Factors explaining the adoption and impact of LEED-based green building policies at the municipal level

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Abstract

The number of green buildings certified under voluntary, third-party rating systems has been growing, as has the number of jurisdictions that require or incentivize such certification. In this paper, we use logistic and linear regression to demonstrate that for all cities in the U.S. with population greater than 50,000, there is a statistically significant relationship between the presence of a municipal green building policy and the number of registered green buildings (those still under construction), but not the number of certified buildings. We present very strong evidence that the presence of a policy is indeed leading to more green buildings, rather than demographic or other factors.

Keywords: green buildings, municipal policy, climate change, urban environmental governance

Introduction

Green buildings can be simply defined as structures designed and built to have a reduced impact on the natural environment as compared to a standard building. The flexibility of this definition has no doubt contributed to its widespread adoption by the public and private sectors. The most common green building rating system in the U.S. is the Leadership in Energy and Environmental Design (LEED) system of the non-profit U.S. Green Building Council (USGBC). While this rating system was designed to be voluntary, the USGBC has the explicit goal of transforming the way the building industry operates through incorporation of these standards into designers' and builders' practices. Furthermore, as of the end of 2010, there were over two hundred jurisdictions within the U.S. that either mandated or provided incentives for LEED-certified (or certifiable) buildings for some or all of their structures. As this paper demonstrates, these policies *are* having a positive effect at the municipal level in terms of producing more green buildings.

The goal of this research was to answer three questions. First, what factors explain the adoption of LEED-based policies at the municipal level? Second, do the same factors explain the number of LEED-certified buildings within individual cities? Finally, is there evidence that the promulgation of green building policies is, in fact, leading to more green buildings? (Throughout, we use the terms "green building" and "LEED" interchangeably because of LEED's dominance in the US context, even though LEED is only one of multiple certification systems.) Using logistic and linear regression analysis, we find partial answers to the first two questions, centering on personal and municipal networks of green building activity. We also find that while there is no significant relationship between the presence of a green building policy and the number of certified or completed green buildings, we *do* find that the presence of a green building policy significantly explains the number of registered green buildings, which includes those still under construction and therefore not yet certified. As most of the policies we studied are only a few years old, this finding is highly encouraging, as it suggests that policies are leading to more green buildings and not the other way around.

Our results contribute to the growing literature on urban environmental governance and the role of municipal policy in responding to climate change (e.g., Andonova and Mitchell 2010, Bulkeley 2010, Portney 2013). We focus on an area of municipal policy that overlaps with this work, as green buildings are about more than energy consumption, but also water and materials consumption, waste generation, and indoor environmental quality. Nevertheless, green buildings also represent a concrete step towards increasing energy efficiency and are justified by many public and private building owners for that reason. Similar to previous research (Mason et al. 2011), we found a significant and positive relationship between a city being a signatory to a climate compact and having either a green building policy or more green buildings, at least in some cases. This suggests that green buildings represent one aspect of policy contributing to urban sustainability through material changes in the built environment.

In the following section, we introduce the theoretical literature on urban environmental governance, along with more empirical studies on the connections between municipal policy and environmental issues such as climate change and urban sustainability. We then provide more detail about green buildings and LEED certification. Drawing on the empirical studies, we then discuss the variables we chose to consider, along with our research design and methodology. We present our results from logistic and linear regression analysis and discuss their implications for cities and planners, concluding with recommendations for further research.

Literature review and background

Urban environmental governance

The shift from national-level to municipal-level environmental governance has been a common theme of scholarship in planning and related fields in the last decade (e.g., Andonova and Mitchell 2010, Betsill 2001, Betsill and Bulkeley 2007, Bulkeley 2010, Koehn 2008, Kousky and Schneider 2003, Krause 2011a, 2011b, Sharp et al. 2011). Andonova and Mitchell make an important distinction between politics and governance, with the former referring to "The realm in which actors engage in contestation, collaboration, and discourse, using the power, authority, and organizational abilities at their disposal to pursue their interests (Andonova and Mitchell 2010, p. 257) and the latter "defined as the norms, rules, laws, expectations, and structures established to guide behavior with respect to specified public purposes" (*ibid.*). As we are looking at completed policies in our study, not the struggles over establishing them, we place this study (and most of those in this review) as falling into the latter category of governance rather than politics.

Bulkeley (2010) identifies three different waves of municipal policy regarding climate change: an early wave with a few participants in the early 1990s; the establishment of transnational networks such as the International Council for Local Environmental Initiatives (ICLEI) and the U.S. Conference on Mayors' Climate Protection Agreement (CPA) in the late 1990s (Betsill 2001, Bulkeley 2005); and the new wave in the 2000s with more involvement from private and non-profit organizations (Mason et al. 2011). Researchers have argued that cities take on the policy role with regards to climate change because of the failure of their respective national governments to act, but also because they can achieve benefits such as self-promotion, saving money through energy efficiency, or meeting existing local environmental goals (Betsill and Bulkeley 2004, Bulkeley 2010, Koehn 2008, Kousky and Schneider 2003).

Research on urban environmental governance is now moving from uncovering the factors that determine the presence of a sustainability or climate change policy (Brody et al. 2008, Krause 2011a) to studying how it has been implemented (Krause 2011b, Pitt 2010, Tang et al. 2010). Unsurprisingly, these studies have found that there is a gap between policy and implementation (Portney 2013). In particular, demographic factors such as income or population size seem to drive which cities sign an agreement such as the CPA, while internal factors such as staff resources or a mayor vs. city manager form of government drive the degree of implementation (Bassett and Shandas 2010, Krause 2011b, Pitt 2010, Sharp et al. 2011). One of the next steps is clearly to see what kind of material difference is happening on the ground: are climate change or green building policies making cities measurably greener? (Betsill and Bulkeley 2007, Bulkeley 2010).

After several years of research, Betsill and Bulkeley pointed out that focusing on the local or urban as the site of environmental action neglects action happening at other scales and the possible interactions among scales (Betsill and Bulkeley 2007, Bulkeley and Betsill 2005). However, subsequent studies found no statistical connection between state-level policies and local policies or implementation levels (Krause 2011, Mason et al. 2011). Nevertheless, there is significant evidence that cross-scalar initiatives do matter; the consensus is that cities are more likely to have a climate change or green building policy and have implemented it to a greater degree if more of their neighbors have (Brody et al. 2008, Krause 2011a). This has been interpreted by some as competition (Mason et al. 2011) and by others as cooperation (Bassett and Shandas 2010), but in either case it indicates the importance of a spatial perspective.

Other authors have observed the shift in urban governance from a focus on sustainable development to one on climate and carbon (Rice 2010, While et al. 2010). This eco-state restructuring (While et al. 2010) sees the new territorialization and commodification of carbon as a political-economic fix for the latest crises of capitalism. This is an important perspective as it reminds us that we need to consider not only how various levels of government are responding to the challenges of climate change, but how those levels are themselves being reconstituted as part of the new governance (Bulkeley 2010). At the same time, we need to consider how carbon reduction is being used "to legitimate certain kinds of urban interventions over others" (While et al. 2010, p. 87), even if in a good cause.

However, we should also keep in mind that these changes in urban environmental governance are not solely carbon-related. Privileging this particular aspect of environmental regulation over others such as water conservation, habitat preservation, or indoor environmental quality risks missing out on other ways in which the relationship between the state and nature is changing through policy (Rice 2010). Although green building rating systems place a heavy emphasis on energy conservation and carbon emissions reduction, they also include other elements of environmental protection. While numerous authors have observed that climate change policies are often framed as being about something else (e.g., energy efficiency or cost savings) in order to gain citizen support, these other elements have largely been considered in the literature as side benefits and not the main goal (e.g., Bulkeley 2010, Koehn 2008). Considering how municipalities are approaching the issue of promoting or mandating green buildings with their multi-faceted components therefore has implications beyond existing research on climate change and municipalities.

Certified green buildings

While the concept of green building, or deliberately reducing the environmental impact of a structure through the design and construction process, has been around since the 1800s, it is only since 1999 that it has gained significant rigor. That is when the first set of LEED rating system was developed and promulgated by the USGBC for the purpose of creating a common language and set of goals regarding the transformation of the building industry. The credits within the LEED rating system are voluntary, credit-based, and are updated every three years with input from members of the USGBC. There are other certification systems worldwide: BREEAM in the UK, Green Star in Oceania, and CASBEE in Japan are the most common, while the Green Globes and the Living Building Challenge are also present in North America.

As of the end of 2010, there were about 6,000 LEED-certified buildings in the U.S. Buildings are registered by builders or owners who intend to seek LEED certification and then must document how they have met each of the credits they are seeking. There are a few mandatory credits, such as reducing energy usage by 10 percent over a standard building, but the rest are up to the building owner to select. Once a building has been completed and its paperwork submitted, the building can become officially certified by the USGBC. Four levels of certification are possible: Certified, Silver, Gold, and Platinum. These same USGBC data indicate that about 30 percent of projects qualify at each of the first three levels, with Platinum being much more difficult to achieve.

The LEED rating system is not without criticism. One of the first widespread criticisms was that the same credits were awarded in different climatic and bio-regions without consideration of regional priorities: for example, shouldn't conserving water be rewarded more in the Southwest than in the Pacific Northwest? The most recent version of the standards started to take this into account by offering priority credits or "extra credit" for choosing the most regionally-relevant credits. Another problem is that certification is awarded at the time the building is built, and therefore does not correspond to how the building is actually used. Post-occupancy studies have found a wide variation between predicted and actual energy use; for example, a 2008 study of LEED buildings found that 30 percent were performing significantly better than modeled but 25 percent were significantly worse, some even below code (Turner and Frankel 2008). The USGBC has developed a new category of certification, Operations and Maintenance, to try to address this issue by offering additional certification at a post-occupancy stage. Other issues include the uneven value or difficulty of various credits that are nevertheless worth the same, or emphasizing the feasibility of achieving various credits rather than their measurable environmental impact.

Perhaps because most green building certification programs, or at least their widespread adoption, are less than a decade old, there has been little relatively little research on them. The *Journal of Green Buildings* is the main source of published articles, although most of these focus on technical aspects of materials or construction or provide case studies of individual buildings. There are some studies looking at state-level policies (DuBose et al. 2007, Pearce et al. 2007) or at the distribution of green buildings in relation to economic and political factors (Cidell 2009). More commercially-oriented reports focus on the outcomes of green buildings in terms of increasing inhabitants' productivity or increasing property values, while academics have started to look at the motivations for private firms to locate in green buildings (Boyle and McGuirk 20120, Gauthier and Wooldridge 2012).

In particular, the relationship between green buildings and public policy has been little explored. Retzlaff's (2009) discussion of the basics of LEED with regards to planning and policy was based on sixty cities with policies as of the end of 2007. She found three categories of policies: those that apply to municipal-owned or funded buildings, those that apply to private development, or those that are incentive-based rather than mandatory. Within city government, green building activity was housed in different locations: more than half of the cities surveyed had staff in two or more departments, including planning, building, and environment. Mason et al. (2011) recently surveyed cities with population greater than 2,500 in four states of the Pacific Northwest. A more detailed summary of their results appears below, but they found that social and institutional factors such as a private sector champion or dedicated city staff led to more green buildings in a city than did political or economic factors such as the presence of a state-level policy or the value of incentives. More recently, Lee and Koski (2012) carried out a multi-level analysis and found that while state factors do not seem to matter in the number of green buildings a city has, local factors such as population, level of education, and presence of environmental NGOs do lead to more green buildings.

Our work goes beyond existing studies in that we consider the entire U.S. (for cities with population over 50,000), and we have a complete sample rather than using survey data. Additionally, we look at both the factors that make cities likely to have green building policies *and* green buildings (including policies that offer incentives vs. mandates, and those that apply to public or private buildngs), as well as the relationship between the two. Finally, in order to answer the chicken-and-the-egg question when it comes to the presence of a policy and the number of green buildings within a municipality, we consider not only certified green buildings, but registered buildings, meaning projects that are still under construction but where the building owner has signaled their intention to seek LEED certification. We do draw on previous research to develop the variables we include in our analysis, as we now explain.

Explaining urban policy and green buildings

We reviewed the existing literature on municipal climate action, since that is where most recent work on urban environmental governance has focused, even though green buildings incorporate other elements besides climate change mitigation. Starting with the presence of a climate change policy, the literature investigates a combination of socioeconomic, political, and geographical variables that influence climate change action at the local level. Highly populated core metropolitan areas, as opposed to low density suburbs, are more likely to have signed onto the U.S. Mayor's Climate Protection Agreement (Dierwechter 2010). Following this, in the Pacific Northwest, large cities that are also signatories of the CPA tend to generate higher levels of green building production at the local level (Mason et al. 2011). Furthermore, for smaller cities, adjacency to another city with green buildings was statistically significant and positively associated with the smaller city's increase in total green buildings (*ibid.*). At the same time, state-level variables such as the presence of a state-wide green building policy have generally been shown not to be significant, and we therefore did not consider them here (Lee and Koski 2012).

Population and/or population density appear in a number of cases to be highly correlated with sustainability policies (Dierwechter 2010; Lee and Koski 2012; Lubell et al. 2009; Portney and Cuttler 2010). Lubell et al. (2009) contend that highly populated and denser cities create an increased level of development and strain on physical resources which in turn generates a need for a climate protection plan. It is unclear, however, if higher populations trigger the adoption of sustainable policies or if policy development is ongoing and policies pass after the city population reaches a critical threshold (Lubell et al. 2009).

Economic factors that are internal to a municipality play a role as well. By and large, the type of sustainability policy passed will depend on the fiscal health of a city (Lubell et al. 2009). Cities with higher per capita tax revenues are more likely to have environmental sustainability policies than those cities with lower tax revenues (Lubell et al. 2009). Sharp et al. (2011) find that perceived cost savings may motivate fiscally *stressed* cities to join a climate change organization, but those same economic limitations tend to mitigate the implementation of a local climate change initiative. Mason et al. (2011) find that while officials and planners cited the value of economic incentives for encouraging green building development, such financial incentives were in fact rarely used. The researchers theorize that this under-utilization is due to a lack of awareness about the incentives, or perhaps because developers take advantage instead of concentrating on long-term benefits to economic development. Sustainability policies may be seen as compatible with a city's efforts to make its local economy "more competitive in a globally integrated arena" (Dierwechter 2010, p. 64), but such an effort is likely a combination of multiple political, geographic and socioeconomic factors.

In terms of demographics, there is a close link between median family income, population, percent employed in manufacturing, and local nonprofit support of sustainability policies (Portney 2009). Median household income strongly correlates with local support of sustainability policies in both urban and suburban city types (Lubell et al. 2009; Dierwechter 2010). The literature also discusses the influence of "carbon sector" employment, such as that in construction and manufacturing (Zahran et al. 2010). Theoretically, employees from these sectors would be less likely to support a policy regulating carbon output. Overall, there would be less willingness in these industries to modify production processes to fit with new environmental requirements. However, the influence of these "carbon employment" sectors could be positive if new environmental policies were viewed as progressive avenues for increasing local economic development (Lubell et al. 2009).

A city's capacity to implement plans, in terms of both local knowledge and support, is an important factor in driving sustainability initiatives. Local elected officials' support for environmental protection is strongly associated with positive green building outcomes, although this may be likelier for mayoral cities as opposed to those governed through the city manager model (Lee and Koski 2012; Mason et al. 2011; Portney 2013). Such official support, along with the experience and knowledge of architects, developers, and LEED APs, also contributes positively to explaining local green building development (Mason et al. 2011). Related to experience and local support, it is worth noting that debate exists regarding the influence of a college education on environmental policy. Some studies argue that college education is a key demographic variable used to explain support of sustainability policies (Lee and Koski 2012; Lubell et al. 2009; Portney and Cuttler 2010). Others view college education as less influential on developing local sustainability policies than the economic well-being of the city (Dierwechter 2010). In our study, we find that college correlates very strongly with other variables and therefore did not include it in our final model.

Research design

Data Collection

The units of analysis in this study are U.S. cities with populations over 50,000, a total of 664. For each city, we gathered information on the number of green buildings, the presence and characteristics of green building policies, and socio-economic and demographic variables describing the city's population. The data were collected from a variety of sources, including the U.S. Census Bureau, the U.S. Green Building Council, city government websites, the Atlas of U.S. Presidential Elections, and the U.S. Conference of Mayors. These public data were accessed online, downloaded, and analyzed in Excel and SPSS. Demographic and economic data from the U.S. Census are from 2000-2002. Green building policy data are for all years through 2010, to match the 2010 USGBC list of registered and certified building projects in the U.S. We chose to concentrate on LEED-based policies for three reasons: the consistency of the rating system across the country as opposed to individual state or local programs; the availability of data from the USGBC; and the fact that LEED is by far the most commonly-used green building rating system in the country.

Dependent Variables

Our first research question asks what factors explain the municipal level adoption of LEED-based green building policies. For this question, our binary dependent variable is whether a city has a LEED policy. City policy data are from the USGBC public policy database as well as government websites. We break down the policy variable into five separate dependent variables, based on the policy requirements (for cities with multiple policies, we used the earliest one):

1. LEED policy: City legislated a LEED-based green building policy (111 total).
2. Policy mandated *plus*: Policy mandates LEED standards for some buildings and encourages or incentivizes them for others (28 total).
3. Policy mandated only: Policy mandates the use of LEED standards (69 total).
4. Building type - public *plus*: Policy applies to public as well as some private buildings (33 total).
5. Building type - public only: Policy applies only to public buildings or those that are publically funded (57 total).

We did not analyze incentive-only or encouraged-only type policies because there were insufficient cases to meet requirements for testing statistical significance. Also, our analysis excludes policies that only applied to single family residential homes because the LEED rating system for home projects varies considerably from that for commercial and mixed use (commercial/multi-family) projects.

It is important to note that *mandate* refers to whether a policy mandates the use of the LEED rating system, not whether it requires final LEED certification from the USGBC. In reading the final policies that were passed, and from interviews with city staff or officials, we found that a city may mandate the use of LEED for green building development without always requiring that the building projects achieve final certification; for example, the policy might require building owners to fill out a checklist with the credits they would have earned had they decided to seek formal certification and pay the associated fee. Alternatively, another rating system such as Green Globes might meet the policy requirements. In this study, 111 cities have a LEED based green building policy. Of these, 50 policies require LEED certification, 48 policies require buildings to meet certification standards for specific LEED levels (e.g. Silver, Gold, etc), 13 policies have a combination depending on the building type, square footage, or the LEED standard to be achieved, and 1 was unknown.

The second and third research questions investigate factors influencing the number of green buildings within a municipality. Data on the number of green buildings come from the USGBC global database of 37,053 registered and/or certified LEED projects as of December 2010. We selected the U.S. based, non-confidential projects and created two variables: registered buildings per hundred thousand residents (out of 12,709 total) and certified buildings per hundred thousand residents (out of 3,725 total). These values ranged from 108 registered buildings per capita to 0 with a mean of 10.7, and from 38 certified buildings per capita to zero with a mean of 3.1.

Independent Variables

Based on the sustainability and climate change literature summarized above, we tested three primary types of variables hypothesized to contribute to local LEED building policies: demographic, economic, and political/policy variables.

Demographic variables

Data on total population count and population density were obtained from the 2000 Census for each city, a date prior to nearly all green building policies and LEED certified buildings. The median population for our sample was 156,934 and the median density was 4,177 people per square mile. We also examined age composition as a potential factor, focusing on the percent of population age ≤ 24 and age ≥ 45 as a proxy for college towns and retirement communities. Finally, median household income was taken from the 2000 U.S. Census and is measured in dollars; the median value was $44,896.

Economic variables

Economic variables measure characteristics of a city's economy including local tax base, employment sectors, and change over time. Local tax revenue as reported in the 2002 Census of Governments refers to the total compulsory contribution exacted by a government for public purposes, excluding noncash sources. To analyze economic growth/decline in terms of employment and building activity, we computed the proportional change in civilian employment from 1990 to 2000 for each city; values ranged from -12.95 percent to 482 percent with a median value of 8.76 percent. The percentage of the population employed in construction and manufacturing were also included, since previous research has had mixed indications of their significance in sustainability policy; 2.7 percent and 6.2 percent were the median values, respectively. Finally, we used the number of LEED Accredited Professionals—those individuals who have been accredited by the USGBC as LEED experts—as a measure of the presence of the USGBC and related industries such as architecture and engineering in a city. LEED AP data were obtained from the USGBC and are based on members' self-reported location (i.e., some might have recorded their home address and some their work address). Values ranged from 0 to 5.5 APs per thousand with a median of 0.667.

Political/policy variables

As a measure of general political climate, data on the percent who voted Democratic by county from the 2000 General Election (U.S.) were obtained from the Atlas of U.S. Presidential Elections (David Leip, www.uselections.org). We recognize the scale mismatch between these data and our unit of analysis (city), but since only a few cities in our study share the same county, and our cities are generally fairly large, we felt confident in using the county scale data to represent patterns at the city level. The lowest percentage was 14 and the highest was 80 with a median of 50.6. Second, we identified cities that signed onto the Mayor's Climate Protection Agreement from the listing at the U.S. Conference of Mayors website as of the end of 2010. Finally, we used ArcGIS to calculate the number of cities within 50 miles that had a green building policy; values ranged from 0 to 29 with a median of 3.5.

Methods

Test for multicollinearity

Before estimating the regression models, the independent variables were tested for multicollinearity. Based on bivariate correlations, we noted that percentage of the population with a college degree correlated highly with median household income (0.666) and LEED APs per thousand (0.581), so we decided to remove college from the models. We also assessed the tolerance and Variance Inflation Factors (VIF) for the independent variables using a tolerance cutoff threshold of 0.10. In running our models, most VIF values were close to 1, and we interpreted with caution variables that exceeded a 5.0 value.

Logistic Regressions for binary dependent policy variables

Logistic regression is used to determine which factors are related to cities' enactment of green building policies. The logistic regression produces a set of coefficients that measures changes in the odds ratio, which are in turn typically interpreted as *estimates* of the resulting odds ratio (Hair et al. 1998). We used logistic regressions for our each of our dependent policy variables, with values coded as 1 for yes and 0 for no. Positive coefficients indicate an increase in the probability of an event occurring (a city having a green building policy) and negative coefficients are interpreted as a decrease in the likelihood of that event occurring. Given the exploratory nature of the study, variables were entered in the models using a forward selection method based on partial likelihood estimates.

The logistic regressions test the predictive capacity of our independent variables using different combinations of policy and building types as dependent variables. The first model examines the likelihood that a city has any type of policy. We then test for each of the following as compared to all cities: 1) cities that have policies that combine mandated with incentivized LEED requirements; 2) cities that have a policy that only mandates LEED requirements; 3) cities with a policy that applies to public buildings in combination with other private building types such as commercial or multi-family residential; and 4) cities that have a policy that applies only to public buildings. Policies that only provide incentives for using LEED or only apply to private buildings were both too few in number to analyze separately.

Linear Regression for registered and certified buildings

For the multivariate linear regressions to explain the number of green buildings per city, we used a stepwise estimation method. This method selects the independent variable with the most predictive power and adds additional independent variables if they have statistically significant partial correlation coefficients. That is, as long as an additional independent variable explains variation while the effects of the variables in the model are held constant, the independent variable will be added. This method removes variables from the model if their predictive power drops to a non-significant level once another independent variable is added. In these models, policy types were included in the model as independent variables to test the added influence of LEED policy type on registered and certified buildings per capita.

Results and discussion

We began this paper with three questions: what factors explain the adoption of municipal LEED-based policies, what factors explain the number of LEED-certified buildings within individual cities, and is there evidence that green building policies lead to more green buildings? In this section, we discuss our findings and the answers to these questions, concluding with our strong evidence that the answer to the final question is yes.

Presence of LEED building policies

Here we present the results of the logistic regressions for five different models: whether a city has any LEED-based green building policy, whether a policy includes more than incentives, whether a policy is only a mandate, whether a policy applies to more than private buildings, or whether a policy applies to only public buildings. All five models met the statistical significance criteria ($p \geq 0.05$) for overall goodness of fit based on chi square values.

Any Policy

[Table 1 around here]

In terms of the individual independent variables, we find that LEED APs per thousand, population, and LEED cities within 50 miles are statistically significant ($p < .05$). Holding the remaining independent (predictor) variables constant, the odds of a city having a policy are more likely with higher population, more LEED Accredited Professionals, and more neighbor cities with a LEED policy.

Policy Mandated Plus (required with incentive and/or encouraged)

Looking at cities that have a combination of mandated with incentivized and/or encouraged LEED policies the logistic regression model is statistically significant overall, but the supplementary R^2 statistics show a weaker predictive ability than that of the previous model. Total population and the number of neighboring cities with LEED policies remain significantly associated with this combined type policy. In addition, tax revenue enters into the model with positive coefficient and a p value of 0.074. Although just outside the 0.05 significance level, this begins to suggest that cities must know—or believe—they can afford green building investments in the first place, whether through incentives or directing capital improvement projects to meet LEED requirements.

Policy Mandated Only

Population, LEED APs per thousand, and number of LEED cities within 50 miles remain positively related to having a LEED policy, but in this case specific to a *mandated* policy. Unlike the previous models, we find that a city with a signed climate agreement is almost three times more likely to have a LEED policy if that policy is mandate-only.

Building Type: Public Plus

As with the model of "required plus," the influence of LEED APs and having signed a climate agreement drops out. Increases in total population and number of LEED cities within 50 miles still increase the odds that a city will have a policy that applies to both public and private buildings.

Building Type: Public Only

With policies that apply *only* to public buildings, the influence of a signed climate agreement remains positive and strong: the odds of a city having a LEED policy applying to public buildings only is 2.34 times higher in cities with signed climate agreements. The odds also increase with the local presence of more LEED APs, but it is the only time that the number of cities with a LEED policy within 50 miles drops out of a model. Population remains an important predictor: larger cities are more likely to adopt public-only LEED building policies than are smaller cities.

As Table 2 shows, only four of the variables tested had a significant impact, all positive. [Table 2 around here]. Clearly, larger cities are more likely to have a green building policy; this matches previous findings about the greater resources that large cities can draw on in developing environmental policy (Dierwechter 2010, Lee and Koski 2012; Lubell et al. 2009, Mason et al. 2011, Portney and Berry 2010). There was a significant relationship between the number of Accredited Professionals in a city and the presence of a policy, suggesting that the USGBC is doing well at furthering its own interests in getting its members to advocate its rating system, or that the visible presence of more green buildings encourages professionals to seek USGBC accreditation. This connection held most strongly for policies that were strict mandates and/or only applied to public buildings. As this combination is often the first round of policymaking, it suggests that LEED APs are particularly active or influential within city government.

Peer pressure seems to be a significant motivation for enacting a green building policy. Having more cities within fifty miles with a policy generally made a city more likely to have a policy. Reading the texts of the policies themselves confirms that for public-only policies, a city is frequently starting with a public sector demonstration project as a means of establishing that the benefits outweigh the costs. In this case, they do not need to be looking to other nearby successful cases for justification because they are trying to prove internally that the public sector can be a model for the private sector. However, having LEED policies in nearby cities might be a motivation to move beyond the relatively limited scope of public-only policies to incorporate a wider range of building types in subsequent rounds of policymaking.

Another interesting finding is that having signed a climate protection agreement makes a city more likely to have a green building policy, but only if that policy is a strict mandate or applies only to public buildings. It seems likely that establishing a green building policy is something that signatories to a climate agreement can point to as a concrete step towards implementation (Krause 2011b; Lee and Koski 2012; Mason et al. 2011; Pitt 2010). It also explains why only a fairly narrow policy that mandates the use of LEED rating system for public buildings is significant: the mandate is necessary to indicate seriousness about climate protection, but making it apply only to public buildings makes it more likely to be approved. This raises interesting questions about who these policies expect the major actors on climate change to be—city staff, developers, or residents.

Linear Regressions

Overall Results

In order to test the role of certain types of policy in producing green buildings, we ran linear regressions with the same five types of policies as in the logistic regressions above, encoding them as 0 or 1, this time as independent variables. We also ran separate models to predict the number of certified and registered green buildings; as a reminder, all certified buildings were registered first, but not all registered buildings have achieved certification yet. For all models, we find an adjusted R^2 of between 0.508 and 0.560, suggesting fairly strong explanatory power. In our description of the results, we divide the models between those explaining the number of registered buildings and those explaining the number of certified buildings, and then discuss the meaning of these findings in the following section.

[Tables 3, 4, and 5 here]

Registered green buildings

The socioeconomic variables of population density, manufacturing, and construction negatively relate to the number of registered buildings for a city having any policy and a city having a policy applying to a mix of public and private buildings. However, the individual explanatory power of these variables is minimal, even though they are statistically significant ($p < .05$). We find that LEED APs per thousand is statistically significant and highly predictive of registered green buildings regardless of the policy variable introduced into the model. Finally, we see that both age variables are important predictors of registered buildings, particularly when policies are required and when applied only to public buildings.

Certified green buildings

In examining predictors of certified green buildings, we see a different explanatory pattern. First, having signed a climate agreement is statistically significant with having more certified green buildings. Second, although minimal, manufacturing is significant, but in this case, the relationship explained is positive rather than negative as with the registered models. Both a younger than average and an older than average population are statistically significant in every model predicting the numbers of certified green buildings, although the relative influence of the age variables changes depending on the policy variable entered into the regression. Once again, LEED APs per thousand is a highly important variable.

For our second research question, the factors that explain the number of registered and certified green buildings within a city, the results are more complicated, as Table 6 summarizes. In explaining the number of green buildings within a city, the number of LEED APs was by far the most important factor. Combined with its importance in predicting the likelihood of a green building policy, this confirms that the USGBC is doing well at self-promotion, or perhaps that there is a reverse effect in that more professionals are likely to seek accreditation in cities with more LEED-certified buildings. It also suggests a route for the transmission of knowledge about green building policy and practice between cities (Betsill and Bulkeley 2007). The other variable that was always significant was percentage of the population under twenty-four; ranking our sample cities by this variable finds that college towns such as College Station, TX, Bloomington, IN, Iowa City, IA, and Gainesville, FL, are driving this result. Since many of the early adopters of green building policies were universities as well as university towns, we are not surprised to see this result for both registered and certified buildings.

The percentage of the population over age 45 also turned out to be a significant predictor of the number of certified green buildings across all models, and for most categories of policy regarding registered buildings. In looking at the list of cities ranked by this variable, we find two types: older cities and first- and second-ring suburbs with an aging-in-place population, and retirement-oriented communities in Florida and Arizona. Both are driving this trend; some cities such as Sarasota and Boca Raton, FL, have as many or more green buildings per capita as the aforementioned college towns, while older, wealthier suburbs such as Newport Beach, CA, or Bethesda, MD, contributed as well.

While population density and percentage of the population involved in manufacturing and construction were only occasionally significant, and sometimes negative and sometimes positive, their influence was small and so we will not consider them in detail. Many of the top cities in terms of the percentage of the population employed in manufacturing are in the South Bay Area of California, which is one of the most active green building regions in the country. The negative coefficient for population density may reflect the fact that denser cities have less room in which to build and are therefore less likely to have new buildings of any shade, including green ones.

Recall the distinction between registered and certified buildings: certified buildings are those that are completed, while registered buildings are those whose owners have indicated their intention to seek certification. We can think of buildings that are currently certified as having been early adopters, at the vanguard of the LEED certification movement, while those that are registered are a broader group, more representative of the population as a whole. For example, having signed a climate protection agreement means a city is likely to have more certified green buildings, but not more registered ones. This suggests that these early adopter cities used municipal pilot projects to take the implementation of their climate protection agreement one step further by demonstrating material change rather than just a policy (Krause 2011b). The fact that having signed a climate protection agreement has not led to significantly more *registered* buildings, however, suggests that implementation has perhaps not progressed past those initial projects (Bulkeley 2010).

Finally, our results indicate a very encouraging finding with regards to the relationship between policy and green building activity. Namely, we found the presence of a policy to be a significant explanatory factor for registered but not certified green buildings. We were unsurprised to find no significant relationship between the presence of a policy and the number of certified buildings, as the large majority of the policies were established within the last five years. It is too soon in most of these cases for many buildings to have been completed and certified since the policy was established. However, the fact that there *is* a significant relationship between having a policy and having more registered buildings—those still under construction—suggests that the presence of a policy is, in fact, encouraging more green building activity. It also suggests that rather than demographic or political factors leading to more green buildings, as these would be the same for studying both registered and certified buildings, it is the policies themselves that are making a difference.

When we separate out the policies that apply only to public buildings, having a policy does not make a difference even to the number of registered buildings. We would suggest that this is because within a municipality, the number of public buildings is relatively small, especially as a percentage of new construction. It is therefore not surprising that a policy applying only to publicly-owned buildings does not appear to significantly increase the number of total green buildings. However, this is not to say that such policies are not important; surveys and interviews from a separate part of the research project (see Cidell forthcoming) indicated that establishing a pilot project via a city-owned building is often a first step towards instituting a more wide-ranging building program by demonstrating that green building can be cost-effective. The trick seems to be to enhance or strengthen policies over time so that they move from public to private buildings and from incentives to mandates so that activity really does spread beyond the initial pilot projects.

We also find it interesting that some of the variables which previous studies showed to be significant did not matter. Specifically, political affiliation as measured by the percentage of the population voting Democratic in 2000 was never significant. While this might be a result of the mismatch between county-level data for voting and municipal-level data for buildings, we think it more likely that political affiliation does not matter when it comes to green building policy; some of the most progressive cities with regards to green buildings and LEED-based policies (e.g., Dallas, TX, and Grand Rapids, MI) are located in some of the most conservative regions of the country. Median household income was never significant, and municipal tax revenue was close to significant only once, therefore dispelling the myth that environmental or sustainability policy is only feasible in cities with well-off citizens or a highly robust tax base. Finally, growth in jobs was never significant; since we used this variable to indicate both economic growth and an increase in the amount of building activity in general, this suggests that economic growth is not necessary to have sustainability improvements in the built environment.

Conclusion

Our findings are encouraging regarding the role of policy and planning in reducing the environmental impact of the built environment. Cities which have implemented LEED-based green building policies have produced more green buildings as a result. We can confidently say this not only because of our logistic and linear regression analyses, but because there is a significant relationship between a green building policy and the number of green buildings under construction—not the number of green buildings already completed. While other factors such as demographics, regional activity, and professional organizations also play a role, we found that a municipal green building policy *does* lead to more green buildings.

Our results confirm some of the existing research on the related topic of municipal policy and climate change, namely that larger cities with a younger population, those whose mayors have signed climate protection agreements, and those whose neighbors are also producing green buildings are likely to have more green buildings themselves. Similarly, cities whose mayors have signed climate protection agreements and have neighbors who have green building policies more likely to have a green building policy. This confirms the importance of urban networks both within metropolitan areas and across the country in sharing information and policy ideas, although more research is needed to determine exactly how those networks lead to the spread of specific policies.

However, we also had some different findings than previous work, namely the unimportance of local electoral politics or wealth (either at the household or municipal level), suggesting that green building activity is not like typical urban environmental policy in its correlation with Democratic or wealthier communities, perhaps because of the economic as well as environmental gains to be had from more energy-efficient buildings. This finding is encouraging in that it indicates a wider spread of this particular type of environmental policy beyond traditional strongholds of environmentalism. Finally, in looking at green buildings rather than at sustainability or climate change, we also found the key importance of USGBC-accredited professionals in promoting green buildings and policies thereof, indicating the importance of not only local champions but nationwide organizations promoting their standards and methods.

There are some limitations of our study to consider. First, we only looked at cities with population greater than 50,000 in order to ensure a manageable and complete set of data.

Looking at smaller communities might, for example, change the effect of neighbor cities or of population. Second, our definition of "green building" is based on USGBC certification, and so it should not be surprising that individuals accredited by that same organization would play such a strong role. If there were an alternative certification standard that was equally widespread, we could include it in future research. For now, "green building" and "LEED" are virtually synonymous in the private and public sectors, although this also raises interesting questions about the role of third-party organizations, standards, and rating systems in urban environmental governance. Finally, while we argue that this is a case of policy promoting environmental benefits, we have only made the connection between the promulgation of a policy and its direct effects in terms of producing more certified green buildings. The connection to physical environmental improvements remains to be made via analysis of energy and water usage, indoor environmental quality, waste reduction, and other post-occupancy measures across the urban landscape.

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Predictor Variable	*B*	*S.E.*	*Wald*	*df*	*Sig.*	*Exp(B)*
Cities with any LEED-based green building policy						
LEED APs per capita	1.184	.168	49.439	1	.000	3.267
Population	.260	.047	30.868	1	.000	1.297
LEED City within 50 Miles	.119	.018	42.033	1	.000	1.127
Constant	-4.026	.301	178.638	1	.000	.018
Cities with a LEED-based green building policy with both mandates and incentives						
LEED City within 50 Miles	.077	.023	11.265	1	.001	1.080
Population/50K	0.075	0.025	9.352	1	0.002	1.078
Tax Revenue	.000	.000	3.200	1	.074	1.000
Constant	-4.445	0.413	115.681	1	0	0.012
Cities with a mandated LEED-based green building policy						
Signed Climate Agreement	1.069	.377	8.045	1	.005	2.911
LEED APs per capita	1.059	.163	42.329	1	.000	2.884
LEED City within 50 Miles (n)	.070	.018	14.227	1	.000	1.072
Population/50K	.064	.024	7.081	1	.008	1.066
Constant	-4.377	.387	128.198	1	.000	.013

Cities with a LEED-based green building policy for public and private buildings						
Population/50K	.108	.039	7.930	1	.005	1.115
LEED city within 50 Miles	.081	.020	15.635	1	.000	1.084
Constant	-3.655	.281	168.783	1	.000	.026
Cities with a LEED-based green building policy for public buildings only						
LEED APs per capita	1.142	0.17	44.987	1	0	3.132
Signed Climate	0.854	0.42	4.125	1	0.042	2.349
Popdivided50K	0.075	0.025	9.352	1	0.002	1.078
Constant	-4.445	0.413	115.681	1	0	0.012

Table 1. Logistic regression results, with presence of a policy as the dependent variable. N=562.

	Any policy	Mandate +	Mandate	Public +	Public
Population	+	+	+	+	+
Others w/in 50 miles	+	+	+	+	
LEED APs	++		++		++
Signed climate pact			++		++

Table 2. The influence of various factors on the likelihood of a city having a green building policy.

	City Has Policy	
	Registered	Certified
Variable	*Standardized Coefficient (B)*	
Pop Density	-0.1	
Manufacturing	-0.07	.060
Construction	-0.095	
Under24PerThous	.119	.215
Over45PerThous		.113
Signed Climate		.086
LEEDAPsPerThous	.665	.777
Policy Variable (see column headers)	.109	
Rsq	0.531	0.564
Adjusted R sq	0.526	0.56

Table 3. Regression results, with total number of registered or certified green buildings as the dependent variable and presence of a city policy as an independent variable. N=562.

	Policy Mandated Only		Policy Mandated +	
	Registered	Certified	Registered	Certified
Variable	**Standardized Coefficient (B)**		***Standardized Coefficient (B)***	
Pop Density				
Manufacturing		**.083**		.083
Construction				
Under24PerThous	**0.259**	**.215**	0.271	.215
Over45PerThous	**0.132**	**.113**	.148	.113
Signed Climate		**.086**		.086
	.753	**.777**	.0.75	.777
LEEDAPsPerThous				
Policy Variable (see column headers)			0.091	
Rsq	**0.51**	**0.564**	0.519	0.564
Adjusted R sq	**0.508**	**0.56**	0.515	0.56

Table 4. Regression results, with total number of registered or certified green buildings as the dependent variable and presence of a city policy mandate as an independent variable. N=562.

	Building Type: Gov Only		Building Type: Gov +	
	RegPerHT	CertPerHT	RegPerHT	CertPerHT
Variable	***Standardized Coefficient (B)***		***Standardized Coefficient (B)***	
Pop Density			-.095	
Manufacturing		.083	-.070	.083
Construction			-.091	
Under24PerThous	.259	.215	.117	.215
Over45PerThous	.132	.113		.113
Signed Climate		.086		.086
LEEDAPsPerThous	.753	.777	.706	.777
Policy Variable (see column headers)			.086	
Rsq	0.51	0.564	0.529	0.564
Adjusted R sq	0.508	0.56	0.524	0.56

Table 5. Regression results, with total number of registered or certified green buildings as the dependent variable and presence of a city policy that applies to public buildings as an independent variable. N=562.

	Any policy		Mandate +		Mandate		Public +		Public	
	Reg.	Cert.	Reg.	Cert.	Reg.	Cert.	Reg.	Cert.	Reg.	Cert.
LEED APs	++	++	++	++	++	++	++	++	++	++
< 24	+	+	+	+	+	+	+	+	+	+
> 45		+	+	+	+	+	+	+		+
Signed climate pact		+		+		+		+		+
Policy	+		+		+					
Manuf.	-	+		+		+	-	+		+
Pop'n density	-						-			
Constr.	-						-			

Table 6. The influence of various factors on the number of green buildings in a city, based on the type of green building policy.