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Green Buildings: Economics and Policies

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Introduction

Green building has received increased attention over the past decade from both environmental economists and policymakers. While there is no single definition of "green buildings" or its related policy, researchers and organizations tend to emphasize resource efficiency in building and reducing the impacts of buildings on human health and the environment. Thus a growing array of building sector policies have been implemented in the United States and other countries aimed at energy efficiency and reducing environmental impacts of the structure or site.

This article presents an overview of green building economics and policies through a survey of the theoretical and empirical evidence concerning green buildings. To bound our review and to reflect the importance of life cycle and nonenergy impacts of green buildings, we focus on *whole-building* investments. Green buildings are supported by a suite of policies, including voluntary and mandatory programs, that affects the entire life of the building, from design and construction to operation and deconstruction. Thus we distinguish green building policy from component-level policies to promote energy efficiency, including appliance standards, building codes, and other technology-specific regulations, and more general policies that affect buildings indirectly (e.g., wetlands offset policies, antisprawl policies).

In the next section we provide additional background and definitions concerning green building programs and policies. This is followed by a review of market failures and other barriers that have given rise to green building, and empirical evidence on the impacts of green building policies. Then we describe green building policies in the United States and evidence concerning their effects, and we briefly review initiatives in other countries. We conclude with a discussion of the challenges for the empirical study of green buildings and identify priorities for future research and policies in this area.

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Green Building: Background and Definitions

Green buildings have proliferated as a network of governmental, nongovernmental, and private actors seek to address the environmental and human health impact of the entire life of a building, from construction to deconstruction. Voluntary building certification programs reduce the costs of acquiring information about a building and, by using a third-party certifier, credibly verify the environmental performance of a building. There are two related economic rationales for green building and related policies: to encourage firms to internalize externalities (Kingsley 2008) and to encourage the private provision of a public good (Kotchen 2006). A key strategy of voluntary building certification programs like the United States Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) is to tie a set of private benefits to public good production by program participants via a "club good" approach (Potoski and Prakash 2009). That is, by *building* green, a developer averts environmental damage; by *certifying* green and joining the "club," a building owner signals quality to stakeholders (such as tenants and customers) to obtain a premium for his product. Organizations may be able to capture economic value by certifying hard-to-observe operational improvements.

Rather than stipulating specific standards or technologies, green building certification programs allow for the adoption of customized solutions for individual buildings. This flexibility is a key feature of green building programs. Certification programs, such as LEED, offer a menu of building technologies and construction practices, including Energy and Atmosphere, Water Efficiency, Materials and Resources, as well as other categories. Builders earn credits by fulfilling certain criteria across a range of categories to achieve a tiered certification of the life cycle impact of a building (Certified, Silver, Gold, and Platinum). However, green building certification programs often do not disclose specific building improvements or individual credits. This flexibility also means that the evaluative criteria for green building spans multiple categories of environmental and human health impacts, leaving the definition of what constitutes a green building ambiguous.

The Economic Rationale for Green Building Policies

In this section we detail the theoretical motivations for building green buildings and adopting green building policies. Motivations to build green include improved building performance and marketing opportunities. Green building policies and programs address market failures, such as asymmetric information and negative externalities.

Market Benefits of Green Building and Certification

There are numerous performance advantages of green buildings that arise from more efficient and more sustainable operations. Kats (2003), Singh et al. 2010, and Turban and Greening (1997) are among those showing that enhanced performance can come from energy efficiency, water efficiency, higher-quality outputs, and improved employee productivity (and retention and recruiting). The operational cost savings and improved productivity can enhance the structure's asset value in resale or rental markets. There may be other direct benefits to owners of green buildings if the owner is able to derive economic value from the provision of positive externalities through green marketing opportunities or appealing to other environmentally minded stakeholders. If the green building improves a firm's reputation and yields greater demand for its products, then that firm may capture value from its building's green cachet.

Green buildings may provide other benefits to their owners, including serving as a hedge against climate, regulatory, or other environmental risks. Moreover, less reliance on inputs with volatile prices, like water and energy, can reduce a firm's risk exposure (Jackson 2010). For example, Kahn and Kok (2014b) show that the premium for green-certified homes in California is enhanced by climate-related shocks. While newer and high-quality commercial buildings may consume more energy overall than the existing building stock, these buildings are less sensitive to weather shocks (Kahn, Kok, and Quigley 2014). Deng, Li, and Quigley (2012) show that investments in Singapore's Green Mark certification for sustainable buildings paid off when environmental regulations were tightened. Beyond-compliance behavior may also curry favor with regulators (Coglianese 2001),[1] as well as with green consumers or other stakeholders.

Market Failures

Despite the many potential benefits of building green, there are key market failures that cause the market to systematically underproduce green buildings. These market failures include information asymmetries and externalities. The trend towards green building can be understood as an effort to better align the private costs of buildings with their social costs (Kotchen 2006; Potoski and Prakash 2009; Fuerst, Kontokosta, and McAllister 2014; Allcott and Sunstein 2015).

Information asymmetries

There are often information asymmetries associated with green buildings, leading to the underprovision of difficult-to-observe building attributes. Builders have a better understanding of the construction process than building owners, and building owners or occupants have a better understanding of its design and performance features than potential buyers or tenants. In particular, building qualities like efficiency and indoor air quality are difficult to detect and verify prior to purchase or lease, which makes buildings akin to an experiential good, whereby the quality of the product cannot be observed until after consumption. This means that building owners may not have good information about the future value or operating costs of a greener building (Patel and Chugan 2013). Furthermore, some green qualities (e.g., sustainable material sourcing, construction waste diversion) are impossible to observe even after occupation, making buildings a credence good. The certification process can verify such difficult-to-observe improvements to building performance (Mason 2012; Fuerst, Kontokosta, and McAllister 2014) and its footprint, which might include energy efficiency, indoor air quality, or construction processes.

Detecting building quality is difficult for many stakeholders. The green building literature has, at various times, referred to building buyers, tenants, and employees (Singh et al. 2010) as well as the owning firm's customers and investors (Eichholtz, Kok, and Yonder 2012; Chegut,

[1]For example, the city of Atlanta's energy benchmarking program exempts reporting requirements for LEED 4.0 buildings.

Eichholtz, and Kok 2014; Kahn and Kok 2014a) as being stakeholders who might value the green building signal. Moreover, Chegut, Eichholtz, and Kok (2014) suggest that pressure from institutional investors, who more strongly believe in the cost-effectiveness of energy efficiency upgrades, may lead developers to invest more heavily in energy efficiency investments.

The difficulty in detecting information about building quality can lead to a "market for lemons" in green building construction (Akerlof 1970), whereby low-quality (traditional) buildings crowds out the high-quality (green) buildings and deter new investment in green buildings. This issue provides the motivation for the primary policy tool for promoting green buildings: certification programs such as LEED. Certification programs seek to provide signals to enable those who make the investments in green buildings to recoup their expenses and enjoy a premium, which might be in the form of higher rental or sale prices for the property.[2]

To induce an equilibrium that confers premiums exclusively to green buildings, certification schemes must both clearly differentiate green buildings from other buildings and be more valuable to customers than the costs of obtaining certification. Presumably, higher, greener quality is more costly to produce (Mason 2012). For specific, tangible building qualities (e.g., installation of certain technologies, use of renewable fuels), certification schemes can verify these improvements and distinguish high-quality from low-quality buildings. For the more abstract qualities that might be signaled by green building certification (e.g., quality of management, firm's environmental commitment), less able or less committed owners will find it more costly to successfully adopt a certifiable green building (Mason 2012). However, as discussed later, it is possible that green buildings are not actually perceived as being of higher quality than traditional buildings (Scofield 2009, 2013; Diamond 2011), or that they do not cost appreciably more than traditional construction (Matthiessen and Morris 2007).

Externalities

Buildings are also a major source of pollution, and green building policies certainly target more than just general information problems. The building life cycle has many unpriced externalities related to building construction, operation, and deconstruction. For example, the construction process, including construction waste, can have impacts on air and water quality (Ding 2008; USEPA 2014). Building operation produces unpriced social costs related to energy use (which impacts air quality and water use) and storm water runoff (which impacts water quality). Site selection and site remediation affect urban development patterns and thus, indirectly, congestion, air quality, and other urban problems (USEPA 2014). Chegut, Eichholtz, and Kok (2014) find that a "gentrification effect" from green certified buildings in the United Kingdom enhances the value of surrounding, uncertified properties, indicating the presence of positive externalities from certification.

The presence of these externalities suggests an equilibrium in which markets underproduce green buildings—something likely to occur even if the information asymmetries are fully resolved. That is, although for-profit firms might respond aggressively to a signaling scheme that addresses hidden information on buildings' green qualities, they would still have little incentive to internalize their externalities.

[2]The premium might also be in the form of lower wages for employees, greater availability of financial capital, higher prices for outputs, etc.

Green building programs seek to reduce negative externalities in the building life cycle. Participants in voluntary green building programs such as LEED undertake costly private actions to produce public goods (i.e., use sustainably sourced building construction materials) and to certify operational improvements that reduce operating costs (i.e., improved energy efficiency). Membership in this green building "club" serves as a signaling mechanism to stakeholders, who more easily understand that club members have undertaken certain actions that provide positive environmental externalities (Potoski and Prakash 2005). Therefore, being part of the club reduces the stakeholders' transaction costs of distinguishing between club and nonclub members' operational or environmental behaviors (Potoski and Prakash 2005). In return, members of the "club" receive reputational benefits that nonmembers do not receive. This "club good" concept and the signaling mechanism help to address the information asymmetry and externality market failures.

Empirical Evidence on the Economics of Green Buildings

This section reviews the empirical evidence on the economics of green buildings, including evidence of financial premia attached to these buildings, the costs associated with certification, and the role of certification as a market signal.

A Premium for Green Certification?

A number of studies have found empirical evidence of financial benefits for building owners. For example, Eichholtz, Kok, and Yonder (2012) find that real estate investment trusts (REITs) that have a larger percentage of LEED-certified properties in the portfolio have a higher value and lower price volatility than REITs with a lower percentage of LEED-certified properties. Deng and Wu (2013) find that Green Mark–certified properties in Singapore command a 9.9 percent premium in the resale market, but that initial transactions command a premium of only 4.4 percent, suggesting that green certification may reduce information asymmetries in the resale market. Chegut, Eichholtz, and Kok (2014) show that buildings in the United Kingdom that are certified according to the BRE Environmental Assessment Method rent for longer contracts and at a 28 percent rental premium. They also find that green certification provides a higher premium for rental properties than for properties that are for sale, highlighting the role of certification in reducing information asymmetries and providing a low-cost way for prospective tenants to judge the overall quality of a property.

Interestingly, the financial value of green buildings does not appear to be limited to operational costs. Eichholtz, Kok, and Quigley (2013) find a premium for the sustainability certification, in addition to energy use certifications. Similarly, Reichardt (2014) finds that the price premium for LEED buildings exceeds the value of its lower operating expenses, suggesting a premium for "sustainability" or market advantages that goes beyond reduced operating expenses. Note that Chegut, Eichholtz, and Kok (2014) find that market premiums on green building certification deteriorate as more nearby buildings certify, indicating that late adopters will gain less premium for certification.

Costs and Cost-Effectiveness of Investments

There is very limited rigorous empirical evidence regarding the cost and cost-effectiveness of investments to achieve green building certification. The generalizability of cost estimates is limited by the flexibility of green building certification programs and the highly building-specific nature of individual investments. Although it seems intuitive that actions needed for certification or achievement of higher tiers of certification would increase building costs, in many circumstances green buildings do not appear to cost more to construct (Matthiessen and Morris 2007). There do appear to be additional costs associated with the green building certification process and other "soft costs" such as the design of the building and the modeling of its environmental footprint (Mapp, Nobe, and Dunbar 2011). However, when the full cost of a certified green building is accounted for, including search and design costs (beyond simple engineering and construction costs), lower-tier green buildings may cost only slightly more than traditional construction (Mapp, Nobe, and Dunbar 2011). This finding is consistent with hypotheses in Fischer and Lyon (2014) and Li and van 't Veld (2015), suggesting that tiered certification schemes like LEED will keep entry-level certification costs very low in order to attract builders with low willingness to pay for "green" qualities.

A Noisy Signal of Quality

Because green building certification allows for flexibility and does not entail specific technological requirements, and because each type of green building or energy efficiency label is unique, some authors have referred to green certification as a "noisy" signal of building quality (Fuerst and McAllister 2011b; Jaffee, Stanton, and Wallace 2012; Kok, McGraw, and Quigley 2012). Often the certification tier itself, rather than the building's raw score or specific improvements, serves as a market signal. In fact, Fuerst and McAllister (2011b), Deng and Wu (2013), Reichardt (2014), and Shewmake and Viscusi (2014) note significant premium effects at each tier.

Historically, green building certifications have been far more about initial quality at the time of completion than about evaluating ongoing building performance. This adds to the noise in certifying performance. Recent LEED criteria and other municipal benchmarking efforts have attempted to address this disconnect between building design and performance by mandating energy efficiency requirements, requiring the use of energy monitoring, and using other behavioral nudges to encourage building users to optimize building performance (Palmer and Walls 2015). There is limited evidence suggesting that, on average, certified buildings cost less to operate than similar but uncertified buildings (Kats 2003). Energy efficiency would appear to be a promising area for operational cost savings and central to policy efforts aimed at promoting cost-effective green building upgrades (Chegut, Eichholtz, and Kok 2014).

The ambiguity of certifications that distill the many dimensions of green buildings into a single numeric score or tiered levels raises questions about the value of these certifications to the market. The fact that consumers appear to value the building's raw certification score over its tier (Eichholtz, Kok, and Quigley 2013) suggests there is a demand for information in the face of information asymmetries. Conversely, that LEED buildings tend to score just enough points to achieve the next certification tier suggests that the supply side of the market clearly recognizes the lumpy demand for environmental cachet and the symbolic value of green signals (Matisoff, Noonan, and Mazzolini 2014).

U.S. Green Building Policies

Although private sector approaches like LEED rely on voluntary participation, federal, state, and local governments have promulgated a wide range of policies explicitly aimed at promoting green building. We focus here on policies that encourage adoption of whole-building green strategies to reduce life cycle impacts of the built environment, rather than single-characteristic policies [see Sun et al. (2015) for a review]. This section reviews the scale and scope of U.S. green building policies and briefly discusses international green building programs and evidence regarding the diffusion of green buildings.

State and Local Green Building Policies

States and cities across the United States have implemented policies that require or encourage whole-building approaches to green building. We compiled a comprehensive database of state and local policies by examining policies tracked and provided to the authors by the USGBC and lists of whole-building policies from the International Energy Agency (IEA 2015) and the Database of State Incentives for Renewables & Efficiency (DSIRE 2015). These policies, which include mandates, incentives, and symbolic gestures, are summarized in table 1.

Mandates for LEED certification

As shown in table 1, a large number of green building policies mandate LEED certification or equivalent design and performance for a particular sector. Most often these requirements apply to government buildings, as is the case for 24 states, 30 counties, and 170 cities.[3] While government procurement requirements are common at the state level, requirements for the commercial sector tend to be found at municipal or county levels. Only Connecticut, through its state building code, requires major commercial developments to achieve at least LEED Silver, although nearly 60 cities have similar requirements. Requirements that target the residential sector often do so through affordable housing programs, as in Minnesota, Washington, Maryland, and nearly 90 cities and counties. These policies do not always require certification. They may simply require design teams to utilize green strategies that would be sufficient for certification.

Incentives and symbolic gestures

Although about half of all U.S. states have a LEED requirement for at least some buildings (usually public buildings), incentive programs are also common. As shown in table 1, five states offer limited grants to cover certification costs, while ten states offer some form of state tax relief for certifying firms. Kentucky is among a handful of states that offer only symbolic gestures promoting certification (i.e., without providing financial, human, or information resources to incentivize green building).

[3]Note that at least two states—Georgia and Maine—have effectively banned LEED certification in public buildings. These actions seek to protect local timber interests (Torres 2015).

Table 1 Summary of green building policies across U.S. states, counties, and cities

	Common designs	Impacted U.S. regions				Example locations	
		States	Counties	Cities	Total U.S. population, %	State	City
Mandate	LEED/equivalent: government	24	30	170	57.77	VA	Honolulu, HI
	LEED/equivalent: residential	3	12	76	11.33	MN	Annapolis, MD
	LEED/equivalent: commercial	1	10	58	7.60	CT	Washington, DC
	GreenPoint/LEED checklist for permit	0	0	51	3.52	—	Atlanta, GA
	LEED AP required on design team	0	2	17	1.31	—	San Francisco, CA
Incentive	Grants for certification costs	5	1	14	22.60	NY	Portland, OR
	Property tax abatement, exemption, credit, rebate, or refund	10	10	11	21.08	NV	Salt Lake City, UT
	Fee reduction or rebate	1	10	46	9.16	OH	Las Vegas, NV
	Expedited permitting	1	13	48	7.97	HA	Chicago, IL
	Density (floor area ratio) bonus	0	3	54	2.70	—	Tampa, FL
	Publicity	0	2	18	1.19	—	Columbia, SC
	Height bonus	0	0	20	0.64	—	Pittsburg, PA
Other	Symbolic gestures	3	5	59	4.87	KY	Madison, WI
	Energy emphasis	34	12	42	66.72	SC	Fort Worth, TX
	Water or open space emphasis	0	2	10	0.53	—	Chattanooga, TN
	Multiple certifiers incentivized	17	14	83	46.15	IN	St Paul, MN
	Incentive tiered by certification level	3	8	37	9.18	OR	Nashville, TN
	Incentive tiered by building size	5	0	15	8.66	NM	Eugene, OR
	Incentive tiered by building vintage	0	0	2	0.02	—	Portland, ME

Note: The number of jurisdictions with each policy is presented alongside the total number of people residing within these jurisdictions as a percentage of the U.S. population.
Sources: Author calculations based on policy data provided by USGBC, IEA, and DSIRE.

There is much greater diversity in incentive structure at the municipal level.[4] Local governments employ a variety of innovative policy designs and incentives, including property tax reassessment moratoriums, green funds, parking incentives, electric bill discounts, green roof mandates, recertification requirements, and mandatory investment in any option with a positive return on investment. Development density bonuses, such as exceptional height or floor area ratio permissions, are available in more than 70 cities, and more than 90 cities offer expedited permitting or fee reductions or rebates. Finally, 25 cities have approved modest financial incentives in the form of grants and tax relief. Although these cash incentives provide very direct incentives, funding for these programs is extremely limited (Kingsley 2008).

As shown in table 1, many incentive programs are tied to the building's characteristics. The most common approach to dividing incentives by category is through the LEED certification level itself, a policy used in nearly 50 jurisdictions to encourage higher tier achievement in green building. Five states and 15 cities vary incentives with the size of the proposed building, providing more incentives for green activity in larger developments. In contrast, the cities of Portland, ME and Wilmington, OH structure their policy levels by the age of the building, targeting renovations of old and potentially less efficient structures.

Links to other planning goals

Rather than focusing solely on environmental externalities, green building policies are often linked to other urban planning goals that address market failures in other parts of the built environment. Several towns and counties emphasize green building certification as a route to smart growth or community planning (San Francisco, CA; Blaine, ID; Germantown, TN; and seven others), and a general "public benefit" (Rolling Hills Estates, CA; Milford, MI; Newcastle, WA). Others (such as several counties in the Southeast) pursue green building policies to promote job creation or economic stimulus. In other regions, particularly in the Northwest, policies have been created to mitigate problems related to affordable housing and the need to retrofit existing buildings.

Federal Green Building Policies

Federal green building policies have been scarce compared with local programs. Nevertheless, public procurement policies for high-performance buildings have been implemented through various legislation and executive orders. For example, under the George W. Bush administration, a memorandum of understanding (MOU) established voluntary guidelines in 2006 that defined high-performing and sustainable buildings. These guidelines resemble the LEED scoring system (Keller 2011). Later, in 2007, Executive Order 13423 required new federal construction to comply with the MOU. In fact, federal procurement policies often rely explicitly on LEED as a benchmark or requirement.[5] For example, the U.S. Department of Agriculture mandates LEED Silver and the U.S. Department of Energy requires LEED Gold for all newly

[4]Only nine municipalities have incentives encouraging certification but do not explicitly mention LEED.
[5]Keller (2011) describes the variation in the implementation of this MOU across agencies and the potential impacts.

constructed buildings, but the Departments of Defense and State simply encourage adherence to LEED without strict requirements for certification tiers.

In related actions, the Energy Independence and Security Act of 2007 required new federal buildings to reduce energy consumption, and the General Services Administration (GSA) was asked to evaluate certifiers and recommend the most comprehensive programs. This law resulted in the GSA recommendation that federal agencies use either LEED or a similar certification (Keller 2011). In addition, the Energy Policy Act of 2009 allocated $31 billion to green buildings and conservation.

Public procurement policies may also influence the private sector. Simcoe and Toffel (2014) found local spillover effects from public procurement of green buildings that stimulate private sector green building practices. Although these effects are identified for local policies, they suggest the potential for spillovers from federal policies. Diffusion and peer effects affect certification rates among neighbors and produce clusters of green buildings in urban areas and in states with a strong environmental ethic (Cidell 2009; Kahn and Vaughn 2009). The spillover effect observed from green government buildings to other sectors could be a sign that certification can help shift norms in the building industry, because green building practices are easier to adopt as builders follow the lead of initial certifiers (Matisoff 2015). Green government buildings and housing (see table 1) have also promoted LEED's diffusion to less affluent neighborhoods.

Impacts of Green Building in the United States

Measuring green building and LEED adoption and impacts is difficult because of differences in definitions of green buildings and heterogeneity within the LEED label itself. By some measures, less than 1 percent of the total U.S. building stock is LEED certified (Fuerst, Kontokosta, and McAllister 2014), while others found this proportion to be closer to 11 percent within high-quality office buildings (Kok, McGraw, and Quigley 2011). Kok and Holtermans (2014) later found that this proportion had grown to nearly 20% for office space in major U.S. cities. In fact, there are some estimates that up to 48% of new, commercial construction is currently "green" in terms of energy efficiency, resource efficiency, or both (Bernstein 2012).

Complicating efforts to assess green building trends is the diverse array of certification schemes. Even within the LEED label, there are separate certifications for Retrofit for existing buildings, Core and Shell for building envelopes of rental spaces, Interiors for finished spaces, and more. Most research has focused on LEED's New Construction certification because of the relative ease of understanding this designation and comparing it against other new construction. About half of LEED projects are for the other types of certifications. Yet green building's impact on total building energy demand and use depends heavily on retrofitting and renovating older building stock. Rust Belt cities like Chicago, Detroit, Milwaukee, Baltimore, and Pittsburgh are all in the top 30 U.S. cities in terms of green building adoption (Kok and Holtermans 2014), despite low population growth. LEED buildings are widely dispersed across and within U.S. cities. Nationwide, census tracts hosting new LEED construction have the same poverty rates (circa 2000) as those tracts that do not. Thus the extent of green building diffusion beyond new construction merits careful attention in the future.

Table 2 International Green Building Programs and Certifiers

Program	Home country	Sponsor	Public?	Structure
BEAM	Hong Kong	GBC	No	Tiered
BREEAM[a]	England	BRE, GBC	No[b]	Tiered
CASBEE	Japan	GBC	No	Score
DGNB	Germany	German Sustainable Building Council	No	Tiered
EEWH	Taiwan	Green Building Label	Yes	Tiered
Green Globes	Canada, U.S.	Green Buildings Initiative	No	Tiered
Green Mark	Singapore	Building & Construction Authority	Yes	Tiered
Green Star	Australia	GBC	No	Binary
HQE[a]	France	NF HQE	No	Binary
LEED	U.S.	GBC	No	Tiered
Living Building Challenge	U.S.	GBC	No	Tiered
Three Star	China	Ministry of Housing & Urban Affairs	Yes	Tiered

[a]HQE and BREEAM have announced plans to synchronize certification systems for a pan-European rating scheme.
[b]Although now privately operated, the program began as a government initiative.
Notes: BEAM: Building Environmental Assessment Method; BREEAM: Building Research Establishment Environmental Assessment Method CASBEE: Comprehensive Assessment System for Building Environmental Efficiency; DGNB: Deutsche Gesellschaft für Nachhaltiges Bauen; EEWH: Ecological/Energy Saving/Waste Reduction/Health; HQE: Haute Qualité Environnementale.

International Green Building Efforts

There are green building programs around the world, as well as organizations that certify those buildings (see table 2). Although most buildings certified under a particular scheme are located in the same country as the certifier, certification programs also certify buildings abroad. For example, the U.S.-based LEED program has certified projects in more than 150 countries and territories.

The World Green Building Council (WGBC) is an international federation promoting green building practices tailored to local markets. As shown in table 2, WGBC members run independent programs, including BREEAM, CASBEE, Green Star, LEED, and the Living Building Challenge, which are privately operated and independently financed through local GBCs or other certifiers. However, these programs often share goals or language within their scoring systems and typically have tiered certification schemes. As shown in table 2, in addition to these private certification programs, there are government-run certification programs in Taiwan, Singapore, and China.

We next turn our focus to China and India, which account for a large amount of new construction in the developing world. Table 3 summarizes the common green building certifications in China and India by region and program. In India, 275 buildings are currently certified. Although these certifications are mostly in large cities like New Delhi and Mumbai, some of India's poorest states like Uttar Pradesh and West Bengal have green certified office space. In China, the relative prominence of the U.S.-based LEED program over the Chinese-based Three Star program likely reflects pressures from foreign investors and governments. Further research is needed on the drivers of cross-border certification trends and impacts.

There is scant evidence on the global diffusion (or market penetration) of green building, especially in developing countries. However, some evidence suggests that programs in

Table 3 Green buildings in China and India, by region and program

Program (origin)	LEED (US)	BEAM (HK)	LEED (India)	Three Star (CH)	Green Mark (Singapore)	BREEAM (UK)
China (Total)	588	179	0	38	5	2
Shanghai	121	1	0	13	2	1
Beijing	56	0	0	7	2	1
Hong Kong	63	178	0	0	0	0
Guangzhou	21	0	0	7	0	0
Other	327	0	0	11	1	0
India (Total)	275	0	38	0	0	1
Mumbai	78	0	12	0	0	0
Bengaluru	47	0	4	0	0	1
New Delhi	66	0	13	0	0	0
Chennai	45	0	2	0	0	0
Other	39	0	3	0	0	0

Source: Authors calculations based on Green Building Information Gateway (or GBIG) data.

developed countries have influenced India's LEED program (Potbhare et al. 2009). Others have argued that the unique settings in which green building occurs in developing regions demand programs that are tailored to their specific environmental, social, and economic contexts (Ali and Nsairat 2009). Indeed, serious obstacles remain for promoting greener building in China (Chan, Qian, and Lam 2009) and other rapidly developing Asian countries. The diffusion of green building practices in developing countries will be especially important as demand for energy services increases in those markets.

Discussion and Conclusions: Challenges and Priorities for Research and Policy

This article has defined green building, summarized the theoretical motivations for green building, and reviewed evidence of green building policies and their impacts. Green building policies offer flexibility of implementation and often certify improvements to reduce information asymmetries between owners and consumers. This allows program participants to signal stakeholders, including investors, consumers, tenants, and employees. To the extent that firms and other organizations can capitalize on these reputational benefits through improved relationships with stakeholders, and through financial premiums associated with desired building improvements, green building certification helps align private costs with social costs. However, there has been little research that explicitly addresses how actors from different sectors use green building practices and policies. Moreover, it is unclear which potential stakeholders are the targets of these certification signals and how green building benefits transfer to them.

Understanding the origins and impacts of green building policies requires an approach that goes beyond markets with eco-labels and corporate social responsibility. The study of green buildings is further hampered by a lack of systematic evidence surrounding the cost of green building improvements (including the soft costs associated with adoption), the benefits of these improvements, the types of green building practices adopted, and the overall (including uncertified) penetration of green building practices in the built environment. We conclude with a discussion of the challenges facing researchers seeking to understand and address issues related to green buildings and some priorities for future research and policy.

Difficulty Defining Green Building Outcomes

The first challenge is that the flexibility inherent in green building programs and policies results in a lack of consensus on the outcome to be measured. Several potential outcomes include energy and resource efficiency, development density, employee productivity, and firm or building financial performance. Some researchers have used total LEED points as a proxy for total environmental performance (Eichholtz, Kok, and Yonder 2012; Matisoff, Noonan, and Mazzolini 2014), consistent with intentions of Green Building Councils. Others compare the benefits of certifying energy performance and certifying other sustainability characteristics by comparing the Energy Star rating system and the LEED certification system (Turner and Frankel 2008; Fuerst and McAllister 2011a, 2011b; Kok and Kahn 2012; Eichholtz, Kok, Quigley 2013; Reichardt, 2014). The continuous LEED building score, based on the total number of credits achieved, has been viewed as a proxy for operational performance, while the tier of certification (e.g., Silver, Gold, Platinum) has been viewed as more symbolic or marketing driven (Corbett and Muthulingam 2007; Matisoff, Noonan, and Mazzolini 2014). Given these differences in approaches, linking specific performance outcomes to specific investments remains a challenge.

Difficulties in Evaluating Green Building Policies and Programs

The great heterogeneity of individual green-certified buildings, even within certification programs, has made it challenging to evaluate the market and nonmarket benefits of green buildings. For example, although LEED is the main certifier for the majority of U.S. green building policies, 17 states and 83 cities in the United States identify other certifiers (e.g., Green Globes) as options for compliance with mandates or incentives. This flexibility makes it difficult to compare "greenness" (or any outcome variable) across buildings. Because many policies mandate only that buildings must be built to certification standards, not that they must be certified, estimates of the total number of "green" buildings are likely low.

Data Limitations

Evaluation of the performance gains from voluntary or mandatory green building programs is further constrained by data limitations. First, although some data on green buildings and policies are publicly available for certified properties, these data are likely to be real estate characteristics (e.g., square footage, building use, owner type) of building attributes; it is even more difficult to obtain data on noncertified buildings. Many researchers have relied on CoStar commercial real estate data (Eichholtz, Fuerst and McAllister 2011a, 2011b; Kok and Jennen 2012; Kok, and Quigley 2013; Chegut, Eichholtz, and Kok 2014; Kok and Holtermans 2014; Reichardt 2014). However, this often limits research to the rental market for high-quality commercial office space, which accounts for only a small part of the certified green building market. Although this sample has many desirable characteristics (e.g., homogeneous units), the data are too thin to answer questions about the motivations for and impacts of green buildings, setting up a classic trade-off between internal validity and external generalizability in green building research.[6]

Performance or outcome data, including energy and water use, are generally private or unavailable. The confidentiality of information about building characteristics and improvements, and their costs, further complicates study. Most of the evidence on green building performance and costs comes from engineering cost studies (i.e., simulations). Impacts beyond building "footprint"—those concerning the relationships among employees, the community, and the city—are the most difficult impacts to measure. Yet these are arguably the largest benefits of green building: changing how people live, work, and play. The ways that people relate to and use their buildings are heterogeneous, endogenous, and often unknown to the researcher. Energy efficiency, water efficiency, and other building upgrades are chosen by the actors who also determine energy use, water use, and other outcomes.

These data limitations are a challenge for green building research generally. While hundreds of thousands of buildings have been certified since the establishment of LEED, and tens of thousands among them are newly constructed buildings, the dataset becomes much thinner when selecting among 15 years of data, regions in the United States, and numerous building sectors. This can result in very few individual building observations in a given market. For example, Fuerst, Kontokosta, and McAllister (2014) find comprehensive CoStar data for commercial building stock show only five metropolitan areas in the United States with 100 or more LEED buildings.

Identification and Interpretation of Peer Effects

Although much of the literature has focused on the *diffusion* of green buildings (Corbett and Muthulingam 2007; Cidell 2009; Cidell and Beata 2009; Kahn and Vaughn 2009; Kok, McGraw, and Quigley 2011; Kok and Holtermans 2014; Simcoe and Toffel 2014), these types of effects are particularly challenging to identify. Green building patterns are endogenous with the demand for green products, and are difficult to separate from overall urban growth patterns. Green buildings may be spatially clustered alongside the overall clustering of new buildings, high-performance buildings, or green preferences. It is unclear whether peer effects observed in green building are driven by supply-side factors such as clustered input prices, learning by building, and contractors that choose building attributes (Cidell 2009; Kok, McGraw, and Quigley 2011), or by demand-side factors such as competition for green consumers, investors, donors, or other stakeholders with environmental preferences. Public policies may have additional effects, in both pushing certification itself and spillovers to sectors that are not required to certify (Simcoe and Toffel 2014).

As suggested by Lyon and Maxwell (2007), the administrators of voluntary programs frequently have incentives to disseminate best practices to nonparticipants as well, creating a spillover effect for nonparticipants. In fact, many projects registered with the Green Building Institute (the organization responsible for approving certification applications in the United

[6]For example, Fuerst and McAllister's (2011b) study of green signal values includes only about 100 certified buildings across the United States, with just eight Platinum buildings. More recently, Eichholtz, Kok, and Quigley's (2013) study on the economics of green building contained nearly 700 green buildings, many of which were also Energy Star certified; however, few Platinum buildings were matched with hedonic price information in their data. This can prevent separate identification of the impacts of energy efficiency versus sustainability ratings, and tiered certification versus total points.

States) appear to meet LEED requirements but never certify. As discussed earlier, many local policies require that buildings be LEED equivalent rather than certified, and local mandates for public building certification can induce adoption by private actors (Simcoe and Toffel 2014). If market transformation or the diffusion of improved building practices occurs due to voluntary programs such as LEED, then traditional evaluation approaches may underestimate the total effect of the program (Matisoff 2015). These peer effects—both generating additional certifications and diffusing green building practices—are important potential impacts of LEED that warrant further study.

Policy Directions

Numerous policies have emerged that promote green building as a means to overcome market failures related to buildings. However, to date, these policies have been incomplete at best, and most rely on mandates. Pigovian taxes and subsidies for building construction and operation have the potential to be far more cost effective than the command-and-control approaches that are typical of the construction market. For example, policies that could align these incentives to improve market efficiency include construction permitting fees, impact fees, and targeting subsidies to buildings that provide positive externalities. Designing a tax and subsidy system that accurately characterizes and quantifies context-specific costs and benefits associated with building construction and operation is far from simple. As noted earlier, several jurisdictions have taken small steps to provide these types of incentives, often relying on the point structure provided by USGBC's LEED program. Nevertheless, policymakers should be mindful of the unintended consequences of encouraging too much new (green) building on undeveloped sites rather than retrofitting existing (brown) building stock.

The implementation of the Environmental Protection Agency's Clean Power Plan, a rule aimed at reducing carbon dioxide emissions from fossil fuel power plants, provides an opportunity for firms, nongovernmental organizations, and governments to internalize the negative externalities associated with energy use. LEED buildings facing higher electricity prices tend to earn more points for energy efficiency (Noonan, Flowers, and Matisoff 2015), unlike what Jacobsen (2015) finds for Energy Star appliance adoption. This suggests that investments in green buildings may be one strategy employed by organizations to adapt to rising prices or uncertain future regulation (Kahn and Kok 2014a).

Policies may also directly target information asymmetry and split incentives (Gillingham, Harding, and Rapson 2012; Levinson 2014; Myers 2014), where building owners and tenants have different information and incentives for green behavior and investments. For example, a number of cities, including New York, Chicago, San Francisco, and Atlanta, have begun mandatory benchmarking programs that require disclosure of energy consumption in order to facilitate improved decision-making and transparency. Although certification programs such as LEED also help signal tenants about potential energy use and environmental characteristics of apartment buildings, many of these programs censor information, limiting their usefulness to tenants (Kahn and Kok 2014a).

Other policy and technological transformations may facilitate or inhibit green building. Investments in smart-grid technology that allow load management and real-time electricity pricing have the potential to reduce electricity costs associated with building operation. Similar advances in dynamic water pricing might foster consumer responsiveness to water scarcity.

Future rate reforms will dictate incentives for costly and durable investments in greener buildings. Policy reforms may alter price levels as well as volatility. Further, the moving target for certification standards may allow the very notion of what constitutes a "green" building to evolve over time. Greener buildings may take advantage of demand-side management to encourage more responsive buildings, or standards may merely reward facilities with smaller footprints. Together, these trends suggest that green building offers fertile ground for both research and new policies worldwide.

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Abstract

This article presents an overview of green building economics and policies through a survey of theoretical and empirical evidence concerning green building practices. We define green building policy as policies that affect the entire life of the building, from design and construction to operation and deconstruction. We examine the economics of green buildings in the United States, with particular emphasis on market failures in the building sector such as information problems and externalities. We also discuss how policy instruments are used to address these market failures. We present original data on the types and potential impacts of these policy instruments in the United States, along with a brief review of international green building programs. We conclude by describing challenges for the empirical study of green buildings and priorities for future research and policy in this area.