificant hedonic prices." "[F]orests and farmland in the immediate vicinity of houses have positive hedonic prices, whereas roads have negative ones."
S	Kang and Cervero 2009	Seoul, South Korea	N	"urban stream and linear park"	"Seoul's unique freeway disinvestment/greenway investment conferred net benefits to both residential and non-residential land markets."
S	Kaufman and Cloutier 2006	Kenosha, WI	N	"green space" (and brownfields)	"[R]emediation and redevelopment of the brownfields into greenspaces would increase property values for the 890 neighborhood residences between \$2.40 and \$7.01 million."
B	Kestens et al 2004	Quebec City, Canada	Y N I	"vegetation" "land-use variables"	"The presence of mature trees has a positive impact both at a very local scale, with a premium of roughly 1% for each additional 10% in coverage, and at a larger scale, with a premium of roughly 2.5% for each additional 10%." "[R]esidential land use with low tree density has a negative impact on property values of roughly 1.9% for each additional 10%." "Woodlands...impact negatively, when considering a 500m radius..." "Agricultural land with dispersed trees has an overall negative impact on property value of 2.3% per 10% additional coverage in close surroundings (100m)." "The significant integration of land-use data on various scales (40m, 100m, 500m, and 1000m) shows that a hierarchical structure of perception has to be considered when analysing locational externalities."
V	Kim and Johnson 2002	Corvallis, OR	N	"forests"	"Proximity to the forest has a positive contribution to property values..." "The sales price is lower for property from which clear-cut sites are visible at the time of purchase..."

Type§	Citation	Location	Scope ^a	Indep. Variables	Representative Results/Conclusion(s)©
V	Kim and Wells 2005	Flagstaff, AZ	N	"tree canopy"	"[F]uel reduction treatments that convert high canopy closure would increase property values significantly (\$190 per 1,000 m ² per home)."
S	Klaiber and Phaneuf 2009	Minneapolis, MN	N	"open space"	"With the exception of local parks, all open space types have significant estimates...with the largest marginal willingness to pay associated with [conservation] sites followed by nonpark open space and regional parks." (p. 1317)
S	Kong et al 2007	Jinan City, China	Y N	"urban green space"	"Green space amenity variables that were statistically significant at the 5% level included the size-distance index of scenery forest, accessibility to park and plaza green space types, and the percentage of urban green space." "In addition, land-use patch richness, the location sector and the education environment also proved to be highly significant variables."
S	Kopits et al 2007	Washington, DC	Y N I	"public and private open space"	"[P]rivate acreage matters to households - a 10 percent larger lot leads to about a 0.6 percent higher house price..." Subdivision open space is also valuable to households, but the marginal effect is much smaller than the marginal effect of private lot space." "[S]ubdivision open space does substitute for private land, but the extent of the trade-off is small."
B	Lake and Easter 2002	Dakota County, MN	N	"open space" (e.g., "public lands, forests, prairies, wetlands, and water bodies")	"Homebuyers paid more (\$111) to live 100 feet closer to natural areas and less (-\$53) to live the same distance closer to farmland." "[S]plitting the observations into urban and rural-urban fringe zones showed regional distinctions in the relationship of open space proximity to property price."
S	Loomis et al 2004	"Front Range" of Colorado	N I	"open space" (also discussed "wetlands")	"[A]djacency of the parcel to existing park or open space adds \$11,039 an acre." "Easements cost \$6,783 less than purchases, a sizeable cost saving." "The prediction capability of the hedonic price equation may be an alternative to traditional real estate appraisal techniques when agencies must determine fair market values of prospective open space parcels that vary in attributes from existing ones."

Type§	Citation	Location	Scope ^a	Indep. Variables	Representative Results/Conclusion(s)©
B	Luttik 2000	Netherlands (8 towns or regions)	Y N	"open space" "landscape" (also discussed water)	"[A] pleasant view can lead to a considerable increase in house price, particularly if the house overlooks...open space (6-12%)." "Attractive landscape types were shown to attract a premium of 5-12% over less attractive environmental settings."
S	Lutzenhiser and Netusil 2001	Portland, OR	N	"open spaces"	"Natural area parks and specialty parks... have a positive and statistically significant effect on a home's sale price for each zone studied." "Homes located adjacent to golf courses (within 200 feet)...experience the largest increase in sale price due to open space proximity although the effect drops off quickly as distance...increases."
B	MacDonald et al 2010	Adelaide, Australia	Y N I	"public parks"	"[W]ater restrictions are not having a significant impact on the value of...private properties." "[H]ouseholds...may be using some public green spaces for recreation in lieu of private areas."
B	Mansfield et al 2005	Research Triangle Region, NC	Y N	"public parks" "forests" "trees" (yard, neighborhood)	"[G]reenness and forest cover add value to parcels, as does proximity to institutional and private forests. However, while adjacency to private forests seems to add value to houses, adjacency to institutional forests was not significant." "[P]arcel greenness can substitute for proximity to private forest blocks and possibly complement proximity to institutional forests." (p. 196)
S	Morancho 2003	Castellon, Spain	Y N I	"parks" "public gardens"	"[T]here is an inverse relationship between the selling price of the dwelling and its distance from a green urban area."
V	Netusil et al 2010	Portland, OR	Y N	"tree canopy"	There are "diminishing returns from increasing tree canopy past a certain level." "Average benefit estimates for the mean canopy cover...are between 0.75% and 2.52% of the mean sale price."
B	Nicholls and Crompton 2005	Austin, TX	N	"greenways"	"Adjacency to a greenbelt produced significant property value premiums in two of three neighborhoods." "Physical access to a greenbelt had a significant, positive impact in one case, but was insignificant in two others." "No negative greenway impacts were recorded."

Type§	Citation	Location	Scope ^a	Indep. Variables	Representative Results/Conclusion(s)©
B	Paterson and Boyle 2002	Avon & Simsbury, CT	N	"land use/cover features"	"[V]isibility measures are important determinants of prices and...their exclusion may lead to incorrect conclusions regarding the significance and signs of other environmental variables."
V	Payton et al 2008	Indianapolis, IN	Y N	"urban forest"	"[G]reener vegetation around a property has a positive, significant effect on housing price..." "This effect is dominated by measures at the neighborhood level."
S	Peiser and Schwann 1993	Dallas, TX	N	"public open space" (e.g., "greenbelts")	"[H]omeowners value the open space - both those who live directly on the internal greenbelts and those who do not. However, where the open space causes a reduction in private backyard space, homeowners do not appear to value public open space as highly as private space."
B	Poudyal, Hodges, and Merrett 2009	Roanoke, VA	N	"parks"	"[D]emand for urban park acres was inelastic in price and income." "[S]ize of the park was a substitute for living space and proximity to park." "[I]ncreasing the average size of parks by 20%...increased...consumer surplus by \$160."
S	Poudyal, Hodges, Tonn, and Cho 2009	Roanoke, VA	Y N	"open space"	"[R]esidents positively valued the varieties of open space but negatively valued the diversity within developed land uses..." "[P]lots with square shape and smooth, straight edges were preferred..." "[R]esidents preferred open spaces in few larger plots to many smaller pieces that are scattered throughout the neighborhood."
S	Qiu et al 2006	St Louis, MO	N	"open space" (and "riparian buffers")	"[R]esidents' [willingness to pay] was consistent with the economic values of open space and proximity to streams embedded in existing home prices."
B	Reginster and Goffette-Nagot 2005	Charleroi & Namur, Belgium	N	"environmental quality" (including "greenery")	"[R]esults confirm the impact of greenery on location choice and the existence of a higher environmental quality at the periphery than near the centre of the two cities." "[T]he impact of environmental quality components on residential location depends on the shape and history of the cities and on the relative scarcity of the environmental attributes."

Type§	Citation	Location	Scope ^a	Indep. Variables	Representative Results/Conclusion(s)©
B	Rouwental and Van Der Straaten 2008	Denmark (3 cities)	N	“parks” “public gardens”	“[W]illingness to pay for parks and public gardens increases with income, although not as fast as that for private residential space.”
V	Sander et al 2010	Dakota & Ramsey Counties, MN	Y N	“urban tree cover”	“A 10% increase in tree cover within 100m increases average home sale price by \$1371 (0.48%) and within 250m increases sale price by \$836 (0.29%).” “In a model including both linear and squared tree cover terms, tree cover within 100 and 250m increases sale price to 40–60% tree cover. Beyond this point increased tree cover contributes to lower price.” “Tree cover beyond 250m did not contribute significantly to sale price.”
B	Sander and Polasky 2009	Ramsey County, MN	N	“views and open space access” (including “parks, trails, lakes, and streams” and “grassy land covers”)	“[S]ale prices increase with closer proximity to parks, trails, lakes, and streams.” “Increasing view areal extents as well as increasing the amount of water and grassy land covers in views also resulted in increased sale prices.” “Increased view richness in terms of the number of different land cover types in a view reduced home sale prices.” (emphasis added)
V	Sengupta and Osgood 2003	Yavapai County, AZ	Y N	“greenness”	“[I]ncreased greenness raises sale prices.” “Access to roads, cities, and neighbors also increase sale prices.”
S	Shultz and King 2001	Tucson, AZ	N	“open-space amenities”	“[L]and use is best aggregated at the block group level and...entire populations or very large sample sizes of census blocks should be used with hedonic models.”
V	Sinden 2003	Moree Plains Shire, UK	N I	“native vegetation” (under conservation restrictions)	“The Act has imposed higher costs on those who had kept most vegetation, and on those who most need to retain their options to clear and develop. Stewardship payments will alleviate the financial situation for some and property plans will provide long-term security for both farmer and vegetation.”
S	Smith et al 2002	Research Triangle Region, NC	N	“open space amenities”	“The results confirm the importance of private open space for residential home values. The estimated effects of golf courses and private vacant land suggest they may well be associated with open space amenities. As the stock of undeveloped land declined, the effect of private open space on prices changes from being insignificant to statistically significant...” (p. 127)

Type§	Citation	Location	Scope ^a	Indep. Variables	Representative Results/Conclusion(s)©
B	Standiford and Scott 2001	Riverside County, CA	N	“dedicated open space” “oak woodland”	“[B]oth land and home value decreased as the distance from the open space boundary, trailheads, and local stands of native oak habitat increased.” “A decrease of 10% in the distance to the nearest oak stands and to the edge of the permanent open space land resulted in an increase of \$4 million in the total home value, and an increase of \$16 million in total land value in the community.”
S	Tajima 2003	Boston, MA	N	“urban parks” (and “highways”)	“[P]roximity to urban open space has positive impacts on property values, while proximity to highways has negative impacts on property prices.”
S	Towe 2009	Howard County, MD	Y N	“open space”	“[I]ncreasing lot acres from approximately 1 to 4 acres per unit...would result in a 12% increase in sales price per unit.” (p. 1323) “[H]omeowners value subdivision open space in agricultural land at a statistically significant premium of 6% [to 12%] per parcel...” (Id.) “Open space owned by the homeowners’ association shows no significant effect in either model. (p. 1324)
V	Tyrvaainen 1997	Salo (district), Finland	N	“urban forest benefits” (and “watercourses”)	“Proximity of watercourses and wooded recreation areas as well as increasing proportion of total forested area in the housing district had a positive influence on apartment price. However, the effect of small forest parks was not clear.”
V	Tyrvaainen and Miettinen 2000	Salo (district), Finland	N	“urban forest amenities”	“[A] one kilometer increase in the distance to the nearest forested area leads to an average 5.9 percent decrease in the market price of the dwelling.” “Dwellings with a view onto forests are on average 4.9 percent more expensive than dwellings with otherwise similar characteristics.”
V	Voicu and Been 2008	New York, NY	N	“community gardens”	“[G]ardens have significant positive effects, especially in the poorest neighborhoods.” “Higher-quality gardens have the greatest positive impact.”

Type§	Citation	Location	Scope^a	Indep. Variables	Representative Results/Conclusion(s)©
B	White and Leefers 2007	Wexford County, MI	N	<p>“open areas”</p> <p>“forested land”</p> <p>(also streams, lakes, and rivers)</p>	<p>“Proximity to lakes and subdivision open areas positively affected the values of some parcel types, while proximity to forested land, publicly owned land, streams, and a National Scenic River did not have a positive influence. Results found in this study completed in a rural setting contrast with the results of other studies completed in suburban and urban settings.” (emphasis added)</p>
V	Willis and Garrod 1993	United Kingdom (multiple sites)	N	<p>“woodland”</p>	<p>“[S]pecific environmental variables such as trees...added a statistically significant amount to house prices.”</p>
S	Wu et al 2004	Portland, OR	N I	<p>“open space”</p> <p>(also “traffic congestion” and “development density”)</p>	<p>“Amenities are important: households are willing to pay more for newer houses located in areas of less dense development, with more open space, better views, less traffic congestion, and near amenity locations.”</p> <p>“A simulation analysis evaluates policy implications and indicates substantial benefits from alterations in housing patterns.”</p>



Hedonic Valuation of Residential Resource Efficiency Variables

**The Center for Resource Efficient Communities
University of California, Berkeley**