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# **Comparative Policy Study for Green Buildings in U.S. and China**

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## Executive Summary

Buildings are the largest energy end-use sector in the U.S. and a rapidly growing energy end-use sector in China. Energy consumption in residential and commercial buildings accounted for over 40% of primary energy use in the U.S. in 2012 and over 25% in China in 2011. With the growing emphasis that each country is placing on energy efficiency and climate change, green building has moved into the spotlight and gained the attention of architects, developers, and occupants in recent years. Much of the green building sector activity has centered on labeling programs, such as the Leadership in Energy and Environmental Design (LEED) in the U.S. and the Green Building Rating System in China.

LEED was established by the U.S. Green Building Council, a non-governmental body. A separate entity, the Green Building Certification Institute, was set up as a third party to handle all professional credentialing and project certification for LEED. China's programs, however, are administered by central and provincial government agencies, specifically the Ministry of Housing and Urban-Rural Development (MOHURD)'s Building Energy Efficiency and Technology Division. This key difference in the types of participating stakeholders between the two green building labeling programs is a key area of divergence.

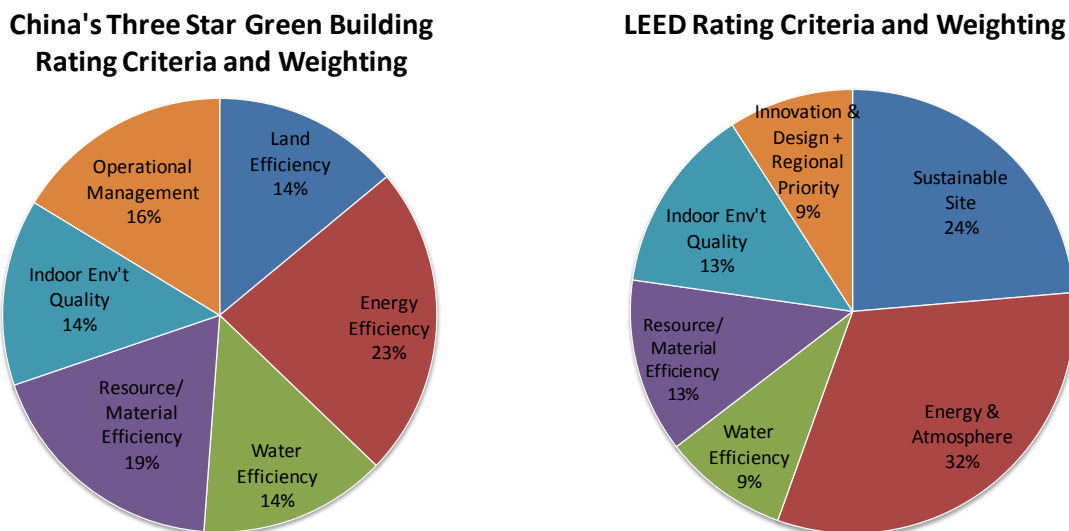
The first version of LEED's rating system LEED 1.0 was launched in 1998, followed by an updated 2.0 version with the LEED certified, silver, gold, and platinum levels of rating in 2000. As of October 2013, 19,416 projects have received LEED certification globally, with 17,270 of those projects based in the U.S. In China, the Green Building Evaluation Standard was launched in 2006, followed by the Green Building Energy Label (GBEL) in 2007. Given that it had a later start, only 494 projects have been certified with GBEL as of August 2012. Updated versions of both LEED and GBEL are expected in 2014.

LEED has nine rating systems, with new construction, existing building operations, commercial interiors, and core & shell being the most commonly used systems. The other rating systems distinguish between specific commercial building types (e.g., hotels, schools, retail, healthcare), homes and most recently, neighborhoods. LEED has four certification levels: certified, silver, gold, and platinum. For existing buildings seeking the operation and maintenance LEED certification, operating data and documentation

for a minimum of three months (longer time period needed for certain requirements) are needed. The building must be recertified at least once every five years or the operational and maintenance LEED certification will expire.

China has separate rating systems for residential and commercial buildings, but does not have specific rating systems for different commercial building types. The GBEL has separate labels for design and operations, which are valid for two and three years, respectively. While operational energy consumption data is not directly required for the operational label, the rating accounts for quality control during construction among other considerations, and the design certified green building has to have been in operation for at least one year before it can apply for the first time. China's rating system is from 1 to 3 stars, with the 3 stars rating reserved for the best performing green buildings.

Both LEED and GBEL have six categories of rating criteria, five of which they share in common: land, energy, water, resource/material efficiency, and indoor environmental quality. The sixth category in China is operational management, whereas innovation & design as well as regional priority make up the sixth category in the U.S. The weighting for the criteria is evenly spread for GBEL, but more heavily weighted on land and energy for LEED, as shown in Figure ES1. Another key difference between LEED and the GBEL is in how a building's specific rating level is determined. Under China's GBEL, the final rating is determined by meeting the minimum rating or credits within each category, whereas a LEED rating is determined by the total points summed over all categories.



**Figure ES1 Comparison of China's Green Building and LEED Rating Criteria and Weight Factors**

In addition to differences in the rating systems used for green building, the U.S. and China green building industries have different policy landscapes. Before understanding some of the different policies that each country uses to promote green building, it is important to have an overview of the barriers that green building faces, including institutional, regulatory, financial, informational, and risk barriers.

Prominent barriers facing the U.S. green building industry include the fact that government bodies that supervise health, fire safety, land, and other public operations are slow to revise codes to accommodate green building (regulatory barrier). Green buildings generally cost more to design and build due to greater system integration and the need for more building controls and measurement points. This higher upfront cost is often a big financial and risk barrier for architectural and design firms to do an integrated design for a new green building. The building industry also has many established practices that discourage various stakeholders from trying new or different approaches. Subcontractors in the construction process often view green technology as inherently risky and therefore worry about the liability of installing such technologies in projects they are ultimately responsible for.

In China, the lack of a green building professional accreditation process similar to the LEED AP process limits the green building workforce capacity development (informational barrier). While there are a growing number of institutes of building research around the country, good education on green design is not yet widespread among university architecture and engineering programs. Second, financial barriers are perhaps even more pronounced in China than in the U.S. since the industry is in an earlier phase of development. Developers cite higher incremental cost as one of the biggest barriers to investment in green buildings. Lastly, more oversight is needed in the green building industry in China to improve the quality of construction (such that it follows design requirements) and building materials (such that they perform as claimed).

The main policies highlighted in this report to tackle these barriers are 1) comprehensive codes and labeling plan (informational, institutional), 2) government-led targets and demonstrations (risk), 3) education and awareness programs (informational), 4) fiscal policy that supports green building investment (financial), and 5) integrated design promotion (institutional, financial). Table ES1 summarizes the performance of U.S. and China in each of these policy areas.

**Table ES1: U.S. and China green building policy comparison**

<b>Policy</b>	<b>U.S.</b>	<b>China</b>
<b>Codes and labeling plan</b>	Codes: States implement codes largely based off of codes developed by professional societies, compliance levels vary widely Labeling: LEED system established in 2000 is popular and growing steadily, requirements updated regularly (LEED v4 was released in Nov. 2013)	Codes: National level building efficiency codes for residential and commercial buildings, compliance occurs at design stage Labeling: GBEL system established in 2007 with uptake slow at first but now growing more rapidly, update for GBEL expected in 2014
<b>Government-led targets and demonstrations</b>	Municipal and federal level LEED building mandates helped galvanize early LEED activity	12 <sup>th</sup> Five Year Plans has requirements that 80% of new large commercial buildings will need to have GBEL rating; many cities have more aggressive targets
<b>Education and</b>	LEED education and professional	GBEL process is entirely government

<b>awareness programs</b>	development key to success; LEED committee leads come from industry and professional societies improving quality, applicability, and popularity of LEED standards	driven, with missed opportunities to involve other stakeholders; workforce development and education is lacking
<b>Fiscal policy</b>	Grants and tax credits available at local level; evidence of rent and sale price premiums for LEED buildings	Tiered incentives available for 2-star and 3-star GBEL buildings; higher upfront cost of green buildings remains a barrier
<b>Integrated design promotion</b>	Early promotion and integrated design incentives available in California	None

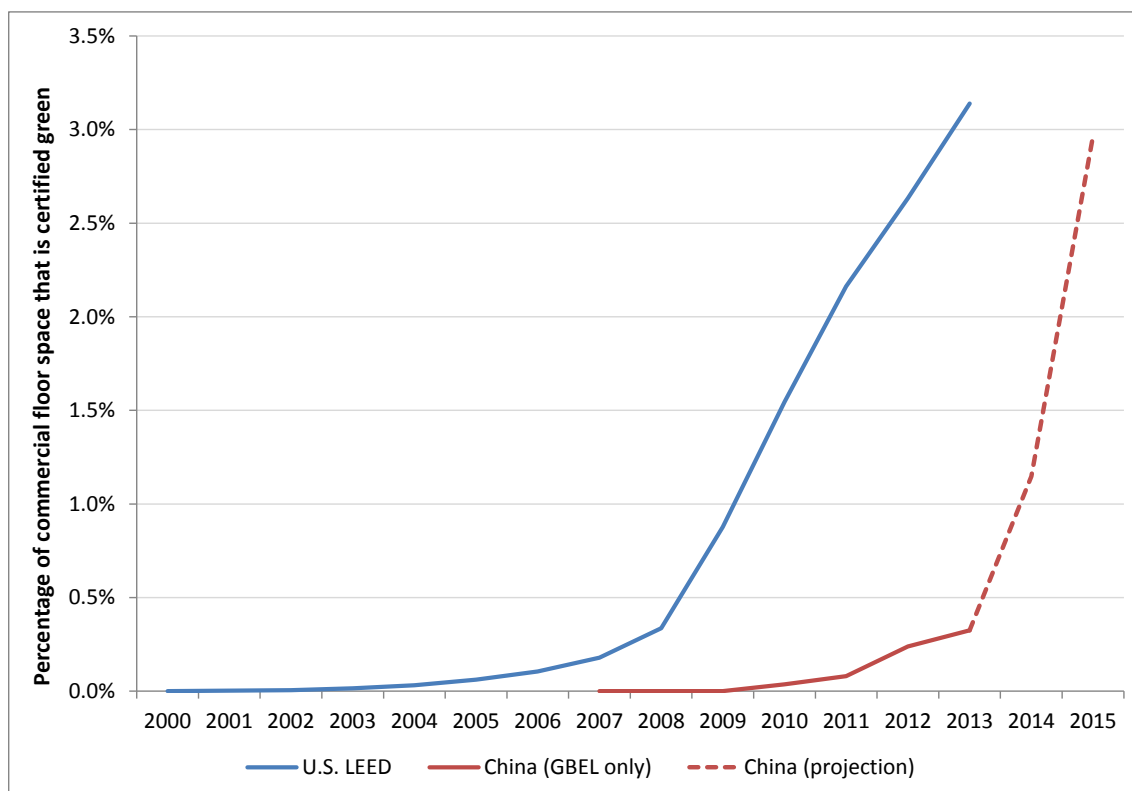
If a country updates its codes and labeling programs as technology costs fall and practice adoption improves over time and if these programs have good enforcement and compliance, then these policies will help “pull” more green construction practices into the building industry. Both the U.S. and China have comprehensive codes and labeling systems, with improvements to be made in how the programs are enforced and potentially more integrated planning for how the stringency of codes and labeling requirements can increase over time. The recent green building action plan released in China encouraged regional level implementation of codes that are stricter than national codes as well as regular and scientifically reasonable increases in the stringency of existing codes.

In the realm of government-led targets and demonstrations, this seems to be an area where the U.S. and China share some common ground. In the U.S., federal and state government agencies were early adopters of LEED standards, accounting for over 40% of LEED certifications in the early years of the program. Gradually, their adoption led to a larger market transformation (more experienced architects and builders, lower costs, fewer barriers) so that green building practices could be adopted more widely. Now, there are 14 federal agencies or departments, 30 state governments, and 400+ local governments with LEED initiatives. And indeed, LEED has grown much faster in the past four years than in the previous eight years. China is embarking on a similar approach in its 12th Five Year Plan, requiring the GBEL for 80% of all new commercial buildings, hoping that this government-led approach will stimulate activity in the wide market.

Although their approaches to government-led targets are similar, approaches to fiscal policy that supports green building investment differ between U.S. and China. In the U.S., small grants and property tax credits are used to spur LEED activity, while in China, incentives are offered on a per square meter basis to get developers interested in designing and constructing 2-star and 3-star buildings. Yet, this difference in approach may be due to the fact that first-cost premiums are much more of a barrier for the younger Chinese industry, whereas in the U.S., although cost premiums exist, evidence for higher rental and sale prices of LEED-certified buildings is accumulating quickly. LEED certified buildings can get anywhere from 5-17% higher rents and from 11-25% higher sales prices, according to one meta-analysis of several studies (Watson, 2011).

Education and awareness levels on green building practices also vary between the U.S. and China. The USGBC's larger programmatic efforts in education and professional development for LEED were key to LEED's increasing popularity over the years. Additionally, committee leads for LEED requirement development and revisions are largely from industry (developers, building materials, professional societies), which keeps the LEED requirements relevant and applicable to current best practices in the green building industry. The GBEL rating development process in China is government-driven, and perhaps, somewhat closed off from industry which may be one reason for an initial slow uptake. More professional development is needed to spur interest and abilities in using the GBEL rating system.

LEED 2.0 was launched in 2000, and about 13 years later, LEED-certified space now accounts for 3% of commercial building space (Figure ES3). In 2013, there was more than 3.2 billion square feet (~293 million square meters) of LEED certified floorspace globally, with 80% of that in the U.S. The 2 billion square feet mark was passed at some point in 2012, with the first one billion of those square feet taking 9 years to accumulate, and the second billion only taking 3 years to accumulate. Certainly, there was a phase change in the U.S. green building industry growth rate once a critical mass of industry experience had been accumulated.



**Figure ES3: Percentage of commercial floorspace certified by LEED or GBEL, with projection for China**

In 2010, China is where the U.S. was in 2004, with only about 0.1% of floorspace owning a GBEL rating, or 8 million square meters. It seems quite ambitious that China aims to have 1 billion square meters of



green building floorspace by 2015. Figure ES3 projects what such growth would look like if they were to meet that target. In 2010, only roughly 100 projects had been certified and as of the end of 2012, more than 500 projects had been certified so the industry is certainly gaining momentum. By 2013, 100 million square meters have been certified with a GBEL rating. In addition to the ambitious national target, Chongqing, Suzhou, Nanjing, Shenzhen, and other cities have all set requirements for 2015 and 2020 to have GBEL ratings on anywhere from 30-80% of new construction (varying by city). While China will have to ride some of the industry learning curves even more quickly than the U.S. (and that would entail some policy improvements), China has the opportunity to grow a green building industry even larger than that of the U.S.

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## 1. Introduction

As the world's two largest energy users and CO<sub>2</sub> emitters, China and the U.S. have placed increasing policy attention on energy efficiency. One focus area has been the buildings sector, the largest energy end-user in the U.S. and a rapidly growing end-user in China. The residential and commercial building sectors consumed over 40% of total primary energy use in the U.S. in 2012, while the residential and commercial building sectors consumed over 25% of total primary energy use in China in 2011. Buildings in the U.S. consumed 63.3 Exajoules of total energy in 2011, with the residential sector accounting for 55% of building sector energy use (EIA 2012). In China, the building sector's share of total energy consumption is expected to rise with recent astounding growth in new building floorspace driven by urbanization and sustained economic growth. Between 1990 and 2010, for example, more than 300 million new residents were added to Chinese cities while urban residential floor space per capita has tripled from 9.6 square meters per person in 2000 to 20.3 square meters per person in 2008 (National Bureau of Statistics, 2009; Tsinghua University Building Energy Research Center, 2011). At the same time, building energy consumption in China increased sharply after 1990 with total consumption more than doubling between 1980 and 2005. Buildings' share of total energy consumption in China will likely continue to rise given its relatively low share compared to other industrialized countries and its lower average energy intensity compared to international levels.

In order to improve the energy efficiency of buildings and curb growth in the sector's total energy consumption, the U.S. and China have adopted a multitude of policy instruments including building energy efficiency codes and standards, building energy rating systems and labels, and financial incentives.

In the area of building energy efficiency codes, the U.S. does not have a uniform national building energy code but the federal government has developed national model energy codes and actively encouraged state governments to adopt and implement codes at the local level. The national model code forms a baseline by providing prescriptive requirements and/or performance criteria for materials and equipment, while giving states the flexibility to tailor the model codes to local conditions as long as it meets the baseline requirements. The 2009 International Energy Conservation Code (IECC) and

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 90.1 serve as national model codes for residential and commercial construction, respectively. In addition, the IECC also provides compliance paths for commercial buildings outside of the ASHRAE 90.1 standards. As of the end of 2011, 39 states had adopted statewide residential and/or commercial building codes. China has three residential building energy codes which cover four out of the five climate zones. The residential building codes differ by climate zone and reflect the initially iterative process of Chinese building code development, which contrasts with the later centralized national code for commercial<sup>1</sup> buildings. All three design standards include a reduction target for heating energy consumption relative to some baseline and apply to new residential construction, residential building expansion or additions, and residential building retrofit projects. China's national building code for commercial buildings went into effect in 2005 and covers lighting and HVAC energy use.

Building energy labeling and rating systems in the U.S. are characterized by a diverse set of programs following a wide range of approaches, and includes voluntary labels that have gained significant market share as well as new labels introduced at the state or local level or in the pilot stage. The major voluntary building labeling programs in the U.S. include the Home Energy Rating System, ENERGY STAR for Homes and Department of Energy's Home Energy Score for residential buildings, and ENERGY STAR Buildings, the Department of Energy's Commercial Asset Score and ASHRAE Building Energy Quotient programs for commercial buildings. The residential building labeling or rating programs are primarily asset ratings based on the designed building energy consumption, while the commercial building labeling programs are based on actual operational energy consumption. In addition, green building ratings and labels – with the Leadership in Energy and Environmental Design (LEED) developed and administered by the U.S. Green Building Council as the mostly wide adopted system – have also had a growing presence in the U.S. China has two relatively new whole building energy labeling programs: the Green Building Evaluation and Labeling (GBEL) Program and the Building Energy Efficiency Evaluation and Labeling program, both of which were established by the Ministry of Housing and Urban-Rural Development (MOHURD) in 2008. The voluntary GBEL program consists of a design and operational rating label, with ratings on a scale of one to three stars based on energy efficiency, land use, water efficiency, construction material resource efficiency, indoor environmental quality, and operational management. The Building Energy Efficiency Label (BEEL) evaluates buildings on a scale of one to five stars in terms of energy efficiency, with a focus on HVAC system efficiency, compulsory standard compliance, and optional building efficiency features. The two programs are linked in that the BEEL is mandatory for buildings that apply for the GBEL program.

Lastly, in support of both building codes and building energy labeling and rating programs, both China and the U.S. have implemented a wide variety of financial and tax incentives for improved building performance. In the U.S., important financial incentives have included equipment and building rating incentives, homeowner discounts for ENERGY STAR homes, tax credits for builders of highly efficient

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<sup>1</sup> In China, non-residential buildings are officially referred to as “public buildings” and include both government-owned and operated and private commercial buildings. In this report, the commonly accepted terminology of “commercial buildings” is used instead of “public buildings” to refer to non-residential buildings in China.

homes and homeowners for upgrading building envelope components and equipment and tax deductions for new and existing commercial building owners and tenants who reduce HVAC and interior light use. In China, the Ministry of Finance and MOHURD have provided financial incentives for: decreasing total energy consumption and retrofit and renewable energy integration demonstration projects in existing government office and large-scale commercial buildings, heating reform retrofits in Northern China residential buildings, and high efficiency and renewable energy technologies for all buildings.

Together, these three sets of policy tools have built a strong foundation for improving the energy performance of new and existing buildings in China and the U.S. Within this policy context, green buildings have emerged as an important policy- and market-driven development in the building sector for further pushing the limits of energy efficiency improvements, as well as improving the broader environmental performance of buildings.

This report reviews and compares the development of green buildings in the U.S. and China in terms of the specific green building evaluation systems and their supporting technology standards, policy support, and future market development prospects. Section 2 provides an overview of building energy consumption and the role that green buildings can play in the U.S. and China, including some historical context for how the green building industry developed. Section 3 goes into detail on the U.S. LEED and China Green Building Rating and Labeling Systems, how the certification processes work, how credits and scores are assigned, and how the U.S. and China systems differ in rating method and program administration. Section 4 begins by providing an overview of the barriers to a growing green building industry and some of the common policy mechanisms being used to overcome those barriers, including codes and labeling plans, government-led targets and demonstrations, education and awareness programs, fiscal policy (incentives and tax policy), and integrated design promotion. Then, examples of each of these efforts are described for both the U.S. and China followed by a brief comparison. The report concludes with Section 5 which describes the green building market development to date in the U.S. and China, with some highlights and statistics from recent years to illustrate how the momentum of the industry is accelerating.

## **2. Overview of building energy consumption and the role for green buildings**

In order to contextualize the development and future role of green buildings in the U.S. and China, as well as the underlying factors for possible differences in green building programs between the two countries, it is important to understand each country's building characteristics and energy supply and consumption trends.

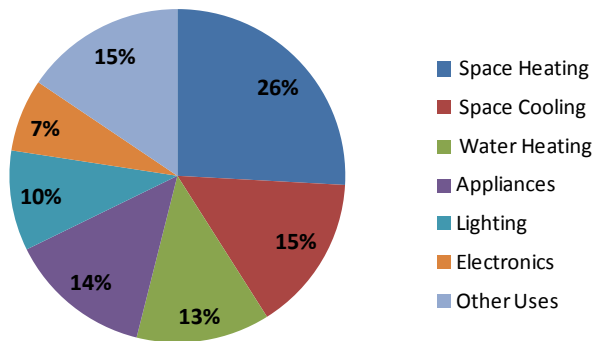


## 2.1. Building characteristics and energy trends

### 2.1.1. U.S.

In the U.S. residential building sector, the vast majority of residential building floorspace is located in urban areas (73%). In terms of climate, the U.S. DOE divides the country into five main climate regions based on temperature, precipitation and humidity: very cold/cold, mixed-humid, mixed-dry/hot-dry, hot-humid, and marine. Almost two-thirds of households are located in the very cold/cold (34%) and mixed-humid (31%) climate regions; the remaining third is split between hot-humid (17%), mixed-dry/hot-dry (12%), and marine (6%) climate regions. In all climate regions, at least 90% of homes use space-heating equipment, and at least 75% of homes use air-conditioning equipment except in the marine region where one-third of homes use air conditioning. The main space heating fuel in U.S. households are natural gas, which accounts for nearly half of all households, followed by electricity with 34% of households, and fuel oil, propane/LPG and wood accounting for the remaining 16% (EIA 2013a). As of 2009, the latest year for which there is detailed national statistical data on residential buildings, about 63% of residents live in single-family detached houses, 25% in apartments, 6% in single-family attached houses, and 6% in mobile homes. In terms of total residential floorspace, 80% are single-family detached houses, 11% are apartments, 5% are single-family attached houses and 3% are mobile homes. As a result of the large proportion of single-family houses, the majority of residential floorspace are 1 or 2-story units, with only 3% of total residential floorspace being located in units with 3 or more stories. Owner-occupied homes account for 67% of housing units; the remaining 32% are rented. In terms of building stock vintage, 40% of the total residential floorspace was built before 1970, 27% was built between 1970 and 1989 and the remainder 33% built after 1990 (EIA 2013a).

In terms of residential energy consumption, residential space heating and cooling together represented about 43% of residential primary energy use in 2010, with water heating accounting for 13% (EIA 2013b). Figure 1 summarizes residential energy consumption by end use. Natural gas is the dominant fuel used for space heating (50%) and water heating (51%), followed by electricity (34% and 41%, respectively), fuel oil (6% and 3%, respectively), propane (5% and 4%, respectively), and wood (2% for space heating). In recent decades, population growth has been greatest in the hot-humid, mixed-humid, and mixed-dry/hot-dry regions, driving increased use of air conditioning. The average delivered energy consumption per household is 108 GJ in 2010, with an average intensity of 701 MJ of delivered energy consumption per square meter.

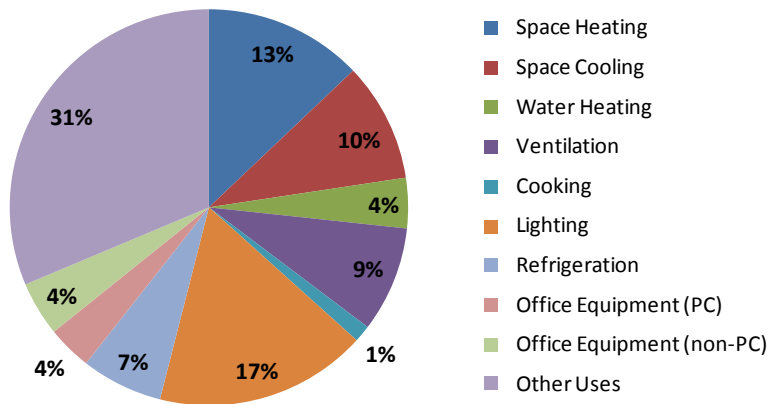


**Figure 1. U.S. Residential Building Energy Consumption by End-Use**

Source: EIA 2013b.

The total commercial building floorspace in the U.S. is more than 6.7 billion square meters, with an average commercial building size of approximately 1,366 square meters in 2003, the latest year of reported national statistical data on commercial buildings (EIA 2006). Nearly 73% of the 4.86 million commercial buildings in the U.S. are smaller than 929 square meters, accounting for 20% of the overall commercial floorspace. Another 30% of total commercial floorspace is made up of buildings of between 930 and 4645 square meters, followed by 40% of floorspace in buildings of between 4645 and 46,450 square meters. The largest buildings (46,450 square meters and larger) account for over 10% of total commercial floorspace but less than 1% of total number of commercial buildings. In terms of principal building activity, office buildings (17%), retail (16%), education (14%) and warehouse and storage facilities make up about half of total commercial floorspace. The remaining half of commercial floorspace consists of hotels, service, religious, healthcare, public space, restaurants and other commercial facilities. The vintage of the commercial building stock is similar to the residential building, with 37% built before 1970, 34% between 1970 and 1990, and 29% built after 1990 (EIA 2013b).

The 2010 total primary energy consumption of the U.S. commercial sector reached 19.3 exajoules (EIA 2013b). As seen in Figure 2 below, space heating, cooling, and ventilation account for 32% of overall energy use followed by lighting (17%), office equipment (8%), and refrigeration (7%). Other end uses make up nearly one-third of commercial building energy use; most are associated with business-specific activities that reflect different commercial-sector end uses, including service station equipment, automated teller machines, telecommunications equipment, medical equipment, pumps, emergency generators, combined heat and power in commercial buildings, manufacturing performed in commercial buildings, and cooking. As with the residential sector, natural gas is also the dominant fuel for space heating and water heating in commercial buildings, but is second to electricity in terms of the total delivered energy to commercial buildings. The average energy intensity of commercial buildings in terms of total delivered energy is 1218 MJ per square meter, or 2549 MJ per square meter in terms of total energy consumption including electricity-related losses (EIA 2013c).



**Figure 2. U.S. Commercial Building Energy Consumption by End-Use**

Source: EIA 2013b.

### 2.1.2. China

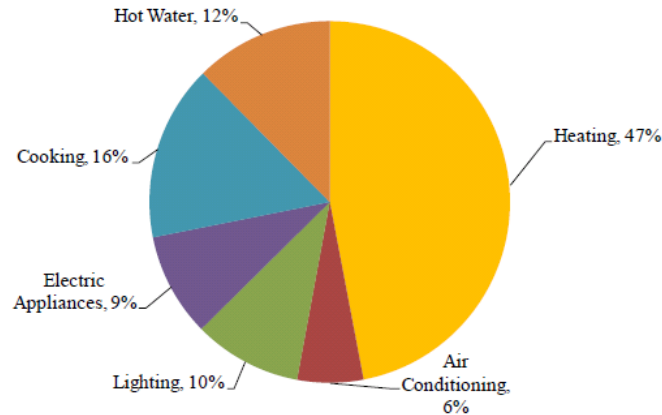
In the absence of detailed national surveys of energy consumption in residential and commercial buildings such as those conducted in the U.S., data in China on both the characteristics of residential and commercial buildings and their energy consumption data are very sparse and less detailed. Moreover, because of China's recent economic growth and urban housing reform that only started in the 1980s, most of the Chinese residential and commercial building stock is relatively new. From 1995 to 2005, the urban building stock nearly tripled to 20 billion square meters, with residential building stock accounting for 65% of the 2005 total. By the end of 2006, a majority – 65% - of existing urban buildings were built within a span of 10 years (Liu et al. 2010). In terms of building structure, urban residential buildings are predominantly multi-stories or high-rise buildings while rural residential buildings tend to be smaller single-house units. Commercial buildings are also multi-story, heavy-mass structures that are increasingly equipped with central HVAC systems.

For energy, there is the likelihood that official statistics for Chinese building energy consumption are underestimated because national energy consumption statistics are recorded and reported for the sector in which the consumption occurred, rather than by the purpose for which the energy was used. For example, residential and commercial energy consumption by buildings operated by enterprises is reported as industrial energy use, rather than building energy use. As a result, the National Bureau of Statistics reported primary energy consumption for buildings in 2008 was only 17% of total energy consumption, with a more recent estimate of 20% of total primary energy consumption by Tsinghua University and NBS (Shui and Li, 2012). However, other sources have reported buildings' share at 25% of total energy consumption (~350 million tons of coal equivalent [Mtce<sup>2</sup>]) once sectoral adjustments are

<sup>2</sup> Mtce or million tons of coal equivalent is the standard unit for energy in China and is equal to  $29.27 \times 10^{15}$  Joules (i.e., million GJ).

made to capture the total energy consumption of all buildings (National Bureau of Statistics, 2009; Zhou & Lin, 2008). Compared to the shares of around 35% in industrialized countries, Chinese buildings' share of total energy consumption is still relatively low with more room to grow (Kong, Lu, & Wu, 2011).

In terms of energy consumption by end-use, the annual research report by Tsinghua University's Building Energy Efficiency Research Center reported that over half of urban residential building energy consumption in 2008 was used for heating and cooling, followed by cooking, hot water, lighting, and appliances. Figure 3 shows the breakdown by end-use:



**Figure 3. 2008 Urban Residential Building Energy Consumption by End-Use**

Source: Shui and Li, 2012.

For commercial buildings, energy consumption differed significantly between large-sized commercial buildings greater than 20,000 square meters and common commercial buildings with less than 20,000 square meters, with average energy intensities (excluding heating) of 90-200 kWh/m<sup>2</sup> and 30-70 kWh/m<sup>2</sup>, respectively (Shui and Li, 2012).

## 2.2. Review of Green Buildings development

### 2.2.1. U.S.

The development of green buildings in the U.S. can trace its roots back to the oil crises of the 1970s, which stimulated a wave of new energy efficient buildings. This was followed by the green design of office buildings for environmental organizations including the Environmental Defense Fund and National Resources Defense Council that considered a wider range of environmental and resource benefits. The cooperation amongst different building team members for the 1992 renovation of Audubon House for the National Audubon Society later served as a working model for the national green building process. In 1992, the establishment of the Committee on the Environment by the American Institute of Architects also led to the creation of a professional body on green building issues. Throughout the early 1990s, green building efforts in the residential sector emerged across the country in different cities including Austin, Texas; Baltimore, Maryland; Denver, Colorado and the states of Washington and New Mexico.

The first highly publicized green building project in the U.S., and a driving force for later federal green building efforts, was the “Greening of the White House.” Architects, engineers, government officials and environmentalists all participate in the renovation of a 600,000 square foot historic office building across from the White House, which produced energy cost savings of \$300,000 per year and 845 tons of carbon emissions reductions per year (Furr et al., 2009).

It was also during the 1990s that the major green building rating programs were first introduced in the U.S., beginning with the founding of the U.S. Green Building Council (USGBC) in 1993. Five years later, in 1998, the USGBC launched the Leadership in Energy and Environmental Design (LEED) version 1.0 pilot program. The pilot version 1.0 of LEED was used by the Federal Energy Management Program to evaluate 18 projects with total floorspace of more than 1 million square feet (Furr et al., 2009). The USGBC released a significantly improved LEED version 2.0 in 2000, including the rating scale and four levels of building certification. Since 1994, LEED has grown from one standard for new construction to nine interrelated rating systems for new construction, existing buildings, core and shell, commercial interiors, retail, homes, neighborhoods, schools and healthcare. LEED committees, made up of architectural, engineering, design, and related professionals, develop and update each LEED rating system using an open, consensus-based process. The newest LEED rating system was introduced as recent as November 2013, but is not considered in this report because details were not released at the time of the report writing. As of October 2013, LEED has certified 19,416 projects globally, including 17,270 projects in the U.S.

### 2.2.2. China

Similar to the U.S., China’s interest in green buildings also began in the 1990s with “research on Chinese green building system” listed as one of the key funding areas of the National Science Foundation of China in the 9<sup>th</sup> Five-Year Plan in 1996. The first attempt at developing a rating system was “China’s Eco-house technical evaluation handbook” released in 2001 to help improve the eco-efficiency of Chinese buildings. This set of guidelines applies only to residential buildings and is based on site and residential environment, energy and environment, indoor environmental quality, water environment, and material and resource use (Geng et al. 2012). In 2002, a special Green Building Assessment System for the Beijing Olympics was developed and became China’s first local green building evaluation and certification system. However, these early green building guidelines and assessment systems were developed to target special building types and were not intended to serve as a national rating system.

China’s national green building efforts began later than the U.S., starting with the adoption of the voluntary Green Building Evaluation Standards (GB/T 50378-2006) by MOHURD on June 1, 2006. The national Green Building Evaluation Standard was established in 2006 with two different green building evaluation standards for residential and commercial buildings. In order to provide more specific guidance for the planning, design, construction and management for green buildings, the Technical Code for Evaluating Green Buildings was released in June 2007. This was followed by the issuance of the “Administrative Rules for Green Building Evaluation Labeling” and implementation guidelines in November 2007, which established the voluntary Green Building Evaluation and Labeling Program. In

In addition to supporting the national standard, the GBEL program is intended to accelerate the market entry of environmentally sustainable green buildings from the top down and to institutionalize green building evaluation as a common process in construction project management. In order to combine theoretical and engineering principles of green buildings more effectively and to make the evaluation result more objective and fair, the Supplementary Instruction of Technical Code for Evaluating Green Buildings: Plan and Design and the Supplementary Instruction of Technical Code for Evaluating Green Buildings: Operation and Management were released in June 2008 and September 2009, respectively. From 2008 to 2011, the number of building projects certified and rated by the GBEL program increased rapidly, from only 10 in 2008 to 20 in 2009, to 83 in 2010 and over 100 in 2011. The majority of projects were awarded the design label, with slightly more awarded to commercial building projects than residential building projects.

### 3. Comparison of Green Building evaluation systems

#### 3.1. U.S. LEED

Development of the U.S. Leadership in Energy & Environment Design (LEED) program of voluntary green building rating systems by the U.S. Green Building Council (USGBC) began as early as 1994, and was officially launched in 2000 with the first rating system for new construction. Since then, LEED has expanded into nine interrelated rating systems covering different building types and has grown from a U.S. program into a program adopted internationally by more than 140 countries and territories with the support of partner Green Building Councils abroad.

##### 3.1.1. Rating Systems

The nine LEED green building rating systems are (USGBC 2013a):

1. **New Construction and Major Renovation:** originally designed for new commercial office buildings but is now applied to other building types including libraries, churches, hotels and government buildings. This rating system addresses design and construction activities including HVAC improvements, significant envelope modifications and major interior renovation, and also takes into consideration sustainable operations and maintenance practices.
2. **Existing Buildings: Operation & Maintenance:** whole-building rating system designed for single buildings of all building types, including owner occupied and multitenant buildings. This rating system addresses major aspects of building operations, including: exterior building site maintenance programs, water and energy use, environmentally preferred products and practices for cleaning and alterations, sustainable purchasing policies, waste stream management, and ongoing indoor environmental quality.
3. **Core & Shell:** designed to be complementary to Commercial Interiors and Retail Commercial Interiors rating systems, the Core & Shell rating system is intended for projects where

developers can control only the design and construction of the core and shell of the base building and not the design construction of the tenant. Examples of buildings covered by the Core & Shell rating system include medical office buildings, retail centers, warehouses, and lab facilities.

4. **Commercial Interiors:** designed for tenants in commercial and institutional buildings that lease their space or do not occupy the entire building. This rating system is intended to be used by tenants and designers that do not have control over whole building operation but can control tenant improvements and interior renovations to improve the indoor environment, and is complementary to the Core & Shell rating system.
5. **Schools:** focuses on the design and construction of schools for kindergarten through the 12<sup>th</sup> grade, but may be used by other educational facilities such as universities, school athletic facilities. This rating system is based on LEED for New Construction, but focuses on aspects unique to schools including classroom acoustics, master planning, mold prevention, and environmental site assessment.
6. **Retail: New Construction & Major Renovation / Retail: Commercial Interiors:** designed to address unique characteristics of retail buildings such as occupancy characteristics and hours of operation, parking and transportation needs and different process water and energy consumption. Two options of new construction & major renovation, and commercial interiors are given to retail building projects under this rating system.
7. **Healthcare:** designed to address the specific needs of inpatient and outpatient medical care facilities and licensed long-term care facilities, as well as medical offices, assisted living facilities, and medical education and research centers. It modifies existing credits to create new, healthcare-specific credits.
8. **Homes:** designed for single-family homes, low-rise multi-family (one to three stories) and mid-rise multi-family (four to six stories) buildings. This rating system is designed to certify homes via third-party on-site performance testing and verification to reduce energy and water consumption, maximize fresh air indoors and minimize exposure to airborne toxins and pollutants.
9. **Neighborhood Development:** developed in collaboration with Congress for the New Urbanism and Natural Resources Defense Council, this rating system emphasizes principles of smart growth, urbanism and green building for projects involving whole or portions of neighborhoods and multiple neighborhoods. This rating system promotes smart location and design of neighborhoods that reduce vehicle miles traveled, and communities where jobs and services are accessible by foot or public transit.

These nine LEED rating systems were developed in an open, consensus-based process in three steps. First, volunteer committees, subcommittees and working groups composed of USGBC members develop a rating system in conjunction with USGBC staff. The draft rating system is then subject to review and approval by the LEED Steering Committee and USGBC Board of Directors. Lastly, the rating system has to be approved by a vote by the USGBC membership. The current status of projects under each of these LEED rating systems are shown in Table 1.

**Table 1. LEED Rating Systems and Projects to Date**

<b>LEED Rating System</b>	<b>Date Launched</b>	<b>Certified Projects to date</b>	<b>Registered Projects to date</b>
New Construction and Major Renovation	2000	9,200	18,800
Existing Buildings: O&M	2004	2,500	6,400
Core & Shell	2006	1,300	4,500
Commercial Interiors	2004	3,800	4100
Schools	2007	600	1,400
Retail	Nov. 2010	400	500
Healthcare	2011	2	200
Homes	Feb. 2008	41,400	116,000
Neighborhoods	April 2010	103	

Source: USGBC 2013.

A total of more than 54,000 projects are currently participating in LEED with a total of 10.1 billion square feet (938 million square meters) of construction space. Of those, over 19,000 projects have been certified by LEED at some level with a total of 3.2 billion square feet (293 million square meters).

### **3.1.2. LEED Certification Process**

The LEED certification process begins with the project participant choosing a rating system to register for; in some cases, a project will need to choose between multiple rating systems that the project may qualify for. The next step is to register the project with the U.S. Green Building Certification Institute (GBCI) online in the LEED Online website, allowing the project team to access software tools and establish communication with the GBCI. The GBCI administers the LEED certification program and is responsible for performing independent, third-party technical reviews and verification of LEED registered projects. Application materials can be uploaded online to the LEED Online database. The project team must also pay the associated registration fees, which are \$1200 for non-members and \$900 for LEED members for most building types except homes.

Once the project has been registered in LEED Online, the next step is to prepare the necessary documentation for the project application. In preparing its application for certification, the project team must first identify LEED credits to pursue and assign them to responsible team members. Each LEED



credit and prerequisite has specific documentation requirements that must be met in the application process. The responsible team members will need to collect information and perform calculations to demonstrate that the prerequisites and the chosen credits have been met. All necessary documentation will need to be uploaded to the LEED Online website and submitted by the LEED Project Administrator as part of the application submission process. Additional requirements to complete the application submission include other general project information forms and the certification review fees, which vary by rating system and review path. For LEED New Construction & Major Renovation Rating system, the possible review paths include a design application review only, a construction application review only, or a combined review. Project teams that split their reviews into a separate design review and a construction can help determine if their project is on track to achieve the desired LEED certification. In the case of LEED New Construction, the fee may be a fixed rate (e.g., \$2250 for USGBC members for buildings with less than 50,000 square feet applying for the new building combined design and construction review) or per square footage rate (e.g., \$0.045 per square foot for USGBC members for buildings with 50,000-500,000 square feet applying for the new building combined design and construction review). For LEED for Existing Buildings, operating data and documentation need to be submitted for a designated performance period. For most prerequisites and credits, the performance period has to be a minimum of 3 continuous months of operation. For the Energy and Atmosphere Prerequisite 2 and Credit 1, a longer performance period of at least 1 year is required. The LEED for Existing Buildings certification application must also be submitted for review within 60 calendar days of the end of the performance period.

A formal application review is initiated once the completed application has been received, with slightly different application review processes for each rating system and review path. In general, a preliminary review is first conducted in which all documentation are reviewed for completeness and forms are designated as “approved” or “not approved” and each prerequisite and credit is reviewed and designated as “anticipated,” “pending,” or “denied” and accompanied with technical advice from the review team. Once the preliminary review has been completed, the project team may either accept the results of preliminary review as final or choose to submit a response to the preliminary review with additional documentation for an optional final review to be conducted. Once the final review process has concluded, the project team can either accept or appeal the final decision within 25 days and with additional appeal fees. If certified, the LEED certified project would receive a formal certification of recognition, information on how to order additional marketing material and have the option to have the project listed in the online LEED project directory and the U.S. Department of Energy’s High Performance Buildings Database. For the LEED for Existing Buildings Operations and Maintenance rating, projects can apply for recertification as frequent as every year but must be recertified at least once every five years.

### **3.1.3. Prerequisites and Credit System**

The LEED certification and rating system is based on a scoring system of up to 100 base points, with 10 additional bonus points possible for Innovation in Design (or Operation) and Regional Priority credits.

The bonus points provide incentives for project teams to pursue innovative strategies and/or address geographically specific environmental issues.

The different rating levels are defined as:

- Certified: 40-49 points
- Silver: 50 -59 points
- Gold: 60-79 points
- Platinum: 80 points and above

The number of points needed to achieve a specific LEED certification rating is the same across rating systems, but the credit prerequisites and categories for points vary by the rating system. The number of points awarded for a specific credit (i.e., the credit weighting) is determined on the basis of the relatively importance of the building-related environmental impact that a specific credit addresses. In other words, credits with the greatest value are those that most directly address the most important impacts to the building category.

Two examples of credits for which building projects can receive a certain number of points are given in Table 2 and

Table 3 below. A summary of the credit categories and possible points in each category is given for the current LEED 2009 rating system for New Construction (effective April 1, 2013), while a more detailed summary of each prerequisite and credit under the current LEED 2009 rating system for Existing Building Operation and Maintenance (effective July 1, 2013) is provided.

**Table 2. Summary of LEED for New Construction Rating System Credit Categories**

Category	Possible Points	Summary of Credits
<b>Sustainable Sites</b>	<b>26</b>	<b>Construction activity pollution prevention (required)</b> <b>Site selection, development density, brownfield redevelopment, alternative transportation</b> <b>Storm water, heat Island effect and light pollution reduction</b>
<b>Water Efficiency</b>	<b>10</b>	<b>Water-use reduction (required)</b> <b>Water-efficient landscaping</b> <b>Innovative wastewater technologies</b>
<b>Energy and Atmosphere</b>	<b>35</b>	<b>Fundamental commissioning of building energy systems (required)</b> <b>Minimum energy performance (required)</b> <b>Fundamental refrigerant management (required)</b> <b>Optimized energy performance</b> <b>On-site renewable energy and green power</b> <b>Measurement and verification</b>
<b>Materials and Resources</b>	<b>14</b>	<b>Storage and collection of recyclables (required)</b> <b>Building reuse</b> <b>Construction waste management</b> <b>Materials reuse and recycled content</b> <b>Materials selection: regional, rapidly renewable, certified wood</b>
<b>Indoor Environmental Quality</b>	<b>15</b>	<b>Minimum indoor air quality performance (required)</b> <b>Environmental tobacco smoke control (required)</b> <b>Outdoor air delivery monitoring and increased ventilation</b> <b>Low-emitting materials and indoor chemical and pollutant source control</b> <b>Controllability of systems, thermal comfort, and daylight and views</b>
<b>Innovation in Design</b>	<b>6</b>	<b>Innovation in design</b> <b>LEED-accredited professional</b>
<b>Regional Priority</b>	<b>4</b>	<b>Regional priority</b>

Source: USGBC 2013b. *LEED 2009 for New Construction and Major Renovations Rating System*. Washington, DC: U.S. Green Building Council.

**Table 3. Detailed List of Credits for LEED for Existing Buildings Operation and Maintenance Rating System**

Credit Number	Credit Category	Points Possible
<b>Sustainable Cities Credits</b>		26
1	LEED certified design & construction	4
2	Building exterior and hardscape management plan	1
3	Integrated pest management, erosion control, and landscape management plan	1
4	Alternative commuting transportation	3-15
5	Site development—protect or restore open habitat	1
6	Stormwater quantity control	1
7.1	Heat island reduction - non-roof	1
7.2	Heat island reduction — roof	1
8	Light pollution reduction	1
<b>Water Efficiency Credits</b>		14
Prerequisite	Minimum indoor plumbing fixture and fitting efficiency	Required
1	Water performance measurement	1-2
2	Additional indoor plumbing fixture and fitting efficiency	1-5
3	Water efficient landscaping	1-5
4.1	Cooling tower water management - chemical management	1
4.2	Cooling tower water management - non-potable water source use	1
<b>Energy and Atmosphere Credits</b>		35
Prerequisite 1	Energy efficiency best management practices - planning, documentation, and opportunity assessment	Required
Prerequisite 2	Minimum energy efficiency performance	Required
Prerequisite 3	Fundamental refrigerant management	Required
1	Optimize energy efficiency performance	1-18
2.1	Existing building commissioning - investigation and analysis	2
2.2	Existing building commissioning - implementation	2
2.3	Existing building commissioning - ongoing commissioning	2
3.1	Performance measurement - building automation system	1
3.2	Performance measurement -system level metering	1-2
4	On-site and off-site renewable energy	1-6
5	Enhanced refrigerant management	1
6	Emissions reduction reporting	1

Credit Number	Credit Category	Points Possible
<b>Materials and Resources Credits</b>		10
Prerequisite 1	Sustainable purchasing policy	Required
Prerequisite 2	Solid waste management policy	Required
1	Sustainable purchasing - ongoing consumables	1
2.1	Sustainable purchasing - electric-powered equipment	1
2.2	Sustainable purchasing - furniture	1
3	Sustainable purchasing - facility alterations and additions	1
4	Sustainable purchasing - reduced mercury in lamps	1
5	Sustainable purchasing - food	1
6	Solid waste management - waste stream audit	1
7	Solid waste management - ongoing consumables	1
8	Solid waste management - durable goods	1
9	Solid waste management - facility alterations and additions	1
<b>Indoor Environmental Quality Credits</b>		15
Prerequisite 1	Minimum indoor air quality performance	Required
Prerequisite 2	Environmental tobacco smoke (ETS) control	Required
Prerequisite 3	Green cleaning policy	Required
1.1	Indoor air quality best management practices - indoor air quality management program	1
1.2	Indoor air quality best management practices - outdoor air delivery monitoring	1
1.3	Indoor air quality best management practices - increased ventilation	1
1.4	Indoor air quality best management practices - reduced particulates in air distribution	1
1.5	Indoor air quality best management practices - indoor air quality management for facility alterations and additions	1
2.1	Occupant comfort - occupant survey	1
2.2	Controllability of systems - lighting	1
2.3	Occupant comfort - thermal comfort monitoring	1
2.4	Daylight and views	1
3.1	Green cleaning - high performance cleaning program	1
3.2	Green cleaning - custodial effectiveness assessment	1
3.3	Green cleaning - purchase of sustainable cleaning products and materials	1
3.4	Green cleaning - sustainable cleaning equipment	1
3.5	Green cleaning - indoor chemical and pollutant source control	1
3.6	Green cleaning - indoor integrated pest management	1
<b>Innovation in Operations Credits</b>		6
1	Innovation in operations	1-4
2	LEED accredited professional	1
3	Documenting sustainable building cost impacts	1
<b>Regional Priority Credit</b>		4
1	Regional priority	1-4

Source: USGBC 2013b. *LEED 2009 for Existing Buildings Operations and Maintenance Rating System*. Washington, DC: U.S. Green Building Council.

For each credit, two or more options for fulfilling the credit requirements are typically given in the rating system reference guide along with potential technologies and strategies. As an example, for the LEED 2009 for New Construction and Major Renovations Rating System, the options for earning the alternative transportation – public transportation access credit are (USGBC 2013a):

- Option 1: Rail Station, Bus Rapid Transit Station & Ferry Terminal Proximity: locate the project within ½ mile walking distance from one of these terminals
- Option 2: Bus Stop Proximity: locate the project within ¼ mile walking distance of 1 or more stops for 2 or more buses
- Option 3: Rideshare Proximity: projects outside of the U.S. may locate it within ¼ mile walking distance of 1 or more stops for 2 or more existing rideshare options

The potential technology and strategies for earning this credit would be to conduct a transportation survey of future building occupants' transportation needs and to locate the project near mass transit.

### **3.1.4. U.S. LEED Building Case Studies**

#### ***3.1.4.1. Betty Irene Moore Natural Sciences Building, Oakland, California***

The Betty Irene Moore Natural Sciences Building is an educational building on the Mills College campus in Oakland, California with 26,000 square feet (2230 square meters) of total area. It was certified as a LEED Platinum building under the LEED for New Construction version 2.1 rating system in November 2007. Strategies that were incorporated into the building's design to achieve its LEED Platinum rating included solar photovoltaic arrays, rainwater catchment and re-use, extensive daylighting, under-floor air circulation, evaporative cooling and radiant floor heating. The building's energy efficient measures include indirect and direct evaporative cooling systems for space cooling, low-energy displacement ventilation, a metal roof with rigid continuous insulation and high-performance glazing. Building energy use surpasses local building energy code Title 24 requirements by 43.3%, performs 89% better than a typical lab in the region in terms of energy use, and has 61% overall water savings totaling 338,400 gallons per year (USGBC 2013d). The building achieved 53 out of the total 69 possible credits under the LEED for New Construction v2.1 rating system, including:

- Sustainable Sites: 9 out of 14 points
- Water Efficiency: 4 out of 5 points
- Energy and Atmosphere: 15 out of 17 points
- Material and Resources: 6 out of 13 points
- Indoor Environmental Quality: 14 out of 15 points
- Innovation: 5 out of 5 points

#### ***3.1.4.2. U.S. Federal Bureau of Investigation Chicago Regional Headquarters, Chicago, Illinois***

The FBI Chicago Field headquarters consists of three buildings (a 10-story office building, a 2-level parking deck, and a connecting 1-story vehicular annex facility) with total area of over 800,000 square

feet (74,320 square meters). In December 2008, it was awarded the first LEED Platinum Certification under the LEED for Existing Buildings Operation and Maintenance rating system. The building's sustainability efforts include exterior walls with 60% pre-cast concrete and high-performance, low-emissive glass that provide a highly energy-efficient envelope and ample exterior window areas for daylighting. Additional strategies used to earn LEED credits include reduced site disturbance with 50% of the site area landscaped with native and adapted sustainable plants without need for fertilization, irrigation or maintenance, sub-metering of major energy systems and continuous commissioning program, using sustainable products for 60% of purchased products and a recycling program resulting in over 70% of waste being diverted from the landfill. The facility also improved its ENERGY STAR rating for energy consumption from 78 to 95, and reduced water use by 43%. Of the 91 credits offered in the earlier version of the LEED for Existing Buildings Operation and Maintenance rating system, the FBI Field Office campus achieved 74 credits, including (USGBC 2013e):

- Sustainable Sites: 8 out of 12 points
- Water Efficiency: 7 out of 10 points
- Energy and Atmosphere: 25 out of 30 points
- Material and Resources: 10 out of 14 points
- Indoor Environmental Quality: 17 out of 19 points
- Innovation: 7 out of 6 points

### **3.2. China's Green Building Rating Standard**

China's voluntary Green Building Evaluation and Labeling program was established in late 2007 following the development of the Green Building Evaluation Standards (GB/T 50378-2006) by MOHURD and subsequent management methods and technical guidelines (MOHURD, 2006; 2007; 2008). The national Green Building Evaluation Standard was established in 2006 with two different green building evaluation standards for residential and commercial buildings. In addition to supporting the national standard, the GBEL program is intended to accelerate the market entry of environmentally sustainable green buildings from the top down and to institutionalize green building evaluation as a common process in construction project. The voluntary GBEL program consists of a Green Building Design Label (GBDL) and the operational Green Building Label (GBL). Both labels utilize a three-star rating system, with three-stars awarded to the highest rated green buildings and one-star awarded to the lowest rated green buildings. There is an initial application fee of 1000 yuan (\$140) for the GBDL, with estimated evaluation fees of 40,000 to 50,000 yuan (\$5,700 to \$7,100) (Mo, 2009).

#### **3.2.1. Rating and Labeling Systems**

The GBDL helps pre-certify a green building and rates the building design according to the Green Building Evaluation Standard. The GBDL is valid for two years and uses a rating system of one to three stars, with three stars being the highest level for green buildings. The green building design evaluation system is composed of three types of criteria for each of the six categories being evaluated: mandatory elements that must be included in the building, general elements, and preferred elements where one point is awarded for each item that is included in the building design. For example, mandatory energy-

efficiency items for residential buildings include meeting energy-savings standard requirements for heating and HVAC design and installing built-in temperature controls and heat metering in buildings that have central heating or air conditioning. General energy-efficiency items include the use of highly efficient equipment, lighting, energy recovery units, and renewable energy technologies such as solar water heaters, solar photovoltaics (PV), and ground-source heat pump systems. Preferred items include more efficient heating and air conditioning and greater renewable energy integration (MOHURD, 2007; 2008). This evaluation system is similar to LEED in that the mandatory elements are essentially prerequisites, the general elements are the same as the LEED non-prerequisite credit categories, and the preferred elements are similar to LEED bonus credits that can be pursued to achieve a higher Two- or Three-star rating. The preferred elements are also used in determining qualification for the National Green Building Innovation Award, an award presented to sustainable building projects, materials and products.

Figure 4 shows the key components of a GBDL certificate.



**Figure 4. China Green Building Design Label**

The label star rating is determined by the minimum score for each of the six components, not the total score; therefore, a building must meet a minimum number of requirements in all six categories to qualify for a specific rating (Mo, 2009). For example, as shown in Table 4, for a residential building to achieve a Two-Star rating, it must meet all 27 of the mandatory requirements, 5 of 8 of the performance



items in the Land Use & Outdoor Environment category, 3 out of 6 of the performance items in the Energy Efficiency category, 4 out of 6 of the performance items in the Water Efficiency category, 4 out of 7 of the performance items in the Resource Efficiency category, 3 out of 6 of the performance items in the Indoor Environment category, 5 out of 7 of the performance items in the Operational Management category and 3 out of 9 of the Preferred Items. This arrangement gives equal weight to all six categories and does not allow better performance in one to offset poor performance in another. In essence, a Three-Star-rated green building must excel in all six of the evaluation components, including the preferred items. Table 4 and Table 5 show the minimum requirements and rating evaluation systems for residential and commercial buildings, respectively.

**Table 4. Criteria for Green Building Design Label Rating Evaluation for Residential Buildings**

Rating Level	Mandatory Items Included (27)	General Items						Preferred Items
		Land Use & Outdoor Environment	Energy Efficiency	Water Efficiency	Resource Efficiency	Indoor Environment	Operational Management	
		<i>Total: 8</i>	<i>Total: 6</i>	<i>Total: 6</i>	<i>Total: 7</i>	<i>Total: 6</i>	<i>Total: 7</i>	
★	Yes	4	2	3	3	2	4	0
★★	Yes	5	3	4	4	3	5	3
★★★	Yes	6	4	5	5	4	6	5

Source: MOHURD 2007

**Table 5. Criteria for Green Building Design Label Rating Evaluation for Commercial Buildings**

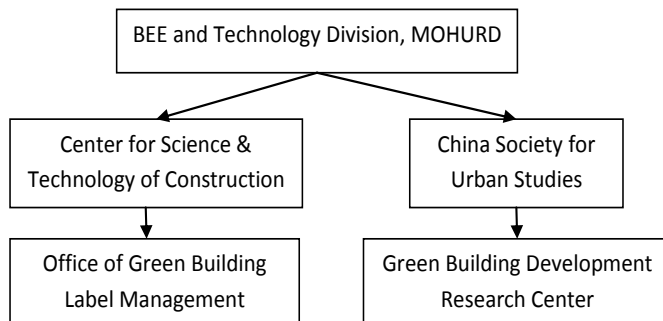
Rating Level	Mandatory Items Included (26)	General Items						Preferred Items
		Land Use & Outdoor Environment	Energy Efficiency	Water Efficiency	Resource Efficiency	Indoor Environment	Operational Management	
		<i>Total: 6</i>	<i>Total:10</i>	<i>Total: 6</i>	<i>Total: 8</i>	<i>Total: 6</i>	<i>Total: 7</i>	
★	Yes	3	4	3	5	3	4	0
★★	Yes	4	6	4	6	4	5	6
★★★	Yes	5	8	5	7	5	6	10

Source: MOHURD 2007

The operational GBL is a more comprehensive evaluation of pre-certified Green Buildings than the GBDL as it also considers quality control during the construction process. The GBL can only be awarded after a minimum of one year of building operation and is valid for three years (Song, 2008). The GBL assessment process also requires an on-site visit; documentation of construction materials and their sources; property management plans for water, energy, and material conservation; and itemized financial documents such as bills of quantities (Zhang, 2011). However, reporting of actual operational energy consumption is not required because the GBL focuses primarily on building design and successful implementation of the design in the construction process.

### 3.2.2. Program Management and Application Process

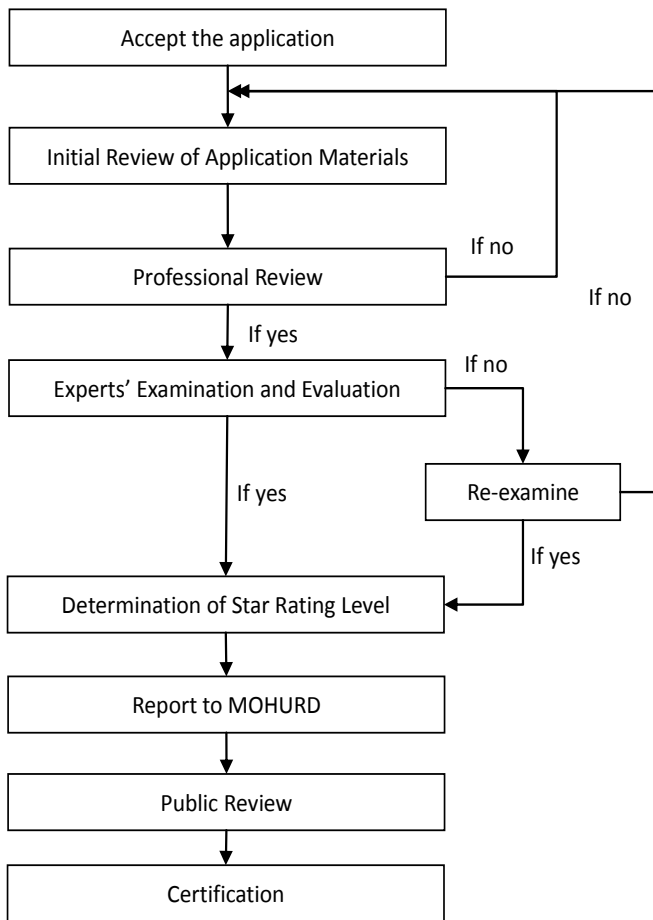
Within MOHURD, the GBEL program is administered by the Building Energy Efficiency and Technology Division. Management responsibilities are divided between offices within two primary institutions, the Office of Green Building Label Management within the Center for Science and Technology of Construction and the Green Building Research Development Center within the China Society for Urban Studies (Figure 5). The Office of Green Building Label Management is authorized by the national government and has the administrative authority to implement the GBEL program. It works closely with the Green Building Development Research Center, which specializes and provides technical support in researching and developing green building standards and providing green building. The Green Building Development Research Center may also provide technical consulting services to building developers and owners who are interested in applying for the GBEL program. Only these two national offices are authorized to approve Three-Star Building Label rating applications while 21 local MOHURD offices are authorized to approve One-Star and Two-Star Rating applications (Li, 2011). Figure 5 illustrates the Green Labeling Program management structure.



**Figure 5. Institutional Organization of Green Building Evaluation and Labeling Program Management**

Figure 6 shows the key steps in the green building labeling application review process, which is managed by local MOHURD offices for one- and two-star building applications, and MOHURD Office of Green Building Label Management for three-star applications. The review process begins with the acceptance of an application and an initial review by the accepting agency (i.e. local or national MOHURD offices) to determine whether the application material and supporting documentation are adequate and complete. After this initial review, the application material is forwarded to appointed experts or qualifying office staff for a professional review of the details of the supporting documentation. If the application passes both rounds of review, the Office of Green Building Label Management will organize a meeting where experts selected from a database of more than 400 individuals will review and evaluate the application to determine the star rating (Li, 2011). The rating is then reported to MOHURD, and the building is officially certified after a 30-day public review process (Ye 2013). MOHURD will take into account any

objections raised during the public review process and make a final judgment on whether to issue a GBL certification.



**Figure 6. Green Building Evaluation and Label Review Process**

Source: Personal communication (Li, 2011).

Although it is a national rating system, China’s GBEL offers some provincial flexibility because local assessment and certification authorities have the discretion to eliminate certain items in the standard that may not be compatible with local geographic or climate conditions. For example, Shenyang municipality requires all commercial buildings seeking the green building certification to consider using a ground-source heat pump for heating and provide justification if a ground-source heat pump cannot be used for a particular project, but this requirement is not available or appropriate for other regions (Geng et al. 2012). The rigidity in measurement may also differ from province to province for One- and Two-Star building projects that are reviewed at the sub-national MOHURD offices.

### 3.2.3. China Green Building Label Case Studies

#### 3.2.3.1. Shenzhen Institute of Building Research Headquarters

The Shenzhen Institute of Building Research (IBR) headquarters building was completed in March 2008 and has been recognized as one of the most energy efficient new buildings in China. This large office building has total floorspace of 180,000 square meters and was self-designed by the Shenzhen IBR. The IBR headquarters building has received several awards for its high energy efficiency and green features, including being certified as the highest rated China Three Star Green Building as well as the most efficient Five-Star building under the China Building Energy Efficiency Labeling program (SIBR 2011). The IBR building's energy performance is impressive in that it has achieved overall energy savings of 65.9% relative to comparable office buildings in the same geographic area that consume on average 109 kWh/m<sup>2</sup>-year (SIBR 2009). More specifically, after months of operational energy data collection following building occupancy, specific energy savings were quantified. In terms of total electricity consumption, the IBR building consumed only 52.9 kWh/m<sup>2</sup>-year, which is 40% lower than the total consumed by local government office buildings in Shenzhen and 45% lower than local non-government office buildings (SIBR 2010). In terms of lighting energy, the IBR building was able to achieve savings on the order of 73% to 82% when compared to typical office buildings in the same region, with an average of only 12 kWh/m<sup>2</sup>-year. For air conditioning energy use, the IBR building achieved energy savings of 60% compared to typical office buildings in the same region. In addition to energy, the building has also achieved 53% savings in water consumption relative to comparable local office buildings. As a result of the significant energy and water savings, the IBR building is able to reduce annual electricity costs by RMB 15 million and water costs by RMB 54,000 (Malone 2010). The building is thus considered very cost-effective, as IBR reported that total investment actually decreased by about 1/3 compared to other offices with total construction cost maintained at RMB 4000 per square meter, or estimated total cost of RMB 720 million (Malone 2010; SIBR 2011).

#### 3.2.3.2. 2010 Shanghai World Expo Center

The Shanghai World Expo Center served as the central exhibition and convention venue of China's 2010 Shanghai World Expo and now serves as an international convention center. The building has seven floors and a total building area of 142,000 square meters. In designing the Shanghai World Expo Center, the three design principles of reduce, reuse and recycle and sustainable development practices helped the building achieve a three-star rating on the China Green Building Design Label. Technologies that were incorporated into the Expo Center's design included a series of solar water heating systems, storage, control and rainwater utilization, once-through cooling water systems, programmable green micro-irrigation systems, and central energy monitoring and management systems. The building achieved an energy savings rate (compared to inefficient 1980s buildings) of 62.8%, with 52% of the hot water supplied by the solar hot water system and 61.3% of water resources provided by non-conventional water resource utilization (MOHURD Green Building Label Management Office 2013a).

### ***3.2.3.3. Shandong Jiaotong University Library***

The Shandong Jiaotong University library, located in Jinan, Shandong Province, is a five-story building with a total gross floor area of 16,000 square meters. As one of the projects for the initial national green technology campaign, the university library building achieved a two-star rating under the China GBEL program. The building incorporated various energy saving and high efficiency technologies including natural shading, daylighting, natural ventilation, high-performance building envelope insulation and a wind tunnel. As a result, the building achieved 40% lower heating and air conditioning energy consumption when compared to similar buildings with annual power consumption of only 14 kWh/m<sup>2</sup>-year and heating coal consumption of 7.8 kgce/m<sup>2</sup>-year. In addition, the building also features natural water collection, the use of natural water reservoirs for cooling and 80% local materials for building materials and 10.7% recyclable material utilization.

## **3.3. Rating System Comparison**

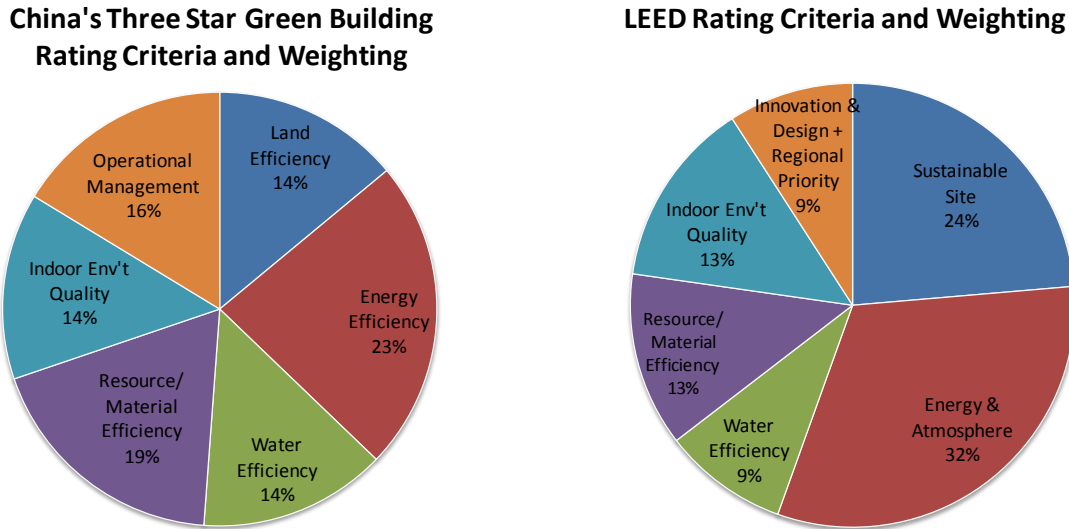
### **3.3.1. Program Administration**

Although both the U.S. and Chinese green building rating programs are voluntary programs, the U.S. LEED program is administered by the USGBC, a non-governmental body, whereas the China Green Building Evaluation and Labeling program is administered entirely by central and provincial government agencies. In particular, the LEED rating systems are developed and updated in a consensus-based process through a committee of GBC members from a diverse array of professional backgrounds, including architects, real estate agents, building owners, lawyers, environmentalists, and industry representatives. LEED project registration and certification is then administered by the Green Building Certification Institute, a third-party organization established with the support of the USGBC to provide independent oversight of professional credentialing and project certification. The development of the China GBEL evaluation standards as well as the labeling application and certification process, in contrast, are all administered by government organizations within MOHURD's Building Energy Efficiency and Technology Division. This key difference in the types of participating stakeholders between the two green building labeling programs is a key area of divergence.

In terms of the scope of the rating systems, the China GBEL program differentiates between residential and commercial buildings, but does not include rating systems unique to specific building types as LEED does. Both programs have different rating programs for design and construction versus operation, although the reporting requirements for the operational rating are different. LEED requires a performance period of only 3 months for most LEED Existing Building Operations and Maintenance credits, but China's operation GBL requires 1 year of occupancy and performance for all credits. However, reporting of actual operational energy consumption is not required in the application for the Chinese green building operational rating. For both programs, the application costs are borne by the project developer.

### 3.3.2. Rating system

In terms of the specific rating systems, LEED has similarities and differences with China's GBEL program. A key similarity between the two programs include the use of credit-based systems with some flexibility for what credits or measures building developers want to pursue, along with mandatory requirements that must be met for certification. For rating new construction, both LEED and GBEL also use similar rating criteria focusing on land, energy, water, resource/material efficiency, and indoor environmental quality. A comparison of the relative weighting of each evaluation criteria category is shown in Figure 7.



**Figure 7. Comparison of China's Green Building and LEED Rating Criteria and Weight Factors**

Note: China Three-Star Green Building rating based on point allocation for commercial buildings and do not include preferential items, which are not designated to one of the six categories. LEED rating based on 2009 LEED for New Construction rating system.

The figure shows that China's GBEL has more equal weight distribution in terms of the total points possible across the six categories of options, although energy efficiency and resource and material efficiency are given slightly higher share of total available options than the other four categories. LEED also gives energy and atmosphere category the highest share in terms of total point allocation, but the sustainable site category has the second greatest weighting before resource and material efficiency. Within each category of credits or options, the emphasis of available credits or options also differ between the two rating systems due to different national conditions. In the area of water efficiency, LEED credits promote water conservation planning, wastewater recycling and water resource conservation whereas the GBEL options focus on consumption of rainwater, reclaimed wastewater and reclaimed sea water (Geng et al. 2012). In addition, the Chinese rating also has a unique requirement of reduction in the total land used for building construction because of high population density, whereas the Sustainable Sites credits in LEED focuses on other environmental considerations such as alternative transportation, heat island effects and site development. For credits or options related to energy, the

Chinese GBEL rating clearly prioritizes energy efficiency with the bulk of options dedicated to efficient equipment and energy conservation measures and design. In contrast, LEED for New Construction emphasizes energy performance but places almost equal emphasis on other non-efficiency related items such as renewable energy and green power, refrigerant management and measurement and verification.

Another key difference between LEED and the GBEL is in how a building's specific rating level is determined. Under China's GBEL, the final rating is determined by meeting the minimum rating or credits within each category, whereas a LEED rating is determined by the total points summed over all categories. Thus, a Three Star-rated building under the GBEL will have to meet the minimum requirements in all categories, whereas a similarly rated LEED building has more flexibility in receiving the highest Platinum rating by possibly excelling in several areas but performing poorly in one or two areas. For example, a Three Star-rated commercial building must meet 8 out of the 10 available options for the energy efficiency category under the Chinese GBEL program whereas a commercial building could theoretically be certified as LEED Platinum if it achieved all or nearly all of the points in all categories except the Energy and Atmosphere category but achieved very few points in the Energy and Atmosphere category.

## **4. Comparison of policy support for green buildings**

Transforming the built environment to more sustainable energy and resource use requires a wide array of policy support due to a number of economic, informational, and institutional barriers that exist in the buildings industry. Policy support for green building practices has been rising in the U.S. and China over the past through different mechanisms that will be described in this section. First, a brief overview of barriers faced by the green building industry will be provided. The second section will describe five policy mechanisms either commonly used by energy efficiency policy makers or frequently cited by green building literature as crucial to the green building industry's success. The third and fourth sections will outline use of these policy mechanisms in the U.S. and China, respectively, at the local and national levels. The fifth section will offer a relative comparison of the U.S. and China green building policy landscapes.

### **4.1. Barriers to a growing green building industry**

A recent survey of 140 green buildings (in ten different countries) carried out by Good Energies found that green buildings have an average cost premium of only 2.5% over conventional buildings (Kats, 2008). The energy savings of these buildings alone would be enough to make the green building cost effective, not to mention the water savings, productivity gains, health improvements, and other related benefits produced by the green building. Specifically, the net present value of 20 years of energy savings was estimated to range from \$7 per square foot for LEED certified buildings to \$14 per square foot for LEED platinum buildings, which was more than the cost premium of \$3-8 per square foot (certified) to \$14 per square foot (platinum), more than the average cost premium of \$3 to \$8 per square foot (Kats, 2008). Moreover, research is beginning to show that LEED certified buildings command a rent and sales price premium, which also make the investments financially worthwhile. One study showed a rental

premium of 6% for LEED and Energy Star certified buildings, and a 35% sale price premium (127 price observations) and 31% sale price premium for LEED certified buildings and Energy Star certified buildings, respectively (Fuerst and McAllister). A summary of other studies presenting similar evidence is discussed later in section 5.

So the question is: if building green makes good fiscal sense, then why is the green building industry not growing more rapidly? What are the barriers to growing a green building industry that can save money and resources, reduce carbon emissions, and improve health and productivity? In fact, many studies have been carried out on the barriers to energy efficient and green building, but understanding of these barriers is still evolving. The design of policies that will help break down these barriers and create a more rapidly growing green building industry is also a subject of a growing and evolving body of knowledge and experience.

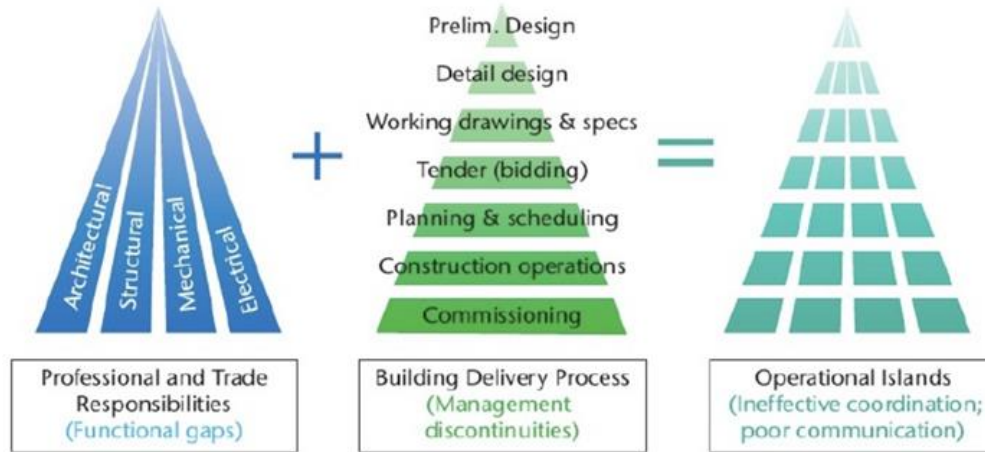
The types of barriers that the green building industry faces include institutional, regulatory, financial, informational, and risk barriers. The following paragraphs will provide examples of each of these types of barriers.

**Institutional barriers** help describe the number of parties involved in any given building and their associated communication and collaboration, or lack thereof. This passage describes the expansiveness of the design and construction processes:

*“However, the creation of a building typically involves hundreds of people, each of whom can individually or collectively influence the outcome or “sustainability” of both design and construction processes, as well as the final product. These roles include architects (building and landscape), contractors, engineers, energy consultants, daylighting consultants, sub-contractors (e.g. plumbing, electrical, or heating, ventilation and air conditioning (HVAC)), product manufacturers, product distributors, code inspectors, government officials (local, state, and federal), non-profit organizations, industry trade organizations, and more.” (Hoffman & Henn, 2008)*

Figure 8 offers another commonly offered perspective that not only are there many organizations and stakeholders involved, but there is also a division of responsibilities and building processes that leads to “operational islands” and inhibits collaboration. This is especially harmful to the green building industry, where collaboration and communication are needed to ensure that a holistic, sustainable design can be created and that the design can be fully constructed and commissioned as intended. Figure 9 offers additional context from Amory Lovins on the vocabulary that different professionals use to describe whether they have met their objective or not. No one is using the same measures for success.





**Figure 8: The operational islands of the building industry**

Source: WBCSD, 2009

Specialist	Performance Measures/Objectives
Developers	dollars per square foot or meter
Investors	risk/reward ratios; return on investment
Asset managers	net operating income
Lender's counsel	due diligence; liability
Electrical engineers	watts per square foot
Lighting engineers	footcandles or lux
Mechanical engineers	square feet per ton; kilowatts per ton
Estimators	tables and modification factors
Contractors	budget and schedule
Construction workers	signoff
Construction managers	critical path and specifications/drawing adherence
Building inspectors	code-section compliance
Commissioning agents	punchlist items
Indoor air quality experts	concentrations and exposures
Leasing brokers	deals
Appraisers	comparables
Building managers	occupancy
Building operators	simple payback
Maintenance staff	complaints
Suppliers	sales and margins
Tenancy managers	gross effective occupancy costs
Space planners	square feet per person
Occupants	comfort
Utility DSM program designers	dollars per avoided peak kilowatt; cents per saved kilowatt-hour
Utility measurement and evaluation staff	process and impact data

**Figure 9: The Tower of Babel, Technical Specialization and Disparate Vocabularies**

Source: Lovins, 1995

In the U.S., the consensus-based approach of the USGBC to the development and revisions of LEED rating systems and the involvement of multi-stakeholders in a transparent LEED certification process has helped address some of these institutional barriers. For instance, institutions such as the body of LEED Accredited Professionals help developers apply for the LEED certification while the GBCI, an independent third-party organization, bring together experts from across the green building industry to

evaluate and rate the project seeking LEED accreditation. Additionally, many of the professional accreditation programs that LEED runs emphasize integrated design principles in their teachings.

**Regulatory barriers** could be categorized as a specific extension of institutional barriers. Government bodies that supervise health, fire safety, land, and other public operations are slow to revise codes to accommodate green building. In the meantime, green buildings are in violation of many basic codes simply because of new practices they employ that are unconventional. “If you really want to build a green building today in any city in the U.S., you’ll find yourself in violation of, maybe, two dozen codes,” said Denis Hayes, the president of the Bullitt Foundation, which recently finished construction one of the greenest buildings (water and energy self-sufficient) in the U.S. in Seattle, WA as part of the Living Building Challenge. Codes and standards for energy efficiency in the built environment need proper enforcement in order to be effective, but the bodies that oversee this enforcement often lack capacity and funding. One other commonly seen regulatory barrier is when a new policy prescribes a specific approach in green building, while unintentionally inhibiting approaches that would be even greener, more energy-saving, etc. For example, one building energy efficiency code prescribed smaller area windows in order to control heat intake and associated HVAC loads. This prescription led to large HVAC systems and energy usage, when an integrated approach would have introduced larger, well-insulated windows with some sort of active or passive shading to bring a much higher levels of energy savings (Lee, Selkowitz and DiBartolomeo, 2009).

**Financial barriers** typically include issues related to the cost of a green building, established investment norms, and fiscal “carrots” that can incentivize better decisions. First-cost barrier, short-term investment horizons, and split incentives are terms often mentioned in the literature. While the cost premium for a holistically designed green building should not be significantly high, new and innovative technologies can often be cost prohibitive. Green buildings generally cost more to design and build due to greater system integration and the need for more building controls and measurement points. For architectural and design firms to do an integrated design for a new green building, it often takes more time and money to do so than a design for a conventional building. If the firm is just one party in a bid for a project, they are often not willing to spend as much time and money on the design in order to defray the risk in the case that they do not win the bid. This risk to spend more time on an integrated design ends up also being a large barrier in the industry. Split incentives refer to the situation where the financial benefits from investments made in a building will often be received by the owner or user of the building as opposed to the original investor. However, split incentives are more common for retrofits than for new buildings (WBCSD, 2009).

**Informational barriers** include a basic lack of awareness and understanding of energy efficiency among building professionals. Even if a green building is designed and commissioned well, there is a question as to whether the operations staff and occupants of the building are informed to make decisions in line with the short and long-term sustainability goals of the building. According to Lovins, “Buildings are normally designed with no customer feedback.” (Lovins, 1995) Only in the modern age of smart meters and thermostats are owners and occupants beginning to make wise energy decisions, albeit at a very

slow rate of uptake. Behavior and decision-making constitute an entire subset of energy efficiency literature.

**Risk barriers** are characterized by established practices in the industry that discourage various stakeholders from trying new or different approaches. Subcontractors in the construction process often view new technology as inherently risky and therefore worry about the liability of installing such technologies in projects they are ultimately responsible for. To justify this risk they are taking, they often charge higher fees; other times, they will simply refuse to work with the new technology or practice (Hoffman & Henn, 2008). In Lovins's 1995 study on energy efficient buildings, he highlighted the risk barriers with the following succinct statements:

“Nobody ever got fired for making a mechanical system too big...Engineering fees reward oversizing ... Designers' concerns about liability are most easily met by oversizing equipment.”  
(Lovins, 1995)

In addition to perceived and avoided risk of new technologies, many architects and engineers lack the tools needed to simulate the performance of a new technology and its interaction with other systems, even if they desire to employ these technologies.

Due to established business practices and risk perception, the overall decision to design and build a green building may be the largest barrier. This decision making process encompasses many of the institutional, risk, and information barriers outlined previously. Additional regulatory and financial barriers will become more pronounced once the decision to build green has been made, and the financing, design, and construction processes actually begin.

### **Barriers in China**

The above section on barriers is written largely from a U.S. perspective, but many of those barriers exist in China as well. First off, the lack of a green building professional accreditation process similar to the LEED AP process limits the green building workforce capacity development. In China, where the emphasis on building energy efficiency and development of green buildings is relatively new, informational barriers resulting from limited capacity and knowledge of green building design are more pronounced. While there are a growing number of institutes of building research around the country, good education on green design is not yet widespread among university architecture and engineering programs. The lack of public information and transparent database of existing green building projects also make it more difficult for the Chinese building industry to recognize and realize the potential for green buildings development. Additionally the GBEL program is administered entirely by government entities and the evaluation and rating process is a closed process based entirely on expert review, in contrast to the LEED process which is more open, transparent, and participatory.

Second, financial barriers are perhaps even more pronounced in China than in the U.S. since the industry is in an earlier phase of development. Developers cite higher incremental cost as one of the biggest barriers to investment in green buildings. While some government subsidy programs for green buildings

have been introduced to address this barrier, operational challenges with implementing and paying the subsidies have limited the subsidy's effectiveness.

Lastly, more oversight is needed in the green building industry in China to improve the quality of what is being built and what materials are being used. Not only does the supply of green building materials need to grow quickly to meet demand, but there is also a need for higher quality materials and a better certification process for ensuring materials meet their claimed performance (insulation properties for windows, for example). Additionally, many buildings that are awarded the GBEL are certified at the design stage and then built such that the construction does not meet the design standard.

## **4.2. Common green building policy mechanisms**

The previous section has provided a broad overview of the types of barriers faced in the building industry. On the one hand, some barriers may be easily targeted by short-term policy mechanisms. On the other hand, some barriers may not be overcome without larger cultural, social, and institutional changes. Policy mechanisms may be able to assist in making those changes, but the changes will likely happen over longer time scales (decades, as opposed to years). This section will focus on the shorter term policies that governments frequently implement.

The following five policy categories were selected to encompass both strategies for success frequently highlighted in the literature as well as common strategies for promoting green building employed in the U.S. and China.

1. Codes and labeling plan
2. Government-led targets and demonstrations
3. Education and awareness programs
4. Fiscal policy that supports green building investment
5. Integrated design promotion

The following subsections provide an explanation and simple examples within each policy category. The sections following this introductory section will discuss how these types of policies have been implemented in the U.S. and China.

### **4.2.1. Codes and labeling plan**

Codes and labeling have been key components of improvement in the efficiency of the built environment to date and should therefore be an important component of any larger policy framework that seeks to encourage green building. While a subsidy policy may “push” new green building technologies into the marketplace, codes and labeling help “pull” these technologies into the market so that they become more commonly used. Codes help to ensure that every building, residential and commercial, has a basic level of energy efficiency that has been proven to be cost effective and achievable. Voluntary labeling programs for green buildings, such as the USGBC's LEED program and China's Three Star labeling program, encourage public education and awareness and reward first-

movers with recognition. One way of thinking of the difference between codes and labeling is that a code tells you “what to do” while a label or rating system tells you “how you did” (Sigmon, 2012).

As the state of green building technology and design is constantly improving, there is a need to provide regular revisions and upgrades to codes and labeling programs. Also, many requirements for green building labels are linked directly to standards (this topic is addressed in more depth in the Appendix), so it is important that there is a strong integrity in both the standards and labeling programs. Additionally, strong codes and labeling programs need transparent approaches, consistent funding, and enforcement and compliance strategies in order to be as successful as possible in promoting energy efficient and green building. Countries that have voluntary labeling programs may also consider mandatory labeling and energy disclosure policies for all buildings, which can help promote awareness and action among more stakeholders.

#### **4.2.2. Government-led targets and demonstrations**

Targets and demonstrations are typical policy mechanisms used to initiate larger green building initiatives. These targets and demonstrations are often spearheaded by local or national government bodies. For instance, the national government of a country may declare that 10% of all new commercial buildings need to be LEED certified by 2020, but that all new government-owned buildings need to be LEED certified going forward. Since government bodies often have longer investment time horizons as well as more money to invest, they will create more aggressive targets for themselves as a way to galvanize early market activity so that the cumulative body of experience in green building can grow among various stakeholders, including architects, contractors, engineers, and manufacturers. Additionally, green-building technologies that are currently expensive may decrease in price as the number of installations grows. The targets that local or national governments typically set can come in a variety of forms: mandatory or voluntary; for new construction only or for existing buildings as well; for commercial buildings only or for residential buildings as well. Demonstrations are also a popular mechanism for showcasing new technologies as well as measuring and verifying their performance, as an avenue for defraying risk or perception of risk for these new technologies from the perspective of architects and builders. In addition to targets and demonstrations, governments may develop action plans or strategic plans that consist of a number of policy mechanisms (codes, targets, incentives, education) meant to drive innovation in and adoption of green building technology.

#### **4.2.3. Education and awareness programs**

Since there are so many stakeholders involved in the design, construction, operations, and use of any given building, education and awareness programs are key components of a successful green building campaign. Often, builders say they do not build green because their clients do not demand green buildings. In fact, it is the duty of building professionals – architects, engineers, and contractors – to educate their clients about why they should build green. Education about green building also needs to spread beyond just the professional community and extend to realtors, developers, lenders, and others involved throughout the building supply chain (Lovins, 1995).

Education and awareness programs focus on a range of topics including, integrated design, energy savings measurement and verification, commissioning and retro-commissioning, and finance for green buildings. Training programs for construction workers are also important as the installation of green building technologies can often be more complex than that of conventional technologies. When a green building is commissioned, its users (the occupants) need to also be engaged to learn how to interact with the building and engage in its energy and water saving activities day to day.

Having the numerous stakeholders engage with each other in order to break down the “operational islands” mentioned in the section on institutional barriers will aid in establishing best practices in green building. Professional societies, such as the U.S. Green Building Council, offer opportunities for continuous education and are often a proponent of growing education and awareness about green building.

#### **4.2.4. Fiscal policy that supports green building investment**

There is a truly wide array of fiscal policy that could help increase green building investment, but each building market is unique in building types, geography and climate, and other factors. Therefore, the fiscal policy that is implemented should match the market in terms of these needs. It is also important to ask for how long each policy should be implemented and what its delivery mechanism should be (Levine, et al., 2012). Typically, fiscal policies that support green building investment fall into three categories: tax policy, incentives (subsidies and grants), and preferred financing.

Within tax policy, certain efficiency or green building investments may be granted certain tax exemptions to increase the attractiveness of those investments. Carbon and energy taxes have been discussed as important fiscal instruments for inducing higher levels of investment across the energy efficiency and renewable energy field.

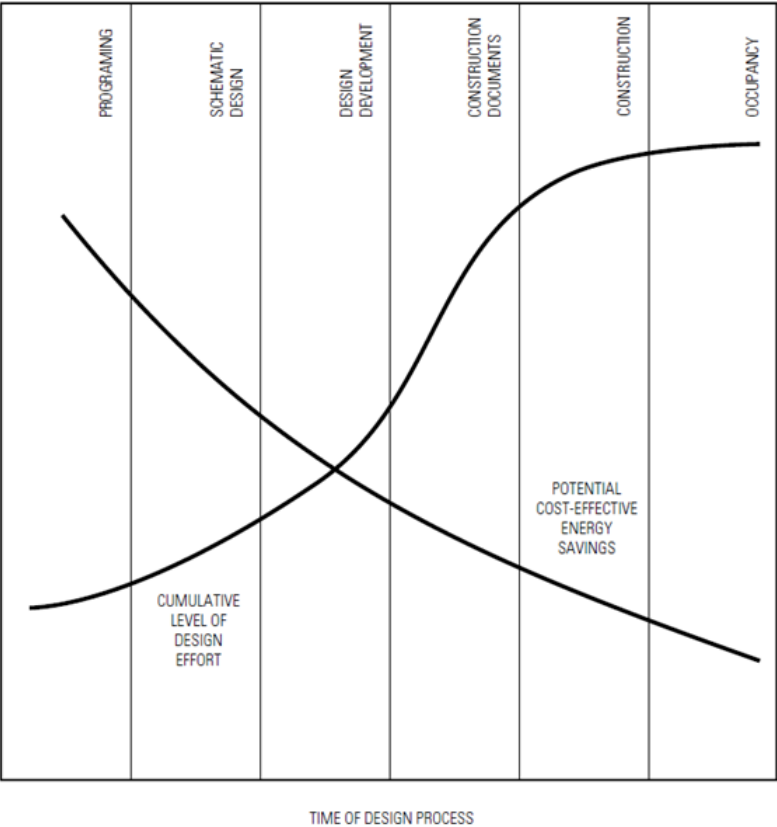
Within incentives, performance or investment based subsidies and grants are commonly used for new and existing construction. Performance based subsidies are ex-post awards generally used for whole building retrofits or new build. They are often granted on a dollar per kWh of energy saved basis to incentivize technologies that have proven savings as well as whole building approaches as opposed to measure specific. Investment-based grants are offered for a specific system within a green building (a solar PV array or an active shading system for a façade, for instance) where the first cost barrier is inhibiting investment.

Finally, there is the question of access to capital for green building projects. Generally, some investors view green building projects as inherently more risky than conventional buildings due to new technologies or less common building practices. Loan-loss reserve programs set up by the government can help defray some of this risk (Levine, et al., 2012). In general, though, as green buildings prove they can get higher rents from their occupants than from those of a conventional building, investors are taking more interest purely from the perspective of profits. For green building retrofits, energy service companies (ESCOs) are assuming all of the technical and performance risk in investing in the necessary upgrades and are then paid with a portion of the money gained from energy savings throughout the life

of the retrofit. These companies solve the problems of building owners having short investment time horizons due to their lack of cash and access to financing.

### 4.2.5. Integrated design promotion

The aforementioned policy mechanisms are all crucial to the success of the industry, but integrated design is perhaps the most important window of opportunity for deep energy savings in the built environment. As shown in Figure 10, the potential for cost-effective energy savings falls steadily as you step away from the early design stages and into the construction phases. Mechanical engineers are rarely consulted at the design phase, when the opportunity for savings in heating and cooling systems is greatest (Lovins, 1995).



**Figure 10: Energy savings opportunities and the design sequence (Lovins, 1995)**

While not every green building will need incentives or financing, every green building certainly does need integrated design. A number of jurisdictions around the world that are advanced in their promotion of green building have recognized the importance of integrated design and created programs to support it. Strategies include forming partnerships with industry and universities to promote education about integrated design, developing tools that enable the deployment of integrated design, and ensuring that normal building standards are advanced at a level that begins to incorporate integrated design (CPUC, 2011).

In the end, integrated design must be applied to each building individually. The Bullitt Foundation, which constructed the Bullitt Center in Seattle – an energy and water self-sufficient building, outlines the following building-level design steps for getting the most out of integrated design: 1) set aggressive goals; 2) analyze site and climate; 3) reduce energy use; 4) use efficient equipment; 5) use renewable energy; and 6) verify performance (Bullitt Foundation, 2013).

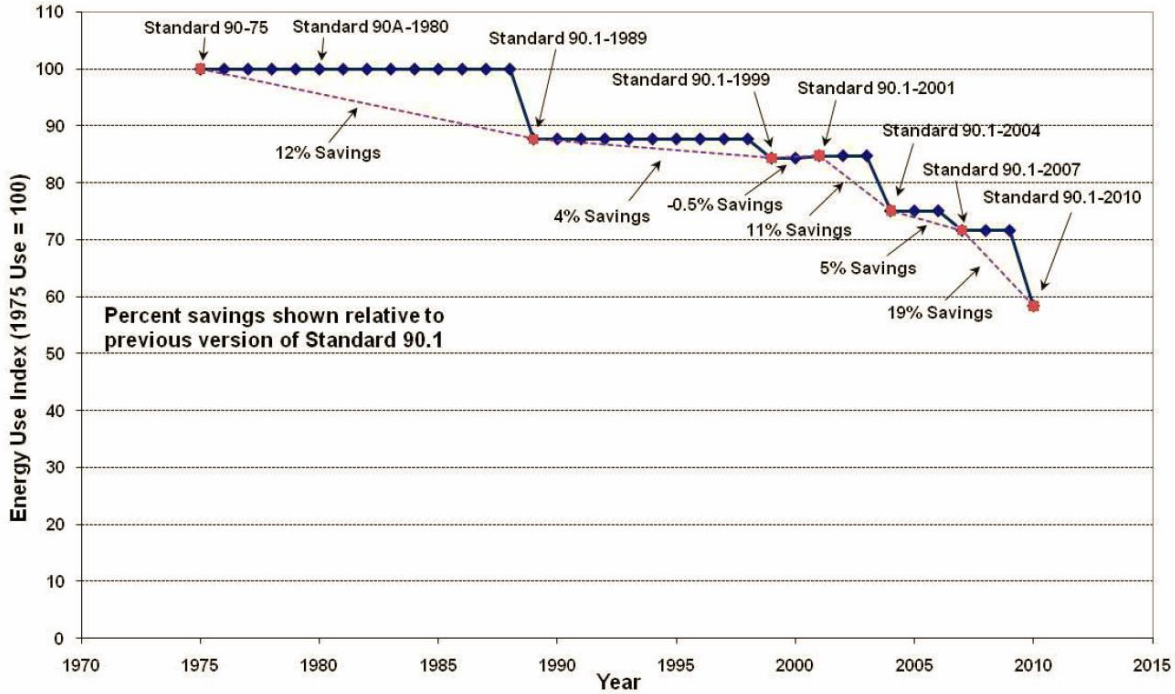
Each of these five policy mechanisms plays an important role in an overall green building policy package. Codes and labeling ensure that best practices will become common practices over time. Government-led targets and demonstrations will galvanize industry progress so that green building materials and technologies lower in price and green building practices will become increasingly familiar. Education and awareness campaigns will bring the various segments of built environment stakeholders together to learn and cooperate. Incentives and other fiscal policy will help reduce barriers to investment in new construction and retrofits. Finally, integrated design will ensure that each building is reaching its full technical and economic potential as a green building. The following sections will describe to what extent these policy mechanisms have been exercised to date in the U.S. and China.

### **4.3. Green building policy support in the U.S.**

#### **4.3.1. Codes and labeling plan**

In the U.S., there is federal legislation that requires states to initiate energy efficiency codes for new buildings. Additionally, under the recent American Recovery and Reinvestment Act (ARRA) of 2009, Congress mandated that any state receiving ARRA funds pledge to adopt energy efficiency codes of certain stringency and to achieve and measure 90% compliance with those codes by 2017. As of Fall 2011, 29 states had adopted residential and commercial building codes that met ARRA requirements. Yet, 11 states still do not have any codes, and even in states that have codes, compliance levels remain low (Building Energy Codes Program, 2010). Generally speaking, the most commonly used codes in the U.S. are the International Energy Conservation Code (IECC) for residential buildings (ICC, 2012) and American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 90.1 for commercial buildings (ASHRAE, 2013).





**Figure 11: History of commercial construction code revisions from 1975 to 2010**

Source: Building Energy Codes Program, 2010; Note: percent savings shown relative to previous versions of standard 90.1

Figure 11 shows how ASHRAE codes have been updated very regularly over time. Commercial buildings constructed according to the latest update of the ASHRAE standard in 2010 would be around 60% more efficient (energy use index falls from 100 to around 40) than that same building built according to the standard in 1975. Although not all states have adopted codes and compliance levels can be very low, at the very least, the professional societies that support code development are very active and ambitious in promoting an increase in the basic energy efficiency levels over time.

More recently, ASHRAE has released a high performance green building standard -- ASHRAE 189.1. ASHRAE 189.1 is not a rating scheme like LEED, but rather a green building standard using prescriptive and performance based evaluation. Focusing on new construction, ASHRAE 189.1 integrates site sustainability, water use efficiency, energy efficiency, indoor environmental quality, building's impact on atmosphere, materials and resources, and construction. The standard has mandatory criteria in all topical areas, and it offers a choice of prescriptive and performance options to achieve compliance. To some extent, ASHRAE 189.1 integrates ASHRAE 90.1 for energy efficiency, ASHRAE 62.1 for ventilation and indoor air quality, ASHRAE 55 for indoor thermal comfort, and ASHRAE 180 for HVAC system inspection. However, ASHRAE 189.1 does not simply adopt the other ASHRAE standards, but rather provides more stringent requirements. For instance, ASHRAE 189.1, for the first time, requires buildings to have on-site renewable energy sources that produce per roof area generation of more than 6 kBtu/hr-ft<sup>2</sup> for single story buildings, and 10 kBtu/hr-ft<sup>2</sup> for buildings with more than one story.

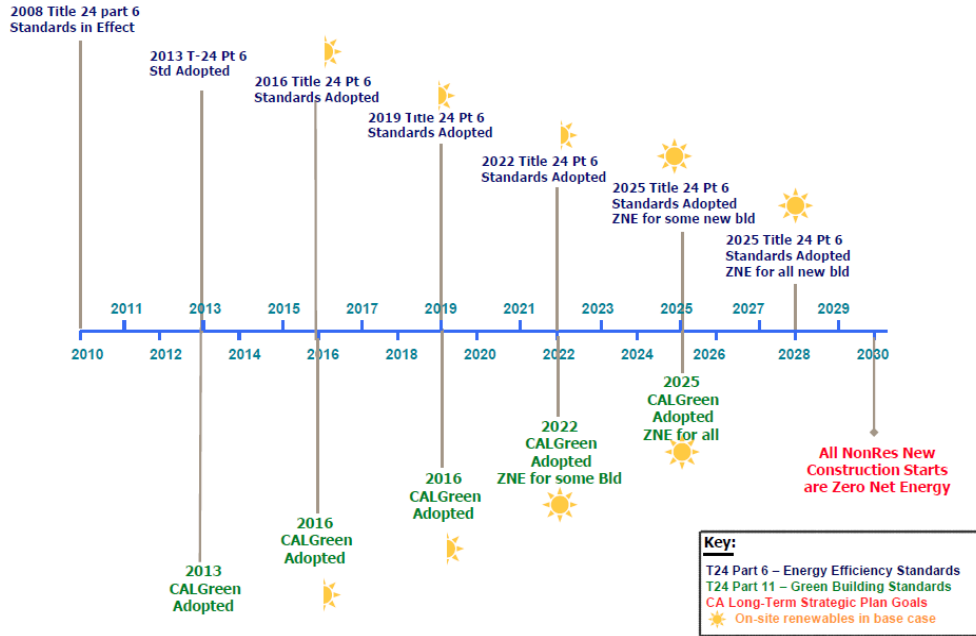
In addition to ASHRAE's development of their green building standard, the International Code Council (responsible for the administration of the International Energy Conservation Code mentioned previously) has also developed the International Green Construction Code (IGCC). IGCC builds off of the International Energy Conservation Code and other standards as well as offering ASHRAE Standard 189.1 as an alternate path to compliance. IGCC was developed using a governmental consensus process over an eight month period by a 29-member committee with input from over 100 working group members across several areas of expertise including government, business, code development and enforcement, architecture, building science, engineering, and environmental health.

Related to this code development are the voluntary ENERGY STAR labeling programs run by the U.S. Environmental Protection Agency (U.S. EPA). The first iteration of an ENERGY STAR for homes specification was launched in 1995, and it is now onto its third version. Qualified homes surpass 2009 IECC standards by at least 15%. This type of labeling development supports the ideas presented in Figure 13 on page 39, whereby labeling programs can help push the building industry to go beyond code and gradually bring greener building practices into the mainstream.

The U.S. EPA has also developed an ENERGY STAR label for commercial buildings, where buildings get scored on energy and water consumption using the ENERGY STAR Portfolio Manager tool on a scale from 1 (worst) to 100 (best) and any building with a score above 75 can receive the label. The difference between the ENERGY STAR labeling programs for homes and for commercial buildings is that the former involves a checklist of design and construction specifications while the latter requires an operational rating that is based on a given building's measured energy performance.

In addition to voluntary labeling programs, mandatory building labeling is beginning to gain traction in a number of state and local jurisdictions around the U.S. Currently, two states (California and Washington) and five large cities (Austin, New York City, San Francisco, Seattle, and Washington DC) require benchmarking and disclosure of building energy ratings, covering an estimated 60,600 buildings and more than 371 million m<sup>2</sup> of space (Burr, Keicher, & Leipziger, 2011).

The State of California, which has ambitious goals for net-zero energy buildings, has its own building efficiency and green building codes that it plans on ramping up over time to help the construction industry remain on track for reaching those goals. Established in 2010, the CALGREEN code defines mandatory minimum green building requirements for energy and environmental performance for all new buildings constructed in California, with separate codes for residential and non-residential construction. There are mandatory minimum requirements as well as voluntary tier 1 and tier 2 criteria of higher stringency. Tier 2 criteria will likely be in line with net-zero energy requirements, and voluntary adoption will be encouraged at the local level (for cities with more ambitious climate goals, for example). California's mandatory building efficiency codes (known as Title 24) will also become more stringent over time. The end goal is that all new non-residential construction will be net zero energy in 2030 (2020 for new residential construction) (CEC, 2011).

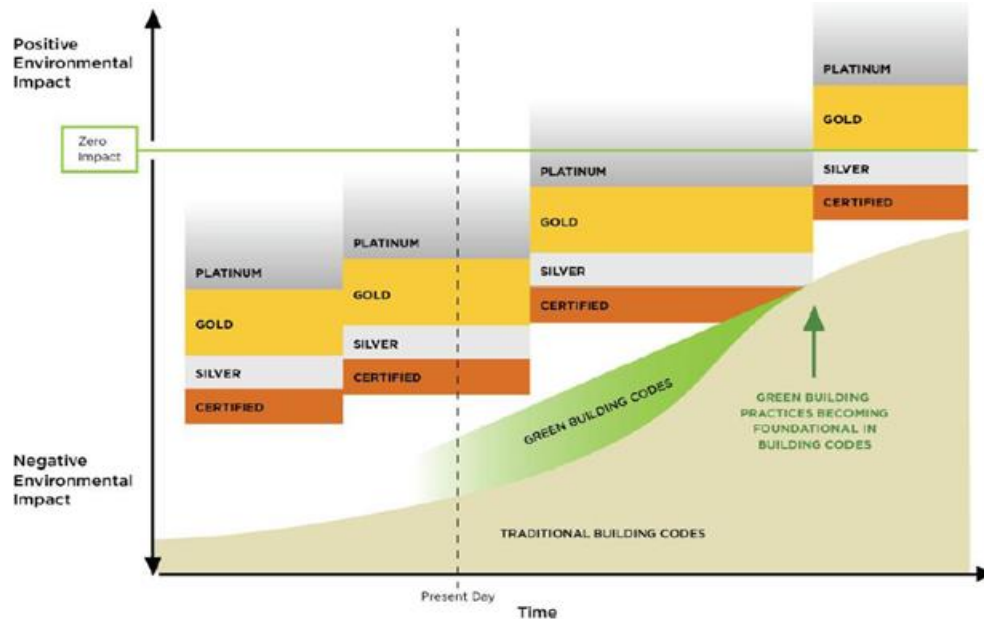


**Figure 12: California potential plan for energy efficiency and green building code updates leading to net zero energy goals**

Source: CEC, 2011

Figure 13 shows one scenario for how existing LEED labeling codes may increase over time until gold and platinum ratings reach the level of zero-impact buildings. Additionally, traditional building codes will become more stringent over time, eventually incorporating green-building practices directly. Green building codes would help fill in the functional gap between traditional building codes and green building rating systems such as LEED, which is precisely the role that CALGREEN and ASHRAE 189.1 are now playing. This figure really helps put green building labeling programs into the perspective of the broader built environment and the eventual goal of having net-zero energy buildings (along with other zero impact metrics, such as net-zero water and net-zero waste).

Overall, the U.S. has code development that is strengthening over time and a number of voluntary and mandatory labeling programs which are contributing to the overall health of the green building industry. So long as compliance rates and compliance thresholds for these codes and labeling programs continue to increase, then these policies will help “pull” more green construction practices into the building industry.



**Figure 13: Evolution of LEED codes over time toward net-zero impact buildings**

Source: Sigmon, 2012

#### 4.3.2. Government-led targets and demonstrations

Federal, state, and local government agencies have been very active in leading green building developments through demonstrative, legislative, and innovative program efforts. They were early adopters of LEED standards, and in fact the U.S. Department of Energy (DOE) was an early funder of the USGBC when it was first developing LEED standards. As of the end of 2004, only 84 buildings had completed LEED certification processes, and 42% of those were for federal, state, or local government buildings (Payne & Harris, 2004).

In the area of legislation, 16 federal government agencies joined in 2006 to sign a memorandum of understanding, “Federal Leadership in High Performance and Sustainable Buildings MOU”, which established early commitments to energy and water efficiency in federal buildings. For instance, new construction at the time was to be 30% more efficient than ASHRAE 90.1-2004. Later, the foundations that this MOU laid were formalized into Executive Order 13423, signed by President Barack Obama. This order accounted for activities beyond buildings into transportation, acquisition, and other areas. Relevant to green buildings, the following requirements were laid out:

*“(i) beginning in 2020 and thereafter, ensuring that all new Federal buildings that enter the planning process are designed to achieve zero-net-energy by 2030;*

*(ii) ensuring that all new construction, major renovation, or repair and alteration of Federal buildings complies with the Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings, (Guiding Principles);*

*(iii) ensuring that at least 15 percent of the agency's existing buildings (above 5,000 gross square feet) and building leases (above 5,000 gross square feet) meet the Guiding Principles by fiscal year 2015 and that the agency makes annual progress toward 100-percent conformance with the Guiding Principles for its building inventory;*

*(iv) pursuing cost-effective, innovative strategies, such as highly reflective and vegetated roofs, to minimize consumption of energy, water, and materials;*

*(v) managing existing building systems to reduce the consumption of energy, water, and materials, and identifying alternatives to renovation that reduce existing assets' deferred maintenance costs;*

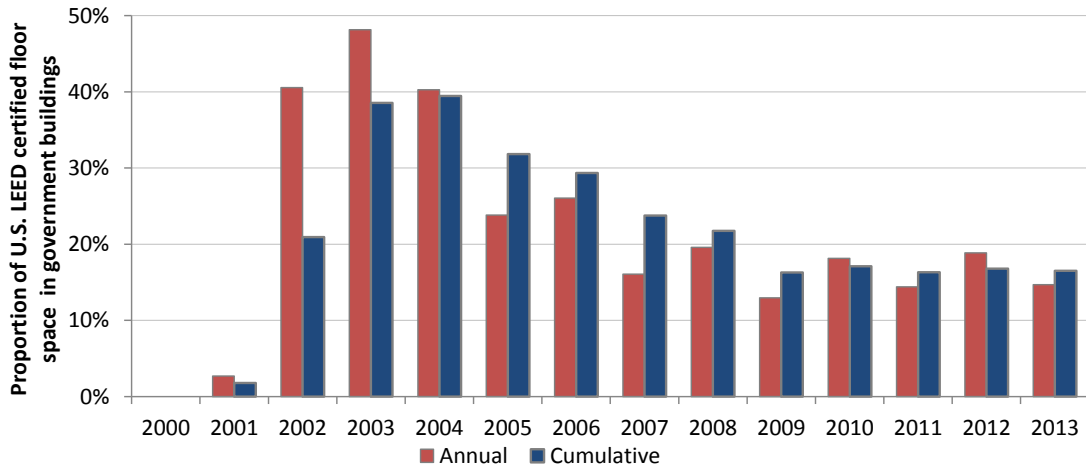
*(vi) when adding assets to the agency's real property inventory, identifying opportunities to consolidate and dispose of existing assets, optimize the performance of the agency's real-property portfolio, and reduce associated environmental impacts; and*

*(vii) ensuring that rehabilitation of federally owned historic buildings utilizes best practices and technologies in retrofitting to promote long-term viability of the buildings;" (Obama, 2009)*

The most significant targets are the 15% target for 2015 (iii) and the net-zero energy target for 2030 (i). The order has significant teeth as well; the Office of Management and Budget now annually evaluates progress towards these goals for every federal agency.

The federal government's General Services Administration (GSA) has been a leader in LEED adoption and general sustainable building practices. Their Public Buildings Service acquires space on behalf of the federal government through new construction contracts as well as leases and as such manages over 370 million square feet of workspace. The GSA has implemented an innovative new program called the Green Proving Ground (GPG) whereby it uses this huge amount of floor space as a laboratory for new green building technologies and practices. The GSA selected 16 technologies to be a part of the GPG program: high R-value windows, smart windows, occupant responsive lighting solutions, integrated daylighting systems, plug load reduction, on-site renewable technologies, solar photovoltaics (PV), PV with solar water heating, various HVAC technologies (chilled beams, condensing boilers, variable-speed chiller plant controls, magnetic bearing compressors, variable refrigerant flow, commercial ground-source heat pumps, wireless mesh sensor network), and non-chemical water treatment (Kandt & Lowell, 2012). The program is a good example of federal money and resources coming together to produce two things: 1) technology validation with measurement and verification of in-field technology testing and 2) successful demonstration case studies. This program directly addresses major informational barriers in the field of green building technologies. Soon, there will be a myriad of performance data, which can hopefully lower the perception of risk for these technologies common amongst architects and contractors.

In addition to legislative and programmatic efforts by federal agencies, a number of state and city governments are taking aggressive action. California is leading the way with its net zero energy building goals. The California Public Utilities Commission (CPUC) created a strategic plan calling for, among other energy-efficiency goals, net-zero-energy commercial buildings by 2030 and net-zero-energy residential construction by 2020 (CPUC, 2011). Meanwhile, the City of Austin, Texas has perhaps the most aggressive goal in the country: All new residential construction will need to be net zero energy capable by 2015. A home is zero-energy capable when it is energy-efficient enough to achieve net-zero energy consumption over the course of the year with the addition of on-site renewables. The City of Austin defines a net-zero capable home as a single-family home that is 65% more energy-efficient than a typical home built to the Austin Energy Code in 2006. San Francisco also has aggressive green building goals. Their 2008 Green Building Ordinance requires new commercial construction and major renovations over 5,000 square feet to have basic LEED certification. In 2010, similar new construction will have to reach LEED Silver certification levels, and in 2012 they will have to reach LEED Gold. A study done in 2004 noted that 17 municipal governments (other than the ones already mentioned) had LEED requirements that largely mandated that all new construction should be LEED certified (Payne & Harris, 2004). Data from the USGBC show that government buildings accounted for a significant amount of LEED-certified floor space in the early years of the program (Figure 14). In the early years of the program (2002-2004), 40% or more of newly LEED certified floorspace in any given year was in government buildings at the federal, state, or local levels. According to the USGBC, there are 14 federal agencies or departments, 30 state governments, and 400+ local governments with LEED initiatives (USGBC, 2013).



**Figure 14: Proportion of U.S. LEED certified floor space that is in government buildings**

Another local government policy to stimulate green building has been the offer of expedited permitting for buildings going for a LEED certification. The State of Hawaii recently required priority processing for all construction or development permits for projects that achieve LEED Silver or similar requirements (DOE, 2012). Other localities that have similar requirements include Dallas, Gainesville, San Diego, Los Angeles, San Francisco (LEED Gold), Santa Monica, and Washington, DC.

Across the U.S., government-led targets and demonstrations galvanized significant levels of green building activity. Early adoption of LEED standards helped establish a pattern of leadership in many federal agencies, which later led to a significant Executive Order. For federal agencies and municipalities, which often have long investment time horizons and own the properties they use, green building is making smart financial sense as well. Gradually, their adoption should lead to a larger market transformation (more experienced architects and builders, lower costs, fewer barriers) so that green-building practices can be adopted more widely.

#### **4.3.3. Education and awareness programs**

The USGBC has 77 chapters across the U.S., comprised of 30,000 professionals, students, and volunteers (USGBC, 2013). These chapters offer continuing education on green building, fostering information and best practice sharing. They also provide support to the LEED professional accreditation program, which has been important in growing knowledge and training surrounding green building while creating an avenue for hiring managers in the buildings industry to identify who has this knowledge and training. Accreditation can be received for the following area: Building Design and Construction, Operations and Maintenance, Interior Design and Construction, Homes, and Neighborhood Development.

Specialized workforce development for construction workers and contractors is crucial to the overall success of the green building industry, as most of the professional workforce is unfamiliar with the relatively new practices of green building in comparison to conventional building practices that are part of standard education packages at professional institutes, community colleges, and universities. A study in 2010 noted that progress was being made in this area, with training programs for the building industry on target to train over 12,000 residential contractors per year in green and performance buildings by 2012. Additionally, \$500 million in ARRA funding was granted to the Department of Labor in 2010 for green workforce development. Furthermore, \$64 million of ARRA funds used by state energy programs specifically went to support energy efficiency training programs. A 2010 study found that most of the energy efficiency service sector suffers from a shortage of trained and knowledgeable workers, and that more college and university-base curriculums are needed to fill in this knowledge gap (Peters, et al., 2010).

#### **4.3.4. Fiscal policy that supports green building investment**

Cash grants and tax credits are the two most commonly used fiscal instruments used in the U.S. to promote green building at the state and local level. Within grants, one example is the State of Pennsylvania's grant program for public schools that are seeking LEED certification. The grant will help cover costs related to the certification process itself, including "building energy simulations and daylight modeling, green coaches and specialty consultant fees, design fees for additional services beyond those conventionally covered, and help with LEED for Schools certification costs" (State of Pennsylvania, 2013). El Paso, Texas came up with a grant program that targeted high performance new construction (LEED platinum) with a maximum \$200,000 grant. Larger grants up to \$400,000 were offered for "multistory existing buildings" that are mixed use and have high vacancy rates, showing how the city believed promotion of LEED could spur new economic development where growth had been stagnant.

In the realm of tax credits, various jurisdictions typically offer tax credits for income or property taxes. The State of New York offers a Green Building Tax Credit Program, provides an income tax incentive to commercial developments incorporating specific green strategies informed by LEED. In Baltimore County, Maryland, the county council passed a bill stating that new residential construction projects would earn 40%, 60%, and 100% property tax credits for Silver, Gold, and Platinum buildings respectively, effective for either three years or up to \$1 million in total tax credits per project. New commercial construction projects would earn 50%, 60%, and 80% tax credits for Silver, Gold, and Platinum buildings for five consecutive years. For existing commercial buildings getting an Existing Building rating from LEED, 10%, 25%, and 50% tax credits were offered for up to three years (DOE, 2012).

#### 4.3.5. Integrated design promotion

The State of California recognized early on its planning stages for net-zero energy building goals that integrated design would play a very important role in achieving very high levels of energy efficiency. CA integrated design plan. In its 2011 strategic plan for energy efficiency, it outlined the following three strategies to help stimulate activity in the area of integrated design:

*“Strategy 1: Form partnerships with industry and architectural/engineering schools and colleges to promote the education and practice of Integrated Building Design and Operations.*

*Strategy 2: Develop an RD&D roadmap and identify/develop tools and protocols for building commissioning, retro-commissioning, and measurement and verification (M&V) to enable the deployment of Integrated Design and Operations.*

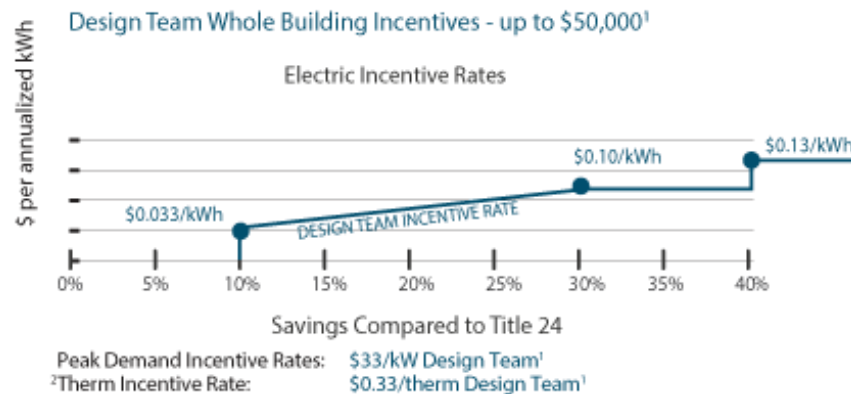
*Strategy 3: Promote Integrated Design development by advancing California Building Standards (Title 24) and market activities.” (CPUC, 2011)*

As noted in the education and awareness section, more training and education is needed, especially in the field of integrated building design and operations. California also plans to advance its Title 24 building codes to “pull” more green building activity into the market. As for other market activities, Savings by Design is one statewide program that California is running to encourage high performance commercial building design and construction. It is sponsored by California’s four investor-owned utilities and offers building owners, investors, and design teams the following basic services:

- Design assistance: provide analysis and information
- Owner incentives: assist owners with any higher upfront investment costs for energy efficient building technologies
- Design team incentives: rewards for design teams that meet assigned energy efficiency targets
- Energy design resources: toolbox and resources to help facilitate integrated design of net-zero energy buildings



Design team incentives help teams to explore levels of energy efficiency that go beyond code, while compensating for the extra time needed for this exploration. This extra time and money is a major barrier for why integrated is not practiced more commonly, especially in the U.S. market where architecture and design firms often bid for projects against many other bidders. Since they have a low rate of success in bidding, they shy away from spending too much time on any one design. The design incentives work as shown in Figure 15.



**Figure 15: Design team incentives under California’s Savings by Design program**

The program has a model that calculates the energy savings of the building design as compared to California’s Title 24 codes. If the design saves at least 10% beyond the codes, then they qualify for incentives beginning at \$0.033 per annualized kWh and ramping up to \$0.10 per kWh for electricity savings and \$0.333 per therm for gas savings. The maximum incentive per project is \$50,000 (CPUC, 2013). This innovative program is quite unique. Although strategic planning, education, and incentives will all continue to play growing roles in the field of integrated building design and operations, widespread application of these ideas has yet to be seen.

#### 4.4. Green building policy support in China

As opposed to the U.S., where this is a mixture of policy support from federal agencies, local governments, and professional organizations, green building policy in China is mostly dictated by the national government and then implemented at a local level. However, there is an increasing level of activity by local city governments that goes beyond national requirements, especially as interest grows in low-carbon cities and eco-cities. The following tables contain information about China’s policies in building energy efficiency and green building. Table 6 outlines targets for the 11th Five Year Plan (2006-2010) and achieved progress, while Table 7 outlines targets for the 12th Five Year Plan (2011-2015). Table 7 delineates two different types of targets in China’s 12<sup>th</sup> Five Year Plan – binding and expected. Binding targets have some enforcement mechanism backing them (often related to the promotion or demotion of officials whose localities fail to reach a target or compliance level). Expected targets are aspirational goals that the country hopes to reach but for which there are punitive ramifications if the goal is not met.

**Table 6: Building efficiency goals in China’s 11th Five Year Plan**

Area	Target	Progress
<b>Energy efficiency – new construction</b>	Implementation of building codes at construction stage greater than 95%	95.4%
<b>Low-carbon, green building demonstration zones</b>	30 zones	217 green building demonstrations of which 113 buildings received the green building label
<b>Metering and EE retrofits for heating residential building systems in northern region</b>	150 million square meters	182 million square meters
<b>Large commercial building energy management and retrofits</b>	Implement building energy monitoring systems for government office buildings and large commercial buildings	Collected energy use statistics for 33,000 buildings, energy audits for 4,850 buildings, commercial energy labels for nearly 6,000 buildings, dynamic energy monitoring in 1,500 buildings with comprehensive dynamic energy monitoring platforms for nine provinces or provincial level cities, implementing energy efficient building pilots on 72 campuses
<b>Demonstration of renewable energy in buildings</b>	200 demonstrations	371 renewable energy demonstration projects, 210 building integrated solar photovoltaic demonstration projects, 47 renewable energy building city, 98 demonstration counties

Source: MOHURD, 2012

**Table 7: Building energy efficiency targets in China’s 12th Five Year Plan**

Area	Target	Type of target
<b>New construction</b>	EE of new urban construction no lower than 65% of “energy efficient” level, 95% of new construction meets mandatory EE standards	Binding
<b>Existing residential building retrofits</b>	North region	Metering and EE retrofits for heating residential building systems in northern region for 400 million square meters
	Transition and south region	50 million square meters of residential building retrofits
<b>Large public building energy management and retrofits</b>	Monitoring system	Increase energy use statistics, audits, public display of energy use, energy efficiency quota system
	Monitoring platform	Comprehensive dynamic energy monitoring platforms for twenty provinces, dynamic energy

		monitoring for 5,000 buildings, energy efficient building pilots on 200 campuses	
	EE operations and retrofits	10 city pilots for major commercial building EE retrofit programs, with total retrofits to reach 60 million square meters, 50 retrofitted university campuses	Binding
		Commercial buildings reduce energy consumption per unit area by 10%, and 15% for medium to large commercial buildings	Expected
<b>Renewable energy application in buildings</b>		250 million square meters of new construction with renewable energy applications, achieving 30 mtce in energy savings	Expected
<b>Large scale promotion of green building</b>	Promote green building	Implementation of 100 green building demonstration cities	Expected
	Government investment in commercial buildings	80% of government-invested new construction at schools, hospitals, and other commercial buildings and 70% of affordable housing projects to enforce green building standards	Binding
	Real estate sector	>20% of new construction should be green in the following jurisdictions: Beijing, Shanghai, Tianjin, Chongqing, Shenzhen, Dalian, Xiamen, Jiangsu, Zhejiang, Fujian, Guangdong, and Hainan	Binding
<b>Promotion of EE building materials</b>		Energy saving building material to account for >60% of total building material production, >70% of total construction materials	Binding

Source: MOHURD, 2012

#### 4.4.1. Codes and labeling plan

China has comprehensive energy efficiency codes for both residential and commercial buildings that include provisions tailored to China's wide range of climate zones. Although there are questions about the data, MOHURD declared that 95.4% of new construction had achieved compliance at the construction stage in its review of the 11<sup>th</sup> Five Year Plan targets.

For residential buildings, China has three residential building energy-efficiency design standards, which cover four out of the five climate zones and apply to new residential construction, expansions, or retrofits. Each design standard has its own reduction target for heating energy consumption relative to a baseline. For commercial buildings, China has a national design standard that took effect in 2005 (JGJ 50189-2005) and covers new construction, expansions, and retrofits. The standard looks at building envelope and HVAC systems and sets a goal of reducing lighting and HVAC energy use by 50% compared with a baseline of buildings from the 1980s (Levine, et al., 2012). A revision of this standard is expected to be released in early 2014. The recent green building action plan released by MOHURD encouraged

regional level implementation of codes that are stricter than these national codes as well as regular and scientifically reasonable increases in the stringency of existing codes.

As detailed in Table 6 and Table 7, the central government has begun promoting building energy end-use data monitoring platforms through various pilots in large commercial buildings, which could be seen as a primitive form of mandatory labeling. Incentives are also provided in some cases. Universities are eligible for subsidies in the amount of CNY 5 million (USD 0.8 million<sup>3</sup>) to establish an energy end-use monitoring platform if it results in a 15% reduction in measured energy consumption. Cities are also eligible for subsidies of CNY 15 million (USD 2.5 million) per city to establish energy end-use monitoring platforms (Wu, 2012). The government is also supportive of opening this data up to the public through public information systems and displays.

#### **4.4.2. Government-led targets and demonstrations**

Table 6 and Table 7 list energy efficiency retrofit, green building, and building integrated renewable energy targets for the 11<sup>th</sup> and 12<sup>th</sup> Five Year Plans. Green building targets in the 12<sup>th</sup> Five Year Plan, specifically, are “government-led” in that they are mandating that the large majority of government-invested commercial building will need to be efficient enough to receive a rating under China’s Green Building Rating System.

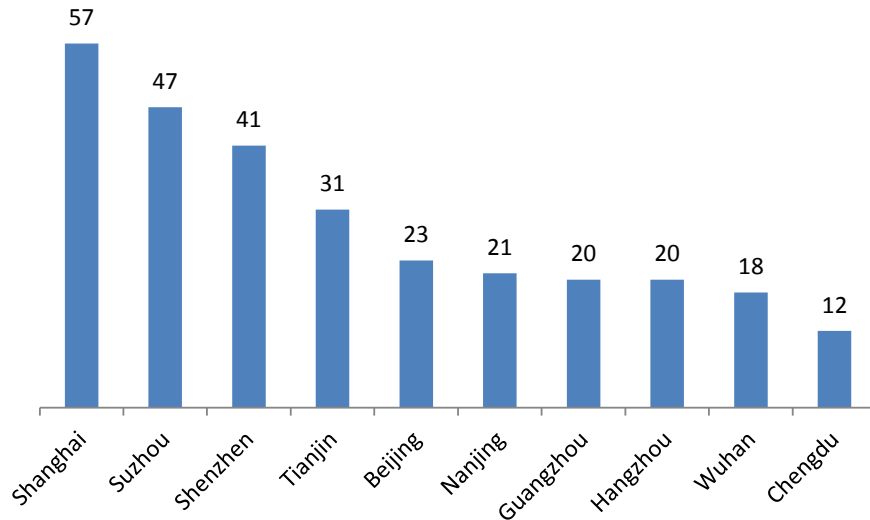
In the 11<sup>th</sup> Five Year Plan, China completed 217 green building demonstration projects, 113 of which ended up receiving a rating under China’s Green Building Rating System. Targets for building integrated renewable energy (such as geothermal heating and cooling, solar hot water heating, and solar photovoltaics) have gone from a targeted number of demonstrations in the 11<sup>th</sup> Five Year Plan to a total floor space target of 250 million square meters in the 12<sup>th</sup> Five Year Plan, which is expected to achieve 30 Mtce in energy savings.

In 2013, the State Council and Ministry of Housing and Urban Rural Development (MOHURD) issued the “green building action plan”, which increased some of the targets seen in 12<sup>th</sup> Five Year Plan. During the 12th FYP, there is a cumulative target to build 1 billion square meters of green building floorspace. By 2015, 20% of new urban construction should meet at least the basic level of China’s Green Building Rating System. While the 12<sup>th</sup> Five Year Plan stated that 80% of government-invested new construction at schools, hospitals, and other commercial buildings should achieve a green building rating, the action plan does not mention this percentage and says such a green building rating is required for all government-invested construction of such types.

While 113 projects had received a rating by the end of 2010, nearly 500 projects had a received a GBEL as of the end of August 2012. Out of 494 projects, 60% were found in one of ten cities: Shanghai, Suzhou, Shenzhen, Tianjin, Beijing, Nanjing, Guangzhou, Hangzhou, Wuhan, and Chengdu (Figure 16).

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<sup>3</sup> USD equivalent is based on approximate conversion using 2010 average currency exchange rate of 6.05 Yuan per USD.



**Figure 16: Top ten cities by number of GBEL approved projects, as of Aug. 2012**

Many of these cities have specific local policies that are providing an extra impetus for green building development, going beyond national policies. For instance, the Shenzhen Development and Reform Commission, in its medium to long-term plan for low carbon development, announced a target that 40% and 80% of new construction should have GBEL rating by 2015 and 2020, respectively (Shenzhen Development and Reform Commission, 2012). In Suzhou, 30% of new construction should have GBEL rating by 2020, while in Nanjing, 40% of new construction should have GBEL rating by 2015. At the end of 2013, Chongqing, which only had 5 GBEL projects as of 2012, announced its own green building action plan, requiring that all new commercial construction within its main district would have to be at least of a 1-star GBEL rating. By 2015, all new residential construction within its main district would also have to meet the same requirement. Lastly, by 2020, all new construction within the entire area of Chongqing would have to be of at least a 1-star GBEL rating (Chongqing Municipal Government, 2013). Municipal governments are clearly taking steps to hasten the development of the green building industry. In addition, the Shenzhen Institute of Building Research and Shanghai branch of the Chinese Academy of Building Research are also taking active steps to promote green building, as evidenced by the high number of green building projects in those cities.

#### **4.4.3. Education and awareness programs**

Because building energy efficiency - and green buildings even more so – are relatively new areas for the Chinese building industry, there are virtually no education and awareness programs designed to either promote the concept of green buildings or strengthen the workforce capacity needed to support green building development. At present, training efforts are still focused on bolstering the capacity for implementing building energy codes and have not expanded to the broader scope of green buildings. In meeting building energy efficiency codes – which have existed since the 1980s – significant challenges and capacity limitations have been identified for both the design and construction workforces. These include lack of knowledge about new building materials and technologies in building design companies; and lack of knowledge in identifying the quality of building materials, incremental cost barriers for better building materials and lack of knowledge of building techniques in construction companies (Shui

et al. 2011). These challenges show that in addition to continuously strengthening the abilities of design and construction companies to meet building energy codes, more targeted educational, training and awareness programs are needed to help accelerate the Chinese green buildings industry.

#### **4.4.4. Fiscal policy that supports green building investment**

In the 11<sup>th</sup> Five Year Plan, China implemented a number of financial incentive programs focused on efficient lighting, whole building retrofits, and rooftop or building integrated rooftop solar PV systems. New financial incentive programs are also under way for the 12th Five-year Plan period, and a couple programs are specifically related to green building as opposed to energy efficiency retrofits. MOF and MOHURD have announced additional financial incentives in support of the development and expansion of green buildings over the coming decade. For 2012, financial incentives of CNY 45 (USD 7) per square meter are offered for qualifying Two-Star rated green buildings under the Green Building Energy Label program and CNY 80 (USD 13) per square meter offered for Three-Star rated green buildings (People's Daily, 2012). In addition, the central government is also supporting the construction of green eco-cities and eco-districts with total funding allocation of CNY 50 million (USD 8 million). These new financial incentives are intended to help China meet its targets of constructing 1 billion m<sup>2</sup> of additional green buildings by 2015 and green building share of 20% of total new construction by 2015 (People's Daily, 2012).

#### **4.5. U.S.-China green building policy comparison**

Table 8 summarizes the previous policy sections for U.S. and China across the five major areas of policy support. Within codes and labeling, neither the U.S. nor China has a plan by which they have explicitly scheduled improvements in building codes and labeling programs over time that will lead to a high penetration of increasingly efficient and green buildings over time. Yet, both countries have comprehensive codes and labeling systems, with frequency of updates for these systems varying between the two countries. In the U.S., it is up to individual states to implement building efficiency codes, which are largely based off of codes developed and frequently updated by professional societies (such as ASHRAE and IECC). In China, national level building efficiency codes are established by government committees. The codes are not updated as frequently as in the U.S., but a major update is expected for commercial building codes soon.

The involvement of professional societies and industry in the development of green building labeling systems also varies between the U.S. and China. The USGBC's larger programmatic efforts in education and professional development for LEED were key to LEED's increasing popularity over the years. Additionally, committee leads for LEED requirement development and revisions are largely from industry (developers, building materials, professional societies), which keeps the LEED requirements relevant and applicable to current best practices in the green building industry. The GBEL rating development process in China is government-driven, and perhaps, somewhat closed off from industry which may be one reason for an initial slow uptake. More professional development may be needed to spur interest and abilities in using the GBEL rating system.

**Table 8: U.S. and China green building policy comparison**

<b>Policy</b>	<b>U.S.</b>	<b>China</b>
<b>Codes and labeling plan</b>	Codes: States implement codes largely based off of codes developed by professional societies, compliance levels vary widely Labeling: LEED system established in 2000 is popular and growing steadily, requirements updated regularly (LEED v4 was released in late 2013)	Codes: National level building efficiency codes for residential and commercial buildings, compliance occurs at design stage Labeling: GBEL system established in 2007 with uptake slow at first but now growing more rapidly, update for GBEL expected
<b>Government-led targets and demonstrations</b>	Municipal and federal level LEED building mandates helped galvanize early LEED activity	12 <sup>th</sup> Five Year Plans has requirements that 80% of new large commercial buildings will need to have GBEL rating; many cities have more aggressive targets
<b>Education and awareness programs</b>	LEED education and professional development key to success; LEED committee leads come from industry and professional societies improving quality, applicability, and popularity of LEED standards	GBEL process is entirely government driven, with missed opportunities to involve other stakeholders; workforce development and education is lacking
<b>Fiscal policy</b>	Grants and tax credits available at local level; evidence of rent and sale price premiums for LEED buildings	Tiered incentives available for 2-star and 3-star GBEL buildings; higher upfront cost of green buildings remains a barrier
<b>Integrated design promotion</b>	Integrated design incentives available in California and some other states	None

In the realm of government-led targets and demonstrations, this seems to be an area where the U.S. and China share some common ground. Government-led mandates at the federal and municipal level to build to LEED standards helped galvanize green building activity in the U.S. in the early 2000's. China is embarking on a similar approach in its 12th Five Year Plan, requiring GBEL for 80% of all new commercial buildings. Although these approaches are similar, approaches to fiscal policy that supports green building investment differ between U.S. and China. In the U.S., small grants and tax credits are used to spur LEED activity, while in China, incentives are offered on a per square meter basis to get developers interested in designing and constructing 2-star and 3-star buildings.

These different approaches may be due to a difference in barriers in each country. In China, the upfront costs to green building may be more of a barrier in the U.S. where research has shown that green buildings only have higher costs by a couple percent and command significantly higher rental rates. Therefore, direct cash incentives in China are offered to help defray those initial upfront costs. As seen

in Table 9, the increased capital costs for one-star buildings in China is relatively low, and as such no incentives are offered for that building type in the 12<sup>th</sup> Five Year Plan.

**Table 9: Increased capital costs for green buildings in China based on government reports**

<b>Rating</b>	<b>Average incremental capital cost in residential buildings CNY/m<sup>2</sup> [USD/m<sup>2</sup>]</b>	<b>Average incremental capital cost in commercial buildings CNY/m<sup>2</sup> [USD/m<sup>2</sup>]</b>	<b>Payback period (years)</b>
<b>One star</b>	60 [10]	30 [5]	1-3
<b>Two star</b>	120 [20]	230 [38]	3-8
<b>Three star</b>	300 [50]	370 [61]	7-11

Source: (MOHURD, 2012)



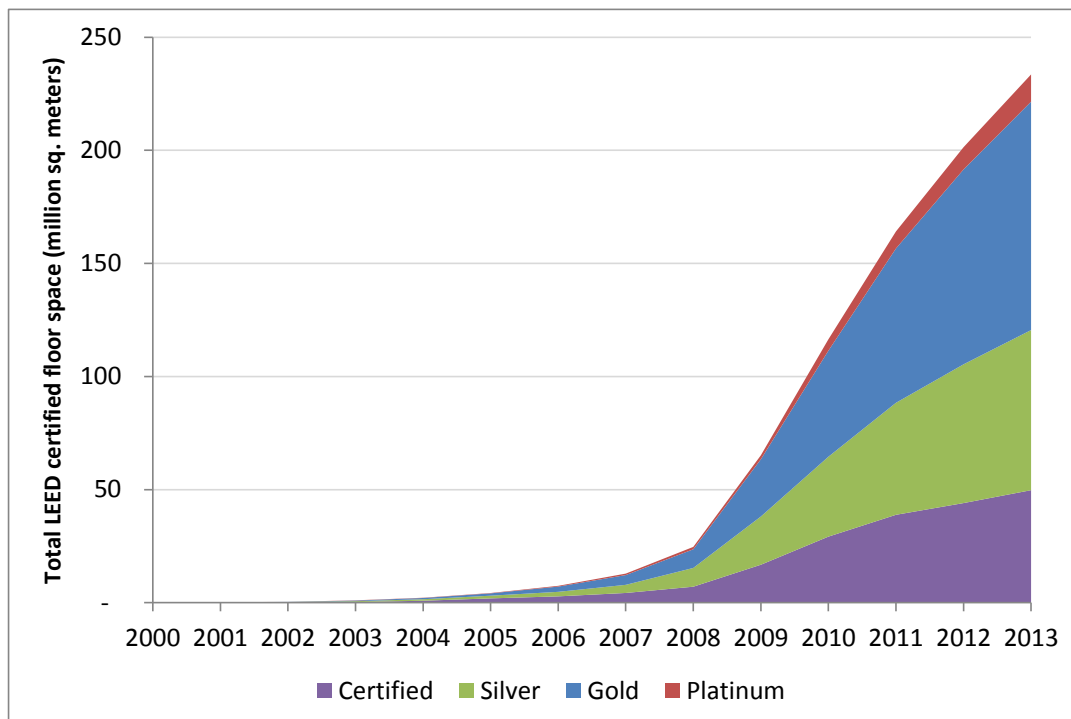
## 5. Green building market development in the U.S. and China

In a 2011 report by Rob Watson, the so-called “father of LEED”, data and projections on LEED certified floor space were presented. While registrations for LEED have grown around 40% per year on average for the past 12 years, certifications have begun to slow in recent years, with 2010, 2011, and 2012 annual certified floorspace growth rates of 79%, 41%, and 23% respectively. In 2013, there was more than 3.2 billion square feet (~293 million square meters) of LEED certified floorspace globally, with 80% of that in the U.S. The 2 billion square feet mark was passed at some point in 2012, with the first one billion of those square feet taking 9 years to accumulate, and the second billion only taking 3 years to accumulate (USGBC, 2013). So the LEED certification market is definitely growing exponentially, and LEED certified buildings accounted for roughly 20% of new floorspace in 2011. Watson’s projections are more than 10 billion square feet (~1 billion square meters) of LEED certified floorspace in 2020 and more than 28 billion square feet (~2.6 billion square meters) in 2030 (Watson, 2011). Official data from the USGBC on the growth in LEED-certified floorspace is shown in Figure 17, where a clear increase in the rate of uptake can be seen after 2008.

**Table 10: Data and projections for LEED-certified floorspace globally**

Timeline	Square feet of certified floorspace	Square meters of certified floorspace
2013 cumulative (Oct.)	3,158,000,000	293,371,000
2020 projection	10,517,000,000	977,061,000
2030 projection	28,313,000,000	2,630,364,000

Source: (2013 cumulative: USGBC, 2013; Projections: Watson, 2011)



**Figure 17: LEED certified floor space in the U.S. by certification level (2000-2013)**

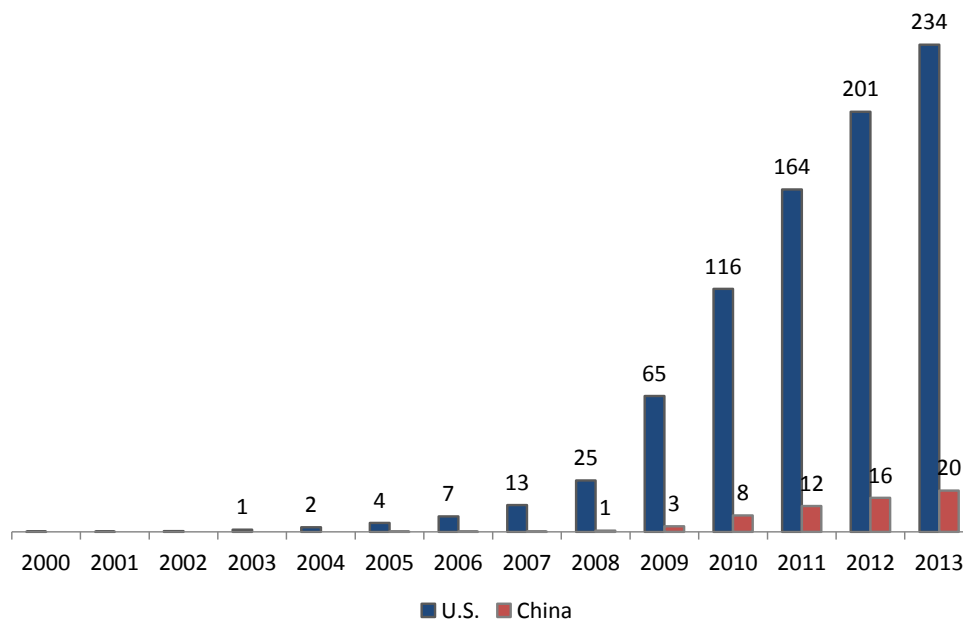
Watson’s report also goes into detail on a number of studies that have looked at the rental and sales price premiums that LEED-certified buildings are able to get in comparison to conventional buildings. LEED certified buildings can get anywhere from 5-17% higher rents and from 11-25% higher sales prices as shown in Table 11 (Watson, 2011).

**Table 11: Summary of US Green Office Value Studies**

Study	Rental Premium	Sales Premium
Fuerst & McAllister (2011)	Energy Star 4%	Energy Star 26%
	LEED 5%	LEED 25%
Eichholtz et al (AER)	Energy Star 3.3%	Energy Star 19%
	LEED 5.2%	LEED 11%
Eichholtz et al (RICS)	Energy Star 2.1%	Energy Star 13%
	LEED 5.8%	LEED 11%
Pivo & Fisher	2.7%	8.5%
Wiley et al (2010)	Energy Star 7-9%	Not addressed
	LEED 15-17%	LEED 16-18%
Miller et al (2008)	9%	None

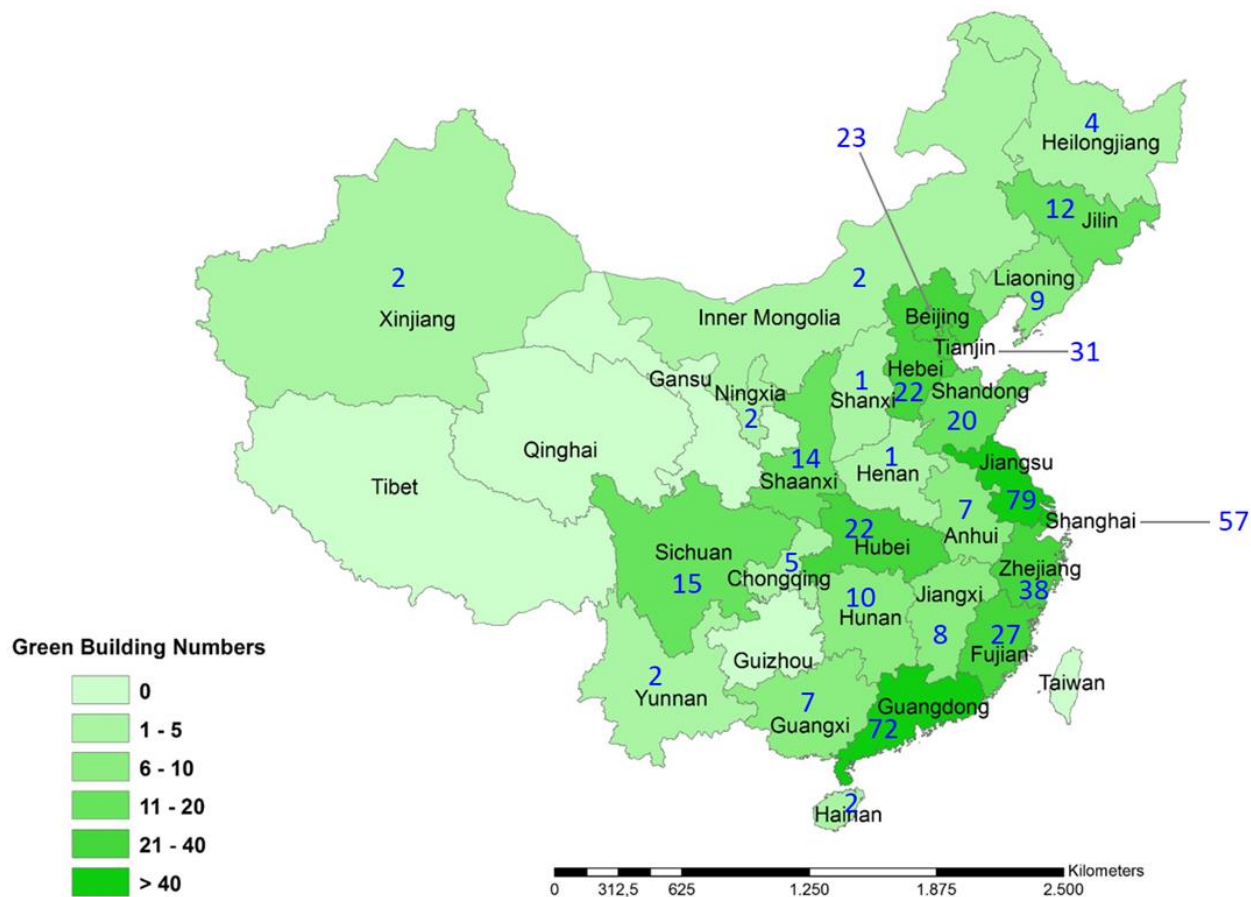
Source: (Watson, 2011) and (Australian Property Institute, 2011)

In China, only 113 projects had received a rating under China’s Green Building Energy Label by the end of the 11<sup>th</sup> Five Year Plan (2010). While initial uptake in the use of GBEL was slow in the 11<sup>th</sup> Five Year Plan, usage should increase much more rapidly in the next couple of years. Initial slow uptake may be due to a preference for LEED or perception that GBEL rating is harder to achieve than LEED. Figure 18 shows that China had about 8 million square meters of LEED-certified floorspace in 2010 (USGBC data), while there were 7 million square meters of GBEL-rated floorspace in 2010.



**Figure 18: LEED-certified floorspace in U.S. and China (million square meters)**

As of August 2012, the number of GBEL projects had grown to 494, with a lot of that growth due to the city-specific targets mentioned in section 4.4.2. Figure 19 below shows the number of GBEL certified projects by province. In general, activity is greater in the coastal provinces, especially since a number of cities in those provinces have their own city-level targets for green building, including Shenzhen, Suzhou, and Nanjing.

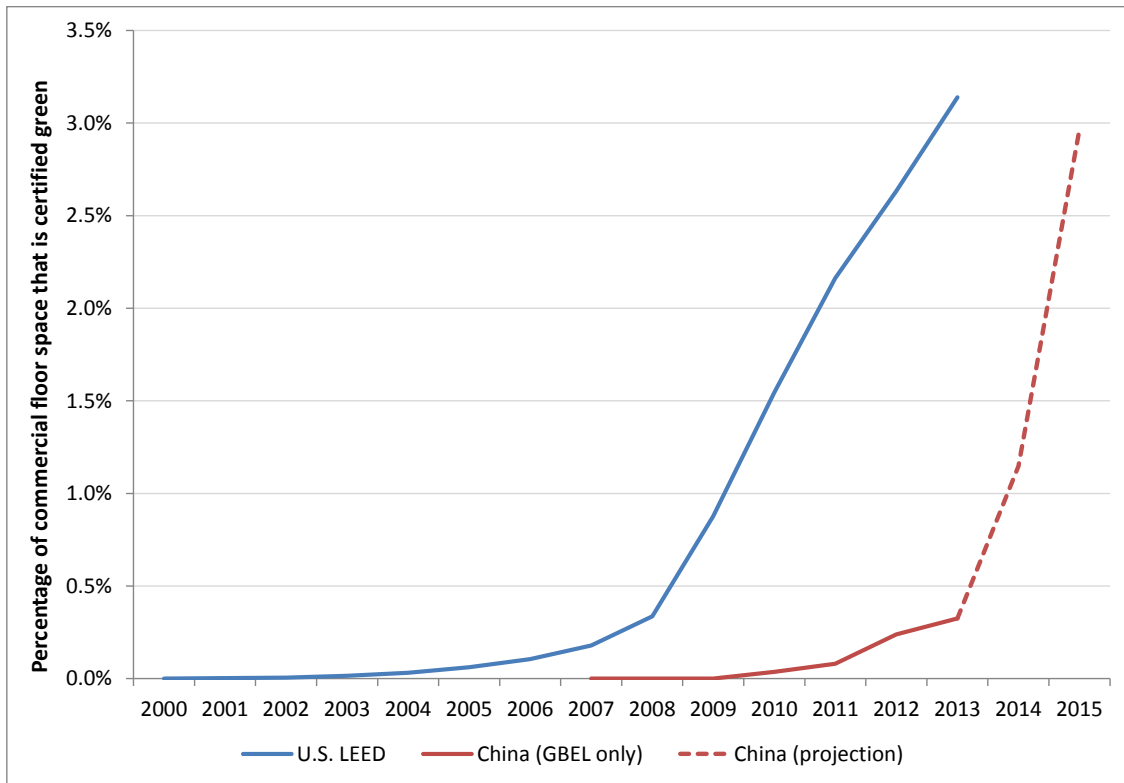


**Figure 19: Number of GBEL certified projects by province as of August 2012, floorspace figures unavailable**

China has much more ambitious goals for the 12<sup>th</sup> Five Year Plan, including a 1 billion square meters of green building floorspace target by the end of 2015. If we make the assumption that 60% of that floorspace will be residential and 40% will be commercial,<sup>4</sup> then around 3% of China’s commercial floorspace will be GBEL-rated according to China Energy Group projections (400 million square meters out of 13.5 billion total square meters). If the other 600 million square meters is residential floorspace, then the proportion of GBEL-rated floorspace in 2015 for the residential sector would be about 1%. Certainly, the incentives being offered are making developers reconsider a GBEL rating as opposed to a LEED rating or no rating. Figure 20 shows some simple projections for the growth in commercial floor

<sup>4</sup> This is one par with current development which has been 55% residential and 45% commercial to date, according to China’s latest Annual Climate Change “Green Book”.

space that is certified green. According to USGBC data (and U.S. government data for total floorspace), LEED-certified buildings accounted for roughly 2.5% of commercial building space at the end of 2012. In China, at the end of 2010, only 0.04% of commercial floor space was GBEL rated, according to our calculations. But by the end of 2013, 100 million square meters of total floorspace had been certified – 45% of which was commercial (about 0.3% of total commercial floorspace was therefore GBEL certified). Yet, if China is to hit its 2015 target, growth will have to be exponential. Indeed, growth in LEED certified floor space in the U.S. has been roughly exponential, with a sharp increase in uptake seen in 2008. Indeed, the two curves have a similar shape in the early years of each respective program, with China’s curve delayed by five to six years due to a difference in the formal beginning of the LEED and GBEL rating programs. It remains to be seen, however, whether LEED certified space will continue on a similar growth trajectory and whether or not China will be able to hit its ambitious targets for GBEL.



**Figure 20: Percentage of commercial floorspace certified by LEED or GBEL, with projection for China**

Note: U.S. LEED percentage based on USGBC data divided by commercial floor space numbers from EIA. China 2010 and 2013 percentages based on government data for GBEL floorspace and CEG commercial floorspace estimates and assumptions. Projections from 2011 to 2015 based on assumption that China will hit 1 billion square meter target in 2015, with half of that floorspace in the commercial building sector

## 6. Conclusion

With growing global and national emphasis on energy efficiency and climate change, the market for green buildings is growing in both U.S. and China, albeit at different speeds and supported by rating systems with similar goals but different approaches. The U.S. LEED program was developed 10 years earlier by the U.S. Green Building Council, a non-governmental body, in a consensus-based process with industry stakeholders. Since 2008, an independent, third-party organization (Green Building Certification Institute) has been responsible for administering all LEED registration and certification as well as LEED professional accreditation. In contrast, the China GBEL program is developed and administered entirely by central and local government offices of the Ministry of Housing and Urban-Rural Development. These differences in program administration have affected the level of awareness and acceptance of the two labeling programs in their respective countries, with informational, institutional, and capacity limitations still major barriers for the GBEL program.

The U.S. LEED and Chinese GBEL rating systems share many common characteristics including the use of separate rating systems for new design versus operational, residential versus commercial buildings, and mandatory versus credit-based score items. There are some differences in the scope of rating systems, with LEED having more specific rating systems differentiated by building types than the GBEL program. More importantly, China GBEL offers less flexibility for developers to achieve a specific rating since a project must meet minimum requirements across all credit categories instead of only a total score, as is the case for LEED. These differences can be traced back to differences between the two countries' building sectors, but also have important policy and market development implications. Although certifications for green buildings are important, a U.S. China green building comparison will also need to compare actual building performance. A performance-based evaluation study is to be written in 2014, as a continuation of this study.

On the green building policy front, government-led green building mandates at the federal and municipal level helped galvanize green building activity in the U.S. in the early 2000's. The sector continues to grow rapidly off the back of a wide network of LEED-accredited professionals, positive local policies, and an increasing body of evidence that green buildings can command higher rent and sale prices. Now, LEED-certified buildings are estimated to account for roughly 3% of commercial building space in the U.S.

China's green building industry is about to enter a critical growth period. In addition to an ambitious 1 billion square meter green building target for 2015 and a mandate that 80% of all new government-invested commercial buildings be GBEL-certified, many cities are establishing their own targets, requiring anywhere from 30% to 80% of new construction to be GBEL-certified. Developers are still slow to take interest in green building, deterred by the cost premium for building green while there have been problems with the implementation of cash incentives offered by the national government. It remains to be seen, whether China can hit its target for green building, but if it does, it will easily become the world's largest green building market.

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## References

Amecke H., J. Deason, A. Hobbs, A. Novikova, X. Yang and S. Zhang. (2013). "Buildings Energy Efficiency in China, Germany and the United States." Climate Policy Initiative Report.

ASHRAE. (2013). "ANSI/ASHRAE/IES Standard 90.1-2013 -- Energy Standard for Buildings Except Low-Rise Residential Buildings." <https://www.ashrae.org/resources--publications/bookstore/standard-90-1>

Australian Property Institute. (2011). *Building Better Returns*. Australian Property Institute, Property Funds Association.

Bradsher, K. (2011 15-June). *China Takes a New Interest in Energy Efficiency*. From New York Times: <http://www.nytimes.com/2011/06/16/business/energy-environment/16green.html?pagewanted=all>

Building Energy Codes Program. (2010). *Measuring State Energy Code Compliance. PNNL-19281*. Prepared by the Pacific Northwest National Laboratory for the U.S. Department of Energy Building Technologies Program. Richland, Wash.: Pacific Northwest National Laboratory.

Bullitt Foundation. (2013). Main floor exhibit at the Bullitt Center. Seattle, Washington: Bullitt Foundation.

Burr, A., Keicher, C., & Leipziger, D. (2011, July). Building Energy Transparency: A Framework for Implementing U.S. Commercial Energy Rating and Disclosure Policy. Washington, DC: Institute for Market Transformation. Retrieved from [www.buildingrating.org/sites/default/files/documents/IMT-Building\\_Energy\\_Transparency\\_Report.pdf](http://www.buildingrating.org/sites/default/files/documents/IMT-Building_Energy_Transparency_Report.pdf)

CEC. (2011). Revised Zero Net Energy (ZNE) Definition. *IEPR Workshop*. Sacramento, CA: California Energy Commission.

CEE. (2010, December). CEE 2010 State of the Efficiency Program Industry. Boston, MA: Consortium for Energy Efficiency. Retrieved from [http://www.cee1.org/files/2010 State of the Efficiency Program Industry.pdf](http://www.cee1.org/files/2010%20State%20of%20the%20Efficiency%20Program%20Industry.pdf)

Chongqing Municipal Government. (2013) Chongqing Green Building Action and Implementation Plan (2013-2020). 23 December 2013. <http://www.cq.gov.cn/publicinfo/web/views/Show!detail.action?sid=3741525>.

CPUC. (2011). *California Energy Efficiency Strategic Plan: Research and Technology Action Plan 2012-2015*. San Francisco, CA: California Public Utilities Commission.

CPUC. (2013). *Design Team Incentives*. Retrieved from Savings by Design: <http://www.savingsbydesign.com/design-team>

DOE. (2012, October). *Database of State Incentives for Renewables and Efficiency*. Retrieved from Baltimore County - Property Tax Credit for High Performance Buildings and Homes: [http://www.dsireusa.org/incentives/incentive.cfm?Incentive\\_Code=MD62F](http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=MD62F)

DOE. (2012, December 12). *Priority Permit Processing for Green Buildings*. Retrieved from Database for State Incentives for Renewables and Efficiency: [http://www.dsireusa.org/incentives/incentive.cfm?Incentive\\_Code=HI25F](http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=HI25F)

Fuerst, F. and P. McAllister. (2009). "New Evidence on the Green Building Rent and Price Premium." Annual Meeting of the American Real Estate Society. Monterey, CA, 2009.

Furr, J.E., N.C. Kibert, J.T. Mayer, and S.D. Sentman (Ed.) (2009). "Green Building and Sustainable Development: the Practical Legal Guide." Chicago: American Bar Association Publishing.

Geng Y., H. Dong, B. Xue and J. Fu. (2012). "An Overview of Chinese Green Building Standards." *Sustainable Development 20*: 211-221.

Han, W. (2009). *Practice and Experience of Promoting Efficient Lighting in China*. Presentation at the International Conference on Green Industry in Asia (September 11, 2009), Manila.

Hoffman, A., & Henn, R. (2008). *Overcoming the Social and Psychological Barriers to Green Building*. Ann Arbor, MI: University of Michigan Ross School of Business.

International Code Council (ICC). (2012). "2012 International Energy Conservation Code." <http://shop.iccsafe.org/codes/2012-international-codes/2012-international-energy-conservation-code/2012-international-energy-conservation-code-soft-cover.html>

Kandt, A., & Lowell, M. (2012). *WREF 2012: GSA's Green Proving Ground: Identifying, testing, and evaluating innovative technologies*. Golden, CO: National Renewable Energy Laboratory.

Kats, G. (2008). *Greening Buildings and Communities: Costs and Benefits*. Washington, DC: Good Energies.

Kong, X., Lu, S., & Wu, Y. (2011). A Review of Building Energy Efficiency in China During the Eleventh Five Year Plan Period. *Energy Policy*, 41, 624-635.

Lee, E.S., et al. (2009) High Performance Building Façade Solutions: PIER Final Project Report. Berkeley, CA: Lawrence Berkeley National Laboratory, 2009.



Levine, M. D., Price, L., Zhou, N., Fridley, D., Aden, N., Lu, H., et al. (2010). *Assessment of China's Energy-Saving and Emission Reduction Accomplishments and Opportunities During the 11th Five Year Plan*. Berkeley, CA: Lawrence Berkeley National Laboratory: LBNL-3385E.

Levine, M., De La Rue de Can, S., Zheng, N., Williams, C., Amann, J., & Staniaszek. (2012). *Building Energy Efficiency Best Practice Policies and Policy Packages*. Berkeley, CA: Lawrence Berkeley National Laboratory.

Li, H. (2011, October 19). Office of Green Building Label Management at Center of Science and Technology of Construction, MOHURD. (Y. Yuan, Interviewer)

Liu F., Meyer A. and Hogan J. (2010). "Mainstreaming Building Energy Efficiency Codes in Developing Countries: Global Experiences and Lessons from Early Adopters." World Bank Working Paper No. 204.

Lovins, A. (1995). *Energy Efficient Buildings: Institutional Barriers and Opportunities*. Boulder, CO: E Source.

Malone, A. 2010. "IBR Headquarters: Best Green Project." Architectural Record Case study. [http://archrecord.construction.com/ar\\_china/China\\_Awards/2010/ibr/default.asp](http://archrecord.construction.com/ar_china/China_Awards/2010/ibr/default.asp)

Ministry of Finance (MOF). 2007. *Strengthening the Implementation of Energy Conservation Management of Government Office Buildings and Large-scale Public Buildings*. MOF: No. 245 [2007].

MOF (2009). *Interim Management Methods on Financial Subsidy for Application of Solar Building Integrated Photovoltaic*. MOF No. 129 [129].

MOF. (2011a). *Further Notice on Public Buildings' Energy Efficiency Efforts*. MOF No. 207.

MOF. (2011b). *Fiscal Policy for Energy Efficient and Emission Reduction Demonstration Provinces and Cities*. MOF No. 383 [2007].

Ministry of Housing and Urban-Rural Development (MOHURD). (2006). *GB/T 50378-2006 Green Building Evaluation Standards (in Chinese)*. Beijing: MOHURD.

MOHURD. (2007). *Technical Code for Evaluating Green Buildings (in Chinese)*. Beijing: MOHURD.

MOHURD. (2008). *Management Methods for Green Building Evaluation and Certification (in Chinese)*. Beijing: MOHURD.

MOHURD. (2012, January 30). 12th FYP Building Energy Conservation Special Plan (Draft for Public Review). Beijing, China.

MOHURD Green Building Label Management Office. 2013a. "Chinese Green Building Evaluation Label Case Studies: China 2010 Shanghai World Expo Center." Retrieved 12 September 2013.

<http://www.cngb.org.cn/showzx.aspx?id=26&cid=128>

MOHURD Green Building Label Management Office. 2013b. "Chinese Green Building Evaluation Label Case Studies: Shandong Jiaotong University Library." Retrieved 12 September 2013.

<http://www.cngb.org.cn/showzx.aspx?id=68&cid=128>

Mo, K. (2009). *China Launches National Green Building Label Campaign*. Retrieved from Natural Resources and Defense Council Switchboard:

[http://switchboard.nrdc.org/blogs/kmo/china\\_launches\\_national\\_green.html](http://switchboard.nrdc.org/blogs/kmo/china_launches_national_green.html)

NBS. (2009). *China Statistical Yearbook 2008*. Beijing: National Statistics Press.

Obama, B. (2009). *Executive Order 13514 — Federal Leadership in Environmental, Energy, and Economic Performance*. Washington, DC: United States Government Printing Office.

Payne, C., & Harris, J. (2004). *DOE Leadership in Energy and Water Efficiency for Sustainable Federal Buildings*. Berkeley, CA: Lawrence Berkeley National Laboratory LBNL Report #55255.

People's Daily. (2012, May 7). *One Billion Square Meters of Green Buildings to be Added During 12th Five-Year Plan Period*. Retrieved from <http://www.chinagb.net/news/waynews/20120507/86083.shtml>

Peters, J., Albers, N., Goldman, C., Stuart, E., & Fuller, M. (2010). Energy Efficiency Services Sector: Workforce Education and Training Needs. *American Council for an Energy Efficient Economy Summer Study*. Pacific Grove, CA: American Council for an Energy Efficient Economy.

REEEP. (2009). *Using Financial and Market-based Mechanisms to Improve Building Energy Efficiency in China*. Vienna: Renewable Energy & Energy Efficiency Partnership.

Shenzhen Development and Reform Commission. (2012). The announcement of Shenzhen's medium to long-term plan for low carbon development (2011-2020). 14 May 2012.

Shenzhen Institute of Building Research. (2009). *Sharing Design, 2<sup>nd</sup> edition (in Chinese)*. Beijing: China Construction Industry Press.

SIBR. (2010). *Sharing Operation & Maintenance (in Chinese)*. Beijing: China Construction Industry Press.

SIBR. (2011). "The Server for Green City Development: Shenzhen Institute of Building Research." Shenzhen: Shenzhen Institute of Building Research.

Shui, B., Lin, H., Song, B., Halverson, M., Evans, M., & Zhu, X. (2011). *Feedback from Focus Group Meeting on Training and Implementation of Building Energy Codes in China*. Retrieved from [http://www.pnl.gov/main/publications/external/technical\\_reports/PNNL-17909.pdf](http://www.pnl.gov/main/publications/external/technical_reports/PNNL-17909.pdf)

Shui, B., & Li, J. (2012). *Building Energy Efficiency Policies in China*. Global Building Performance Network Technical Report. Retrieved from <http://www.gbpn.org/reports/building-energy-efficiency-policies-china-status-report-0>

Sigmon, J. (2012). Code Creep: How Green Is Making Its Way into Codes and What It Means for the Future of Codes and Incentive Programs. *2012 National Symposium on Market Transformation*. Washington, DC: American Council for an Energy Efficient Economy.

Song, L. (2008). *Chinese Green Building Label*. Presentation by Song Ling, Green Building Label Management Office, Beijing. Retrieved from <http://chinagreenbuildings.blogspot.com/>

State of Pennsylvania. (2013). *High Performance Green School Planning Grant*. Retrieved from Pennsylvania Governor's Green Government Council: <http://www.portal.state.pa.us/portal/server.pt?open=514&objID=588218&mode=2>

Tsinghua University Building Energy Research Center. (2011). *China Building Energy Efficiency Development and Research Annual Report 2011*. Beijing: China Construction Industry Press.

U.S. Energy Information Administration (EIA). (2013a). Residential Energy Consumption Survey 2009. Retrieved from <http://www.eia.gov/consumption/residential/data/2009/#fueluses>

U.S. EIA. (2013b). Commercial Buildings Energy Consumption Survey 2003. Retrieved from [http://www.eia.gov/emeu/cbecs/cbecs2003/detailed\\_tables\\_2003/detailed\\_tables\\_2003.html](http://www.eia.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html)

U.S. EIA. (2013c). Annual Energy Outlook 2012. Retrieved from [http://www.eia.gov/pressroom/presentations/howard\\_01232012.pdf](http://www.eia.gov/pressroom/presentations/howard_01232012.pdf)

U.S. Environmental Protection Agency (EPA). (2011). *Best Practices for Program Design and Implementation*. Retrieved October 2011, from ENERGY STAR New Homes: [http://www.energystar.gov/index.cfm?c=bldrs\\_lenders\\_raters.nh\\_benefits\\_utilities\\_2](http://www.energystar.gov/index.cfm?c=bldrs_lenders_raters.nh_benefits_utilities_2)

U.S. Green Building Council (USGBC). (2013a). "LEED Rating Systems." Retrieved from <http://www.usgbc.org/leed/rating-systems>

USGBC. (2013b). *LEED 2009 for New Construction and Major Renovations Rating System*. Washington, DC: U.S. Green Building Council. Retrieved from <http://www.usgbc.org/resources/leed-new-construction-v2009-current-version>

USGBC. (2013c). *LEED 2009 for Existing Buildings Operations and Maintenance Rating System*. Washington, DC: U.S. Green Building Council. Retrieved from <http://www.usgbc.org/resources/leed-existing-buildings-v2009-current-version>

USGBC. (2013d). "Project Directory: New Construction v2.1: Betty Irene Moore Natural Sciences Building" Retrieved from <http://www.usgbc.org/projects/betty-irene-moore-natural-sciences-building?view=stories>

USGBC. (2013e). "Project Directory: Existing Buildings v2008: FBI Regional Headquarters Scorecard." Retrieved from <http://www.usgbc.org/projects/fbi-regional-headquarters?view=scorecard>

USGBC. (2013e, July 19). *LEED Monthly Update*. Retrieved from U.S. Green Building Council: <http://www.usgbc.org/resources/usgbc-monthly-update>

Watson, R. (2011). *Green Building Market and Impact Report 2011*. Oakland, CA: GreenBiz Group.

WBCSD. (2009). *Energy Efficiency in Buildings: Transforming the Market*. Washington, DC: World Business Council for Sustainable Development.

Wu, Y. (2012, January 12). Staff of MOHURD. (N. Zhou, Interviewer)

Yin, S., Liu, Y., & Zeng, D. (2011). China Renewable Energy Architecture Development Forecast in the Twelfth Five-Year Plan. *2011 International Conference on Economics and Finance Research 4*. Singapore: IACSIT Press.

Zhang, X. (2011). *Policy Recommendations for China's Three Star Green Building Rating and Labeling Program*. Berkeley, CA: University of California at Berkeley, Goldman School of Public Policy.

Zhou, N., & Lin, J. (2008). *The Reality and Future Scenarios of Commercial Building Energy Consumption in China*. Retrieved from <http://china.lbl.gov/publications/reality-and-future-scenarios-commercial-building-energy-consumption-china>

Zhou, N., McNeil, M., & Levine, M. (2010). Assessment of Building Energy-Saving Policies and Programs in China During the 11th Five Year Plan. *The 2010 International Energy Program Evaluation Conference*. Paris.

## Appendix

### Supporting standards related to LEED and GBEL

LEED standards use a variety of other standards to evaluate different aspects of green buildings. LEED-NC, for example, cites a couple of ASHRAE standards. ASHRAE 90.1 is used to evaluate building energy performance and quantify energy savings. The calculated savings will be compared with LEED to quantify the credits a project can receive. Similarly, ASHRAE standard 62.1 is used to evaluate green building ventilation and indoor air quality. LEED certified buildings need to demonstrate higher ventilation rate than required by ASHRAE 62.1. ASHRAE standard 52.2 is used to evaluate air filtration media performance in green building.

**Table 12: Select ASHRAE codes relevant to LEED-NC**

ASHRAE standard	Evaluation type	Compliance option	Description of compliance
ASHRAE 90.1/title 24	Energy performance, simulation	EA 1 option1	Demonstrate a percentage energy savings from a baseline building. Baseline should follow ASHRAE 90.1-2007.
	Energy performance, AEDG	EA 1 option2	Prescriptive measures of the ASHRAE Advanced Energy Design Guide
	Energy performance, Advanced Buildings™ Core Performance™	EA 1 option3	Comply with the prescriptive measures identified in the Advanced Buildings Core performance
ASHRAE 62.1-2007	IEQ/IAQ	IEQ P1 C1 Option1	Mechanical ventilation systems must be designed using the ventilation rate procedure as defined by ASHRAE 62.1-2007. ASHRAE 62.1-2007 user manual
		IEQ P1 C2	Naturally ventilated buildings must comply with ASHRAE Standard 62.1-2007, Paragraph 5.1
ASHRAE 62.1-2007	IEQ/IAQ, Increased ventilation	IEQ 2 C1 Option1	Increase breathing zone outdoor air ventilation rates to all occupied spaces by at least 30% above the minimum rates required by ASHRAE Standard 62.1-2007. Use CIBSE Applications Manual 10: 2005, or CIBSE AM 13:2000, Mixed Mode Ventilation.
		IEQ 2 C2 Option1	Determine that natural ventilation is an effective strategy for the project by following the flow diagram process shown in Figure 2.8 of the CIBSE Applications Manual 10: 2005
		IEQ 2 C2 Option2	Use a macroscopic, multi-zone, analytic model to predict that room-by-room airflows will effectively naturally ventilate, defined as providing the minimum ventilation rates required by ASHRAE 62.1-2007 section 6, for at least 90% of occupied spaces.

ASHRAE 52.2-1999	IEQ/IAQ, IAQ management, Filtration media	IEQ 3.1	When developing and implementing an IAQ management plan. Filtration media with a Minimum Efficiency Reporting Value (MERV) of 8 as determined by ASHRAE Standard 52.2-1999
ASHRAE 52.2-1999	IEQ/IAQ, Indoor pollutant source control	IEQ 5	Filtration media is rated a minimum efficiency reporting value (MERV) of 13 or higher in accordance with ASHRAE Standard 52.2-1999
ASHRAE 62.1-2007	IEQ, Thermal comfort	IEQ 6.2	Provide individual comfort controls for 50% (minimum) of the building occupants to enable adjustments to meet individual needs and preferences. Operable windows may be used in lieu of controls for occupants located 20 feet (6 meters) inside and 10 feet (3 meters) to either side of the operable part of a window. The areas of operable window must meet the requirements of ASHRAE Standard 62.1-2007 paragraph 5.1 Natural Ventilation
ASHRAE 55-2004	IEQ, Thermal comfort	IEQ 6.2	ASHRAE Standard 55-2004 identifies the factors of thermal comfort and a process for developing comfort criteria for building spaces that suit the needs of the occupants involved in their daily activities
ASHRAE 55-2004	IEQ, Thermal comfort design	IEQ 7.1 option1	Meet the requirements of ASHRAE Standard 55-2004, Thermal Environmental Conditions for Human Occupancy. Demonstrate design compliance in accordance with the Section 6.1.1 documentation
ASHRAE 55-2004	IEQ, Thermal comfort verification	IEQ 7.2	Agree to conduct a thermal comfort survey of building occupants within 6 to 18 months after occupancy. ASHRAE 55-2004 provides guidance for establishing thermal comfort criteria and documenting and validating building performance to the criteria

In China, labeling requirements for green buildings also often refer to the national standard. The Green Building Evaluation Standards (GB/T 50378-2006), which is the main guideline for the green building label and evaluation, cites other national building codes as the concrete guidance for evaluation. Table 13 shows some of the GBEL evaluation categories that refer to national building codes.

**Table 13: National codes relevant to Green Building Evaluation Standards**

<b>GBEL evaluation category</b>	<b>Related national building code</b>
4.1.4 Daylighting standards of residential buildings	Code of Urban Residential Areas Planning & Design (GB50180-93, 2002) 5.0.2.1
4.1.6 Greening rate, per capita public green areas	Code of Urban Residential Areas Planning & Design (GB50180-93, 2002) 7.0.2.3, 7.0.5

4.1.8 Noise, wastewater	Noise Limits for Construction Site (GB12523-2011) 2.1 Integrated Wastewater Discharge Standard (GB8978-1996) 4.2.2.1, 4.2.2.2
4.1.9 Public Service Facility	Code of Urban Residential Areas Planning & Design (GB50180-93, 2002) 6.0.1-6.0.5
4.1.11 Environmental noise	Environmental quality standard for noise (GB3096-2008) 5.1
4.2.1 Building thermal performance design, HVAC system design	Design Standard for Energy Efficiency of Residential Buildings in Severe Cold and Cold Zones (JGJ26-2010) 4-5 Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Cold Winter Zone (JGJ134-2010) 4-6 Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Warm Winter zone (JGJ75-2003) 4-6
4.2.2 Central HVAC system design	Design Standard for Energy Efficiency of Public Buildings (GB50189) 5.4.5, 5.4.8
4.2.3 Heat metering design for Central heating system	Technical Specification for Heat Metering of District Heating System (JGJ173-2009)
4.2.5 Energy efficiency ratio of pumps and fans	Design Standard for Energy Efficiency of Public Buildings (GB50189) 5.2.8, 5.3.26, 5.3.2, 5.4.3 The Minimum Allowable Values of the Energy Efficiency and Energy Efficiency Grades for Unitary Air Conditioners (GB19576-2004) 5.1, 5.2
4.2.6 Energy efficiency ratio of water chillers and unitary air conditioners	Design Standard for Energy Efficiency of Public Buildings (GB50189) 5.4.5, 5.4.8 The Minimum Allowable Values of the Energy Efficiency and Energy Efficiency Grades for Unitary Air Conditioners (GB19576-2004) 4 The Minimum Allowable Values of the Energy Efficiency and Energy Efficiency Grades for water chillers (GB19577-2004) 4
4.3.1 Water for city residential use	Water Quantity Standard for city residential use (GB/T50331-2002) 3.0.1
4.3.3 Water devices	Domestic Water Saving Devices (CJ164-2002) 4 Technical Conditions For Water Saving Products and General Regulation For Management (GB/T 18870-2011) 6
4.3.5 Nontraditional water source	Code for Design of Waste Water Reclamation And Reuse (GB/T 50335-2002) 4, 5, 6 Code of Design for Building Reclaimed Water System (GB/T 50336-2002) 3, 4, 5, 6
4.4.1 Harmful matter content in building	Limited Releasing Value of Formaldehyde in Artificial Board

materials	<p>and Its Product from Interior Decoration Furnishing Materials (GB 18580-2001)</p> <p>Limited Harmful Matter Value of Wood Coatings with Solvent Type from Interior Decoration Furnishing Materials (GB 18581-2001)</p> <p>Limited Harmful Matter Value of Interior Wall Coating Material from Interior Decoration Furnishing Materials (GB 18582-2001)</p> <p>Limited Harmful Matter Value of Cementing Compound from Interior Decoration Furnishing Materials (GB 18583-2001)</p> <p>Limited Harmful Matter Value of Wooden Furniture from Interior Decoration Furnishing Materials (GB 18584-2001)</p> <p>Limited Harmful Matter Value of Wallpaper from Interior Decoration Furnishing Materials (GB 18585-2001)</p> <p>Limited Harmful Matter Value of PVC floor with Coiled material from Interior Decoration Furnishing Materials (GB 18586-2001)</p> <p>Limited Harmful Matter Value of Carpet, Carpet Lining and Cementing Compound for Carpet from Interior Decoration Furnishing Materials (GB 18587-2001)</p> <p>Limits of Ammonia Emitted from the Concrete Admixtures (GB 18588-2001)</p> <p>Limits of Radionuclides in Building Materials (GB 6566-2001)</p>
4.5.1 Day lighting standards of living space	Code of Urban Residential Areas Planning & Design (GB50180-93, 2002) 5.0.2.1
4.5.2 Daylight factor	Standard for Daylighting Design of Buildings (GB50033-2013) 3.0.3.
4.5.3 Sound insulation and noise reduction of building envelope	Code for Design of Sound Insulation of Civil Buildings (GB 50118-2010) 3.1.1, 3.2.1, 3.2.2
4.5.5 Air pollution concentration	Code for Indoor Environmental Pollution Control of Civil Buildings Engineering (GB 50325-2010) 3
4.5.7 Internal surface of building envelope	Thermal Design Code for Civil Building (GB50176-93) 4.3.1-4.3.5
4.5.8 Highest temperature design for internal surface of roof and western and eastern exterior wall on condition of nature ventilation	Thermal Design Code for Civil Building (GB50176-93) 5.1.1
5.1.5 Noise, wastewater	Noise Limits for Construction Site (GB12523-2011) 2.1 Integrated Wastewater Discharge Standard (GB8978-1996)



	4.2.2.1, 4.2.2.2
5.1.6 Site environment noise	Environmental quality standard for noise (GB3096-2008) 5.1
5.2.1 Thermal performance indices of building envelope	Design Standard for Energy Efficiency of Public Buildings (GB50189) 4.2.2, 4.3
5.2.2 Energy Efficiency Ratio of heating and cooling unit	Design Standard for Energy Efficiency of Public Buildings (GB50189) 5.4.3, 5.4.5, 5.4.8,5.4.9 The Minimum Allowable Values of the Energy Efficiency and Energy Efficiency Grades for Unitary Air Conditioners (GB19576-2004) 4 The Minimum Allowable Values of the Energy Efficiency and Energy Efficiency Grades for water chillers (GB19577-2004) 4
5.2.4 Lighting Power Density	Standard for Lighting Design of Buildings (GB50034-2004) 6.1.2~6.1.4
5.2.8 Air permeability performance of building external windows	Graduations and Test Methods of Air Permeability Water tightness Wind Load Resistance Performance for Building External Windows and Doors (GB7106-2008) 4.1
5.2.13 Energy efficiency equipment and system	Design Standard for Energy Efficiency of Public Building (GB50189) 5.3.26, 5.3.27
5.2.19 Lighting Power Density	Standard for Lighting Design of Buildings (GB50034-2004)
5.3.2 Building water supply and drainage	Code for Design of Building Water Supply and Drainage (GB50015-2003, 2009) 3, 4
5.3.4 Water devices	Domestic Water Saving Devices (CJ164-2002) 4 Technical Conditions For Water Saving Products And General Regulation For Management (GB/T 18870-2011) 6
5.3.5 Nontraditional water source	Code For Design Of Waste Water Reclamation And Reuse (GB/T 50335-2002) 4, 5, 6 Code Of Design For Building Reclaimed Water System (GB/T 50336-2002) 3, 4, 5, 6
5.4.1 Harmful matter content in building materials	Limited Releasing Value of Formaldehyde in Artificial Board and Its Product from Interior Decoration Furnishing Materials (GB 18580-2001) Limited Harmful Matter Value of Wood Coatings with Solvent Type from Interior Decoration Furnishing Materials (GB 18581-2001) Limited Harmful Matter Value of Interior Wall Coating Material from Interior Decoration Furnishing Materials (GB 18582-2001) Limited Harmful Matter Value of Cementing Compound from Interior Decoration Furnishing Materials (GB 18583-2001)

	<p>Limited Harmful Matter Value of Wooden Furniture from Interior Decoration Furnishing Materials (GB 18584-2001)</p> <p>Limited Harmful Matter Value of Wallpaper from Interior Decoration Furnishing Materials (GB 18585-2001)</p> <p>Limited Harmful Matter Value of PVC floor with Coiled material from Interior Decoration Furnishing Materials (GB 18586-2001)</p> <p>Limited Harmful Matter Value of Carpet, Carpet Lining and Cementing Compound for Carpet from Interior Decoration Furnishing Materials (GB 18587-2001)</p> <p>Limits of Ammonia Emitted from the Concrete Admixtures (GB 18588-2001)</p> <p>Limits of Radionuclides in Building Materials (GB 6566-2001)</p>
5.5.1 Room design parameters	Design Standard for Energy Efficiency of Public Buildings (GB50189) 3.0.1
5.5.3 Fresh air volume	Design Standard for Energy Efficiency of Public Buildings (GB50189) 3.0.2
5.5.4 Air pollution concentration	Code for Indoor Environmental Pollution Control of Civil Buildings Engineering (GB 50325-2010) 3
5.5.5 Indoor background noise	Code for Design of Sound Insulation of Civil Buildings (GB 50118-2010) 7.2, 8.2 Hygienic Standard for Commercial Buildings and Bookstores (GB9670-1996) 2.1.
5.5.6 Indoor lighting indices	Standard for Lighting Design of Buildings (GB50034-2004) 5.2.
5.5.11 Daylight factor	Standard for Daylighting Design of Buildings (GB50033-2013) 3.2.2-3.2.7.
5.6.7 Checking and cleaning AC systems	Cleaning Code for Air Duct System in Heating, Ventilating and Air-Conditioning Systems (GB19210-2003) 4, 6