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Building Energy-Efficiency Best Practice Policies and Policy Packages

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Even this array of talented contributors to the report could not change the reality of the paucity of data needed for the research. The project depended on by the availability of quantitative data or well-supported qualitative assessments of policy and program performance, energy savings and costs. High quality, documented information is hard to come by. The challenges are greater for assessing policies affecting space conditioning – the major thrust of this work – because of the complex dependence of heating and cooling energy use on hourly, daily, monthly and annual weather in an endless number of locations.

This is not to say however that the task was impossible or not worth doing. There exists a great deal of data that are not documented. The job is to gather these data, sift through them, select the information that appears to be more robust than others, and then gain confidence in the data through observation and discussions with local people and experts. The research on this project represents a beginning of such an undertaking.

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List of Acronyms

Acronym	Full Name
AAGR	average annual growth rate
ADaRSH	Association for Development and Research of Sustainable Habitats
ARRA	American Recovery and Reinvestment Act
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BCAP	Building Codes Assistance Project
BEE	Bureau of Energy Efficiency
BEEL	Building Energy Efficiency Evaluation and Labeling program
BEMR	Building Energy Management Regulations
bigEE	Bridging the Information Gap on Energy Efficiency in Buildings
BIPV	building-integrated solar PV systems
BOMA	Building Owners and Managers Association
BPIE	Buildings Performance Institute Europe
BPwES	Building Performance with ENERGY STAR
CABR	China Academy of Building Research
CALGREEN	California Green Building Standards Code
CEC	California Energy Commission
CEE	Consortium for Energy Efficiency
CEPHEUS	Cost-Efficient Passive Houses as European Standards
CEPT	Center for Environmental Planning and Technology
CERT	Carbon Emissions Reduction Target
CFL	compact fluorescent lamp
CO_2	carbon dioxide
CPUC	California Public Utility Commission
CSEE	Centre for Sustainable Environment and Energy
DECC	(UK) Department of Energy and Climate Change
DeST	Designer's Simulation Toolkit
DSM	Demand-Side Management
EC	European Commission
ECBC	Energy Conservation Building Code
ECEEE	European Council for an Energy Efficient Economy
ECO	energy company obligation
ECO-III	Energy Conservation and Commercialization Bilateral Project Agreement Phase III
EEOs	Energy-Efficiency obligations
EER	Energy-Efficiency Ratio
EERS	Energy-Efficiency Resource Standard
EIA	India's Ministry of Environment and Forest Environmental Impact Assessment
EPAct	Energy Policy Act

EPBD	Energy Performance of Buildings Directive
EPCs	Energy Performance Certificate
EI	Energy Provider
ESD	Energy End-use Efficiency & Energy Services Directive
ESD	Energy Services Directive
EU	European Union
EUI	Energy Use Intensity
f^2	Square foot/feet
GBDL	GBEL program that consists of a green building design label
GBEL	Green Building Evaluation and Labeling program
GBL	Green Building Label
GDCRs	General Development Control Regulations
GGBP	Greener, Greater Buildings Plan
GHG	greenhouse gas
GIS	Green Investment Scheme
GRIHA	Green Rating for Integrated Habitat Assessment
HERS	Home Energy Rating System
HPWES	Home Performance with ENERGY STAR
HVAC	heating, ventilation, and air-conditioning
IBR	Shenzhen Institute of Building Research
ICC	International Code Council
IEA	International Energy Agency
IECC	International Energy Conservation Code
IEE	Intelligent Energy-Europe
IGBC	India Green Building Council
IOU	investor-owned utility
IPCC	Intergovernmental Panel on Climate Change
IT	Information Technology
JI	joint implementation
KfW	Kreditanstalt für Wiederaufbau (German)
kVA	kilovolts-ampere
kW	kilowatt
kWh	kilowatt-hour
LBNL	Lawrence Berkeley National Laboratory
LED	light-emitting diode
LEED	Leadership in Energy and Environmental Design
LEED-CS	LEED India for Core and Shell
LEED-EB	LEED for Existing Buildings
LEED-NC	LEED India for New Construction
m^2	square meter
m^3	cubic meter

MNRE	Ministry of New and Renewable Energy
MOF	Ministry of Finance
MOHURD	Ministry of Housing and Urban-Rural Development
MOP	Ministry of Power
MoUD	Ministry of Urban Development
MS	Member State
Mt	Million tonnes
Mtce	million tonnes of coal equivalent
Mtoe	Million tonnes of oil equivalent
MURE	Mesures d'Utilisation Rationnelle de l'Energie
MW	megawatts
NBS	National Bureau of Statistics
NDRC	National Development Reform Commission
NGO	non-governmental organization
NMEEE	National Mission on Enhanced Energy Efficiency
NMSH	National Mission on Sustainable Habitat
NYC	New York City
nZEB	near-zero-energy buildings
O&M	Operation and Maintenance
OECD	Organization for Economic Co-operation and Development
PACE	Property-Assessed Clean Energy
PNNL	Pacific Northwest National Laboratory
POU	publicly-owned utility
PV	photovoltaics
R&D	research and development
REEC	Regional Energy-Efficiency Center
REEEP	Renewable Energy & Energy Efficiency Partnership
RESNET	Residential Energy Services Network
Rs	rupees
SDA	State Designated Agency
SVAGRIHA	Small Versatile Affordable GRIHA
tce	tonnes of coal equivalent
TDO	Town Development Office
TERI	Energy and Resources Institute
TRNSYS	TRaNsient SYstem Simulation Program
UDD	Urban Development Department
UK	United Kingdom
U.S. AID	United States Agency for International Development
U.S. DOE	United States Department of Energy
U.S. EIA	United States Energy Information Administration
U.S. EPA	United States Environmental Protection Agency

ULB	Urban Local Body
USGBC	United States Green Building Council

Executive Summary

This report addresses the single largest source of greenhouse gas emissions and the greatest opportunity to reduce these emissions. The IPCC 4th Assessment Report estimates that globally 35% to 40% of all energy-related CO2 emissions (relative to a growing baseline) result from energy use in buildings. Emissions reductions from a combination of energy efficiency and conservation (using less energy) in buildings have the potential to cut emissions as much as all other energy-using sectors combined. This is especially the case for China, India and other developing countries that are expected to account for 80% or more of growth in building energy use worldwide over the coming decades. In short, buildings constitute the largest opportunity to mitigate climate change and special attention needs to be devoted to developing countries.

At the same time, the buildings sector has been particularly resistant to achieving this potential. Technology in other sectors has advanced more rapidly than in buildings. In the recent past, automobile companies have made large investments in designing, engineering, and marketing energy efficient and alternative fuel vehicles that reduce greenhouse gas emissions. At the same time, the buildings sector – dependent on millions and millions of decisions by consumers and homeowners – face a large variety of market barriers that cause very substantial underinvestment in energy efficiency.

How can the trajectory of energy use in buildings be changed to reduce the associated CO_2 emissions? Is it possible to greatly accelerate this change? The answer to these questions depends on policy, technology, and behavior. Can policies be crafted and implemented to drive the trajectory down? Can the use of existing energy efficiency technologies be increased greatly and new technologies developed and brought to market? And what is the role of behavior in reducing or increasing energy use in buildings?

These are the three overarching issues. The information assembled in this study and the knowledge derived from it needs to be brought to bear on these three questions. And thus we turn to some of the insights from the study, presented in the form of findings and recommendation. Of the many findings that could be presented we have chosen the few that we consider to be particularly important. Others reading this report would undoubtedly choose a different set. The reader is encouraged to do so.

1. Findings: Policy

1.1. Building Energy Standards

Building energy standards are ubiquitous in the United States, the European Union, and China. They are the most potent of all policies in reducing energy use from heating and cooling of buildings. Almost all of the standards thus far promulgated in three regions have been cost-effective. There is a long (multi-

decade) tradition of building standards in all of the regions. This is especially true of the north of Europe with extreme cold weather and countries wealthy enough to invest in energy efficiency.

To date, most standards have been applied only to new buildings. The problem of high-energy use of existing buildings – of great importance in the two regions (the United States and the European Union) in which the building stock is growing slowly – has not been well addressed and standards have played little role. There is increasing interest and activity in applying standards at point of sale.

The most important issues in making standards more effective are (1) increasing training (of code officials, builders, and other building professionals), (2) the rigorous updating of the standards to promote the development and use of new, efficient technology, (3) announcing new codes early on so that the industry can prepare for more stringent codes and, (4) demonstrating the feasibility of constructing progressively more efficient buildings that are cost effective.

1.2. Building Energy Labels

Whole building energy labels have been particularly effective in three ways. They provide the necessary knowledge to the building owner or occupant to motivate decisions to invest in energy efficiency (for buildings receiving low ratings). Some of the labels recommend measures for reducing energy use (e.g., the European Union). The effectiveness of this application of labels is strongly dependent on consumers' view of their trustworthiness.

A second application of labels is to provide information about the building's energy-efficiency or energy use at the point of transaction (e.g., as required for example by France). The premise is that such knowledge is likely to be useful and used when the building is sold or rented.

The third use of labels is in our judgment the most important. The combination of standards (setting a floor on efficiency or energy use), a label (serving as a measuring stick), and financial incentives (to improve building performance beyond existing standards) is an extremely powerful means of increasing energy efficiency. If all three policies are well integrated with each other (e.g., California), they can drive efficiency aggressively and over a long period of time. The incentive and labeling policies will promote state of the art energy efficiency on which updates to standards can be based. This is effective as a policy design for new buildings but also can be applied to retrofits of existing buildings.

1.3. Building Energy Incentives

The fundamental issue of incentive programs is how to maintain funding, particularly if the funds come from governments. There are many innovative approaches to the problem that have potential for success. There are at least two approaches that have been successful on a large scale: utility demand side management (DSM) in the United States (funds from ratepayers who are the beneficiaries of the lowered total cost of supplying energy for the utility system) and in Germany (the KfW program where

the increased taxes resulting from the program cover the costs of administering the program plus the cost of the incentives).

1.4. Building Energy Policy Packages

As noted in section 1.2, incentives with labels and standards produces a particularly effective means of reducing energy use in buildings as well as encouraging the development and use of advanced energy-efficiency technologies. Three prime examples of the strong synergy among the three policies are California's utility and standards programs, Germany's KfW loan program, and several innovative municipal programs in China. The approach of packaging policies that can be implemented in many different configurations (e.g., levels of standards and incentives; different rating systems; agents responsible for implementation; form and identity of beneficiary of the incentives, etc.) has the potential for greatly expanding the reach and impact of the individual policies.

2. Findings: Technology

2.1. Opportunities with Existing Technologies and Systems

The biggest opportunity for saving energy in buildings in the coming decade(s) in all four regions (even those with the highest rate of construction) is adopting already available energy efficiency technology. The existence of many underutilized energy efficiency technologies and the associated market barriers strongly justify government policies.

Systems rather than technologies offer the greatest promise of energy savings. They typically underperform and in the process use excessive amounts of energy. This is particularly the case for space conditioning systems in large buildings. Improving system performance has large potential for energy saving in the near time.

For those developing countries with large numbers of poor people in cold regions, the single most important means for reducing greenhouse emissions for heating (cooking and water heating in all climates) is the replacement of inefficient biomass and/or coal burning stoves with modern fuels and equipment.

2.2. Creating Future Technologies

In spite of the plethora of underutilized high-efficiency technology today, research and development (R&D) is needed to achieve technologies and systems with lower costs or better performance. There are numerous R&D opportunities to achieve these goals.

Current R&D programs unfortunately give very little emphasis to systems as distinct from technologies. Passive solar houses, with a combination of many technologies[1], illustrate the importance of systems in reducing energy use. Integrated design is arguably the most important system (in reality, a "system of systems") for designing large buildings with very low energy use. An especially good example of the results of an integrated design process is the seven-story building housing the Institute for Building Research (IBR) in Shenzhen China. The building delivers substantial energy savings (greater than 50%) at construction cost lower than that of comparable buildings.[2] We believe that the integrated design process, with one knowledgeable person or organization having control over all aspects of the design process (architectural and engineering), construction, commissioning, and use of the building played an important role in the success of this building.

Thus R&D needs to focus much more strongly than it does today on designing, creating, testing, and producing techniques to assure effective performance of systems.

3. Findings: Behavior, Comfort Preferences, and the Operation of Buildings

Research going back to the 1970s has shown the variation of energy use as a function of occupant behavior. Studies of identical houses in close proximity to each other showed a factor of two difference in heating energy use between houses with the lowest and highest energy.[3] Numerous measurements and simulations have confirmed this variation or greater in commercial and residential buildings in the United States, China, Europe, and elsewhere throughout the world.[4] The body of this work shows that the effect of behavior and operational practices on energy use in buildings can be and often is greater than that of technology. Unfortunately, policies and programs have not demonstrated an ability to capture a significant portion of this occupant-related variation in energy. A miniscule portion of research on energy efficiency addresses how behavioral issues can best be addressed to achieve long-term energy savings.

4. Policy Research Needs

There is a need for experimentation, demonstrations, policy research, data and/or analysis on:

- Impacts of policies on heating and cooling energy use and costs (treated broadly[5]) based on quantitative and reproducible research.
- The effects of behavior on energy use in buildings and policies that encourage energy-conserving behavior.

[1] Importantly, the passive house as any complex system needs to be operated properly to be successful.

[2] Current estimates are that the construction cost may have been 1/3 less per square meter less than that of a comparable building.

[3] Stated more precisely, the factor of two is the ratio of the highest decile of heating energy use to the lowest decile.

[4] Annex 53 International Energy Agency (IEA), with participants from Asia, Europe, and the United States, has been studying this phenomenon for the past several years with a report scheduled for 2013.

[5] Including costs to consumers, energy suppliers, builders, the environment, etc.

- Well-documented costs and energy savings of buildings with very low heating and cooling energy.
- Quantitative effects of employing multiple policies (policy packages) to reduce building energy use.
- Sharing policy experience on building energy efficiency policies in actionable forms to developing countries.
- Effective methods to communicate information not widely known or understood to policy makers and the public.

5. Recommendations

Earlier[6] we identified the high-level issues that are the intellectual challenge underlying the research on which this report is based. It is our intent that the recommendations collectively provide insight into the issues. They are repeated below.

> *How can the trajectory of energy use in buildings be changed to reduce the associated CO2 emissions? Is it possible to greatly accelerate this change? The answer to these questions depends on policy, technology, and behavior. Can policies be crafted and implemented to drive the trajectory down? Can the use of existing energy efficiency technologies be increased greatly and new technologies developed and brought to market? And what is the role of behavior in reducing or increasing energy use in buildings?*

To increase the effectiveness and energy savings of building energy standards, we recommend that governmental organizations with authority over energy use in buildings should:

- As a matter of highest priority create (if they do not already exist) or strengthen building energy standards and their enforcement in measureable ways.
- Regularly update the standards as new technology or practices are demonstrated to cost-effectively save energy for space conditioning in buildings.
- Provide sufficient advance notice of the specifics and timing of the updates so that industry can prepare for the updates.
- Assure that demonstrations of improved practices and advanced systems and technology take place frequently and of sufficient quality to support standards updates.

To increase effectiveness of labels, organizations responsible for them should:

- Assure that they are designed and promulgated to be easy to use.
- Are as consistent with actual energy use or efficiency of the building to which it is applied.
- Are communicated to consumers, builders, and other building professionals in a manner to assure their trustworthiness.

[6] Third paragraph of this Executive Summary.

For financial incentives programs to have large and sustaining impacts, they need to be long-lived and at assured minimal levels.

Chapter 1 - Introduction

1.1. Importance of Building Energy Use to Reducing Global CO_2 Emissions

Climate change poses a serious threat to mankind over the coming decades. It will likely remain a critical issue through the lifetimes of our children and our children's children. The primary cause of climate change is the increase in greenhouse gas (GHG) emissions, the most significant of which (in terms of impact) is carbon dioxide (CO_2). Energy use and the accompanying CO_2 emissions have grown uninterrupted in the past decades (Figure 1-1). Buildings have been the end-use sector with the largest absolute growth in CO_2 emissions during this period. Figure 1-2 shows the emissions from the building sector for the United States, the European Union, China, India, and the rest of the world. The relatively low energy use in the building sector in India—combined with its large and growing population—foreshadows very substantial future increases in energy and CO_2 emissions from that sector in India (IEA, 2011a).

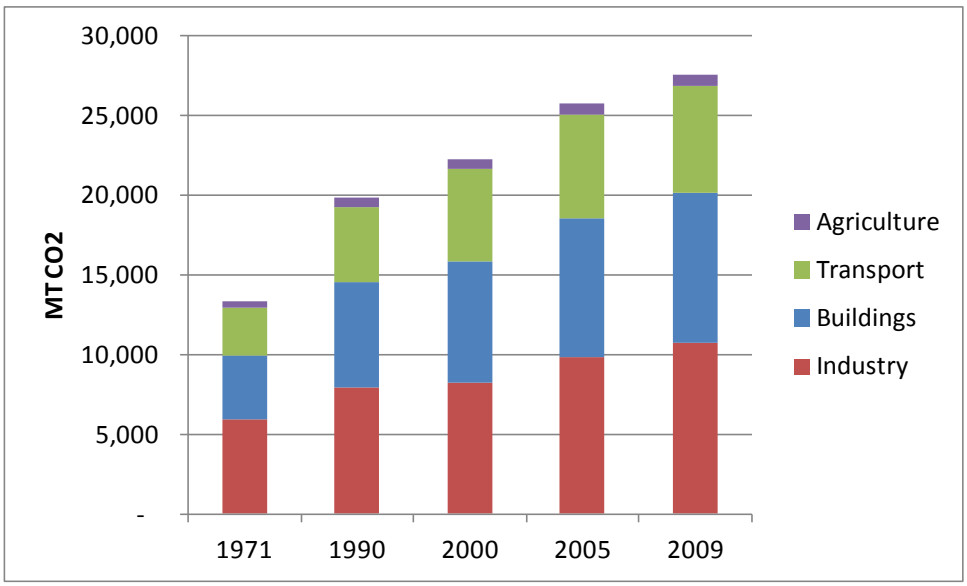


Figure 1-1. Global CO2 Emissions per Sector (Mt CO_2)

Source: Sectoral emissions were calculated based on the IEA data (IEA, 2011b) and following the methodology detailed in (de la Rue du can & Price, 2008).

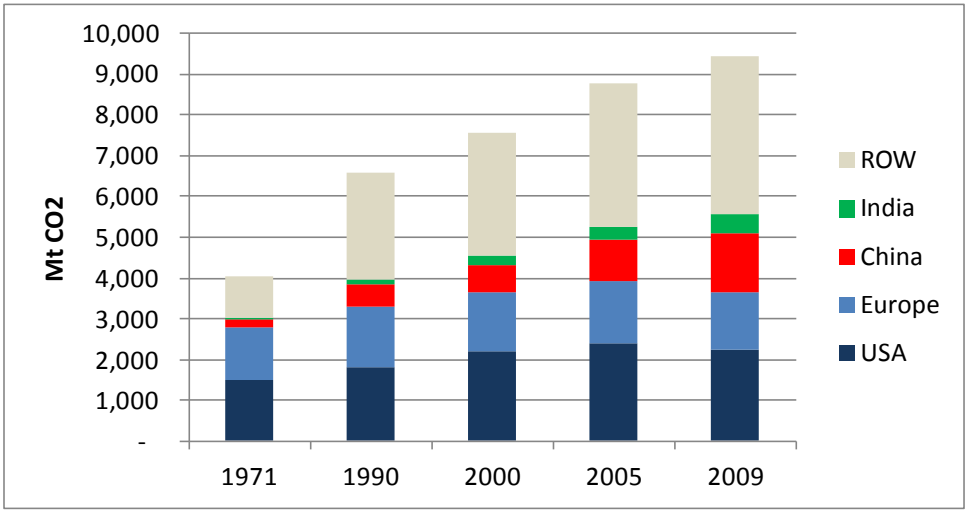


Figure 1-2. Building CO_2 Emissions for the United States, the EU 27, China, India and the rest of the world

Source: Regional emissions were calculated based on the IEA data (IEA, 2011a) following the methodology explained in (de la Rue du can & Price, 2008).

In the four regions of the United States, the European Union, China, and India, as well as in the rest of the world, trends in CO_2 emissions growth from the building sector vary significantly.[7] Emissions have increased rapidly in Asia, notably in India and China, with average annual growth rates (AAGRs) of 6.6% and 5.5%, respectively over the past 38 years. The growth of emissions was slightly greater in the past decade than in the previous three decades.

In Europe[8] and the United States, on the other hand, CO_2 emissions from energy use in buildings over the period 1971-2009 increased at an AAGR of 0.4% and 1.1%, respectively. In the past decade, there had been virtually no growth of emissions in the United States (AAGR of 0.1%) and very little in Europe (AAGR of 0.3%).

These trends are shown in Figure 1-3. Further disaggregation of the data (not presented here) of Figure 1-3 shows that the growth rate of commercial building energy use was greater than residential sector building energy use in all regions (except in China where the two are approximately equal) during the recent past (2000-2009).

[7] Data are not available to separate out heating, ventilation, and air conditioning (HVAC) energy use for the four regions. CO_2 emissions from HVAC energy use have grown at a slower rate in Europe and the United States than non-HVAC energy use, but the trends otherwise follow those in Figure 1-3.

[8] The data we have are for Europe as a whole. Using data from the European Union would not change the observations in the text.

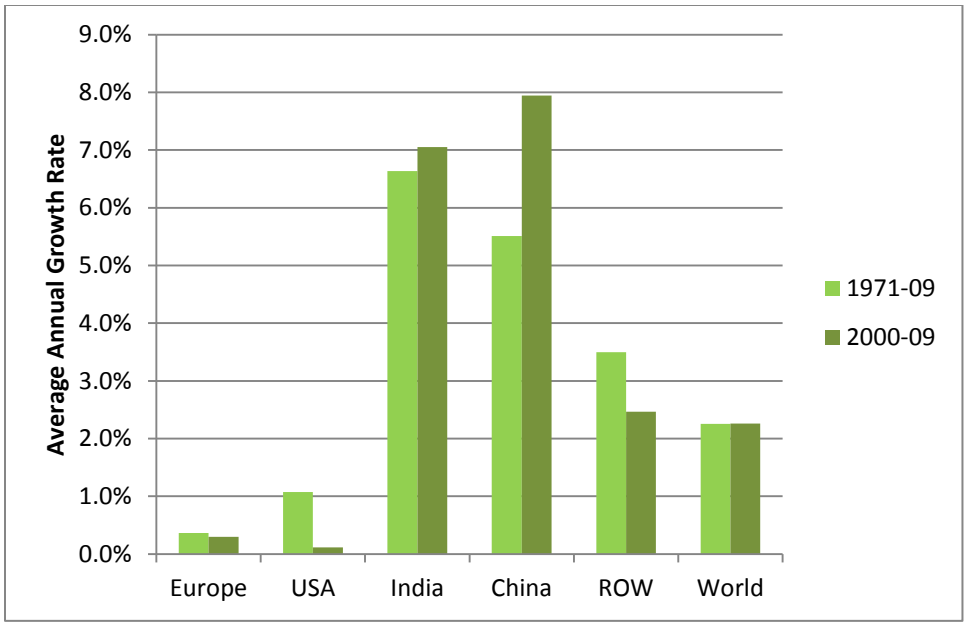


Figure 1-3. Average Annual Growth Rate of CO_2 Emissions from Energy Use in Buildings

Reducing energy use in buildings is the most significant among many opportunities to reduce GHG emissions. A piece of little-publicized analysis from the Intergovernmental Panel on Climate Change (IPCC) contains a remarkable finding that has proven this point. Figure 1-4 shows that, in the absence of carbon taxes or fees greater than $20/tonne CO_2, the potential CO_2 emissions reduction from building energy use is projected to approximately equal the reductions from all other energy-related sources (energy supply, transport, and industry) combined!

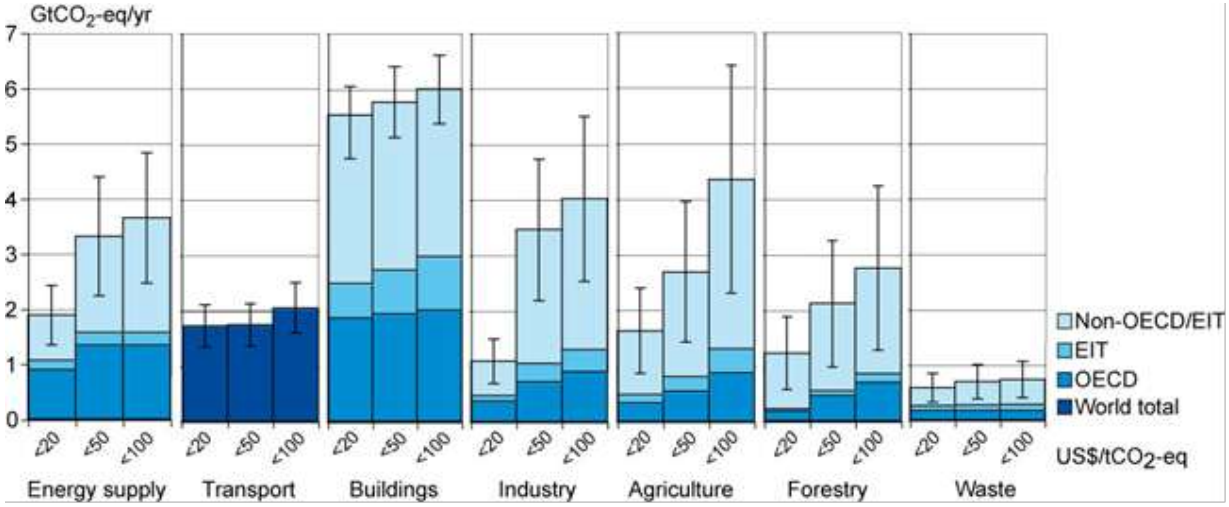


Figure 1-4. Estimated Potential Reductions in Annual CO_2 Emissions by Sector in 2030

Source: (IPCC, 2007)

Note: Estimates do not include non-technical options, such as lifestyle changes.

1.2. Objectives and Scope

The primary objective of this research has been to explore retrospectively the performance of building energy standards, labels, and incentives in reducing space conditioning energy use in buildings and the associated CO_2 emissions in major regions of the world.

We seek to achieve this objective by first reviewing experiences in the design, implementation, and enforcement of the three policies and policy packages[9] in the four regions: the United States, the European Union, China, and India. These regions will produce over the coming decades on the order of 80% of CO_2 emissions from building energy use in excess of emissions today.

The two developed regions (the United States and the European Union) differ importantly in the characteristics of their building stock and in the policies and institutions that underlie their efforts to reduce energy use in buildings. The two developing countries (China and India) differ from each other in the energy use of space conditioning in current and future buildings, as well as their policies, numbers of trained building professionals, and institutions that influence building energy use.

This review examines policies at the national and the regional (e.g., the European Union) level and assesses selected case studies of policies implemented at the sub-regional level in the United States, the European Union, and China[10]. *The combination of experiences in larger-scale (national/regional) policy implementation and smaller-scale (sub-regional) case studies forms the basis for identifying policies and policy packages that exemplify "best practices*."[11]

Although this report does not directly address the future, the information presented provides the context for defining opportunities and barriers to reducing building-related CO_2 emissions. The IPCC notes in its mitigation assessment that for the GHG emission reductions sufficient to limit global temperature rise to ~2°C, a deep, dramatic emissions cut is required. This translates into a need to reduce energy use dramatically. Two factors make buildings pivotal in efforts to achieve such deep cuts: emissions from energy use in buildings are growing faster than in other sectors, and the building sector has the most potential, compared with industry and possibly transportation, to use policies and technologies to cost-effectively reduce energy growth.

[9] By "policy packages" we mean the combination of two or more of the three policies considered in this report with each other (or in principle with other programs and policies), implemented concurrently in the same place.

[10] No case studies are presented for India as that nation is in early stages of implementation of energy efficiency policies. All case studies deal with experiences that have taken place over a five, ten or more year period so that there is information available about their performance.

[11] The next section of this chapter describes how the term "best practice" is used in this report.

1.3. Definition of the Term "Best Practice"

Perhaps it is not a surprise that researchers and analysts do not see eye to eye when it comes to the definition of the term "best practice." Typically, "best practice" is associated with the use of technologies; in this report, this term is used to describe implementation of policies and policy packages to reduce energy use in buildings.

The "first-tier"[12] criteria we use to screen potential "best practice" policies are:

- Large energy savings per building;
- High cost effectiveness;
- Effective administration and minimal administrative costs per building;
- High compliance rates; and
- Ability to scale to states, countries, or collections of countries (for case study policies).

Other details that are essential to understand the policies and how they are implemented include descriptive information such as the purpose and means of carrying out a program, whether it is voluntary or mandatory, the skill set of professionals in the building trades (including policy enforcement agencies), the types of buildings to which the program is applied,[13] features of the building market, and other qualitative factors.

Some of the "second-tier" criteria that one can identify for best practice policies, but for which data are generally not available, are:

- **Policy Design:**
  - Availability of tools;
  - Appropriate use of tools and their results;
  - Degree to which the policy drives advances in technology.
- **Implementation:**
  - Flexibility;
  - Feasibility;
  - Availability and clarity of information for consumers and building professionals;
  - Number and knowledge of implementation and enforcement officials;
  - Frequency of policy updates.
- **Enforcement:**
  - Quality of enforcement program;
  - Existence and magnitude of penalties for non-compliance.
- **Assessment and evaluation:**
  - Existence;
  - Frequency;
  - Quality.

[12] By "first-tier" criteria, we mean those that in our judgment result in the largest energy and net cost savings.

[13] New or existing buildings, residential or commercial, single family or mixed use.

Although additional criteria could be used, we do not use them for this report. This is because, for the majority of selected policies that have been applied in different countries and the regions (i.e., the European Union), it is not possible to find data on all of the "first-order" criteria. In contrast, because the focuses of the sub-regional case studies and technology examples are much more circumscribed than regional policies, in many cases we have information about "second-order" criteria.

Chapters 2–5 present our review of building energy-efficiency policies in the United States, the European Union, China, and India. Chapter 6 examines best practice case studies in the United States, the European Union, and China. Chapter 7 compares the stages of implementation and effectiveness of policies among regions. Chapter 8 concludes the report with findings and recommendations.

Chapter 2 - Review of Building Energy-Efficiency Policies: the United States

2.1. Introduction

The United States has established a robust infrastructure of policies, programs, and tools for buildings energy efficiency that exemplify a number of best practices.

Key features of U.S. energy-efficiency code development and implementation increase acceptance and compliance with codes. These include the use of transparent stakeholder processes for developing codes and allowing builders the flexibility to comply with codes via prescriptive or performance options. Use of code compliance software also makes it easier for building officials to check compliance.

Other elements of U.S. practice result in codes that support ongoing overall improvement in building energy efficiency. These include regular and frequent code revision cycles and allowing local governments to adopt codes that are stricter than state codes. Recent code revision cycles have produced increasing levels of energy savings with leading jurisdictions working toward very low and net-zero-energy-capable new construction.

Providing utilities with incentives to incorporate code support into their programs leverages their relationships with builders, designers, and contractors and takes advantage of the outreach potential of utility educational programs. These activities improve awareness of energy-efficiency measures and encourage their adoption as well as reducing burdens on local building departments. In the U.S. commercial sector, building rating and labeling have become core components of many ratepayer-funded efficiency programs. Similarly, coupling code and building labeling programs enhances the resulting building efficiency.

U.S. labeling programs are considered robust and trustworthy and are widely accepted, in part because of stakeholder participation in program development and excellent education campaigns. The practice of providing recommendations for efficiency improvements along with ratings makes it more likely that owners will undertake energy-efficiency upgrades.

Finally, in the area of financing energy efficiency, the United States excels in using mechanisms to facilitate repayment of efficiency improvements. Use of on-bill financing, where a charge on the customer's monthly utility bill repays the cost of an improvement, relieves owners of up-front costs of efficiency measures. In addition, linking financing to the property or address where the improvement is installed makes it more likely that renters or short-term owners will undertake energy-efficiency improvements. This category of owners and occupants might otherwise not make efficiency

improvements because of concern about not remaining at the property long enough to recoup their costs through the energy savings that result over time from the efficiency improvement.

Despite the United States' strong energy-efficiency policy and program infrastructure, significant opportunities for energy savings remain through improved code compliance and enforcement and updating of rating and labeling programs to promote advanced building performance. In a mature building market like that of the United States, existing buildings represent the greatest opportunity for energy savings but also present the greatest challenges technically, economically, and for program delivery and implementation. Accelerating the rate of building retrofits and deepening the level of energy savings in each retrofit project will be crucial to continuing to improve U.S. energy efficiency and carbon savings.

2.2. Energy Use in Buildings in the United States

The buildings sector is the largest consumer of energy in the United States, using approximately 42.5 exajoules of energy in 2010, which is approximately 41% of total U.S. energy use. The residential sector—roughly 114 million households—accounts for more than half of building sector energy use (23 exajoules), and roughly 5 million commercial buildings account for the remainder (19.3 exajoules).

The U.S. Department of Energy (U.S. DOE) divides the United States into five main climate regions based on temperature 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. About 63% of residents live in single-family detached houses, 25% in apartments, 6% in single-family attached houses, and 7% in mobile homes. Owner-occupied homes account for 67% of housing units; the remaining 32% are rented. Nearly 30% of homes were built prior to 1960, another 27% between 1960 and 1980, and 43% since 1980 (U.S. EIA, 2011).

Residential space heating and cooling together represent about 43% of residential primary energy use; water heating accounts for 13% (U.S. EIA, 2012). Figure 2-1 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. Given current energy use trends in U.S. homes, significant energy and carbon savings opportunities are available from retrofitting buildings, adopting high-efficiency appliances and electronics, and promoting efficient occupant behavior.

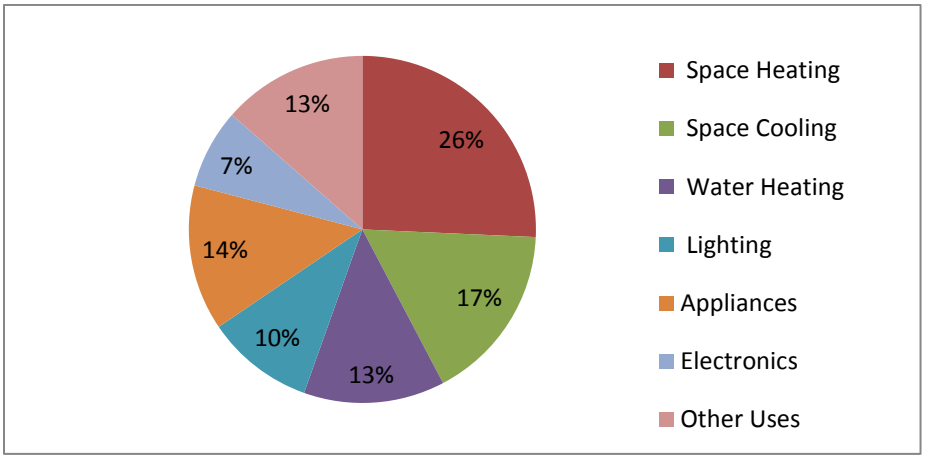


Figure 2-1. U.S. Residential Sector Energy Consumption by End Use

Source: (U.S. EIA, 2012)

U.S. commercial-sector floor space totals more than 6.7 billion square meters (m^2). The average commercial building is approximately 1,366 square feet (ft^2). Almost 75% of the approximately 5 million commercial office buildings in the United States are smaller than 930 ft^2, accounting for 20% of overall commercial space. The largest buildings (9,290 ft^2 and larger) account for only 3% of commercial buildings but approximately 35% of total commercial space (U.S. EIA, 2008).

Total 2010 primary energy use in the U.S. commercial sector is estimated at 19.3 exajoules. 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 a large portion (an estimated 31%) of commercial building energy use; most are associated with business-specific activities that reflect a diversity of commercial-sector end uses: 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. Figure 2-2 summarizes commercial sector energy consumption by end use (U.S. EIA, 2012).

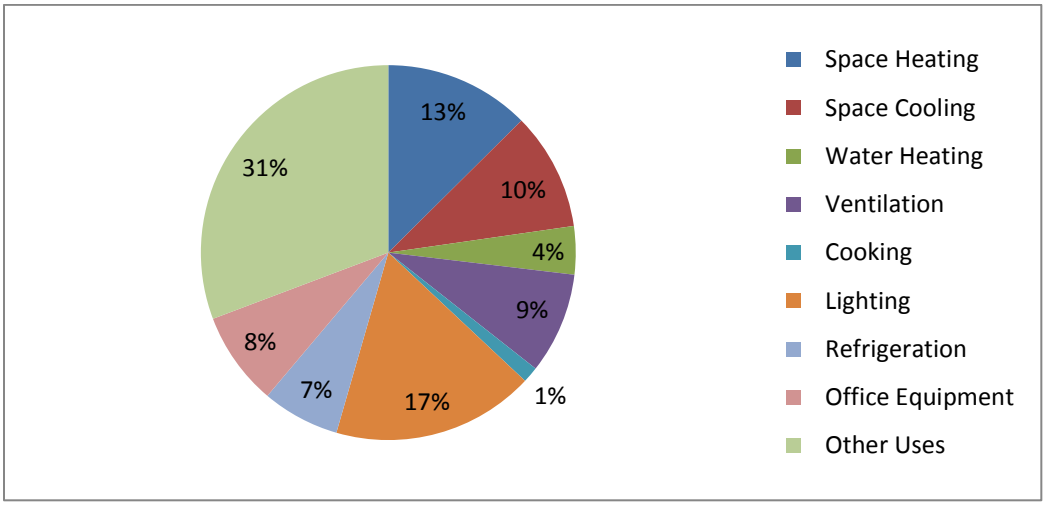


Figure 2-2. U.S. Commercial-Sector Energy Consumption by End Use

Source: (U.S. EIA, 2012)

2.3. Building Energy Codes[14]

Building energy codes establish minimum energy-efficiency standards for the design, construction, and renovation of buildings. Although the United States does not have a uniform national building energy code, the federal government has taken an active role in developing national model energy codes and in encouraging state governments to adopt and implement codes as well as providing education, training, and tools to assist state and local agencies, builders, and contractors in meeting code requirements. During the past quarter-century, federal legislation has required states to initiate energy-efficiency standards for new buildings and to review and consider adoption of national model energy codes (EPAct 1992). Most recently, the U.S. Congress stipulated that any state receiving supplemental state energy program funds under the American Recovery and Reinvestment Act (ARRA) of 2009 (the "stimulus bill") must pledge to adopt codes that meet specific stringency requirements[15] and to create plans to achieve and measure 90% compliance with the codes by 2017. All 50 states and the District of Columbia have submitted letters of assurance in accordance with the ARRA requirements.

The U.S. government's efforts to promote building energy codes have yielded mixed results. On the positive side, code adoption has increased markedly since passage of ARRA in early 2009. As of fall 2011, 29 states had adopted or demonstrated clear progress toward adoption of residential and commercial codes meeting the ARRA requirements; another six had adopted either residential or commercial codes in line with ARRA. However, despite these gains, 11 states still do not have a statewide code. Moreover, among many states with codes, compliance levels still lag. A number of recent studies (Misuriello, Penney, Eldridge, & Foster, 2010; Building Energy Codes Program, 2010b) have focused on the need for better assessments of compliance levels and improved data on where compliance failures are most likely to occur (e.g., insulation, windows, equipment, etc.).

The following Sections of the report address the development, adoption, and enforcement of U.S. codes governing energy efficiency and discuss best practices for maximizing code effectiveness.

2.3.1. Code Development

The 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. The International Code Council (ICC) and ASHRAE update each code on a three-year cycle. Once a new edition of the IECC or ASHRAE 90.1 is published, U.S. DOE issues a determination of the relative impact of the new version of the code compared to current model code versions. If U.S. DOE concludes that the new version is justified, the new version becomes the new model code for states to review and adopt. States have two years after publication of U.S. DOE's final

[14] The Building Codes Assistance Project maintains a website with comprehensive information and resources related to building energy codes in the U.S.: www.bcap-ocean.org.

[15] States have pledged to adopt building energy codes that meet or exceed the requirements of the 2009 International Energy Conservation Code for residential buildings and American Society of Heating, Refrigerating, and Air-Conditioning Engineers Standard 90.1-2007 for commercial buildings.

determination to revise their state codes to meet or exceed a new model code or submit to the Secretary of Energy an explanation of why they will not revise their codes. However, the federal government does not have a mechanism or authority to compel states to revise their codes if the explanation for not complying is deemed weak or unreasonable.

The national model codes form a baseline; they contain prescriptive requirements and/or performance criteria for materials and equipment including:

- Building shell: walls, floor, and ceiling;
- Doors and windows;
- Heating, ventilation, and air-conditioning (HVAC) systems and equipment;
- Lighting systems and equipment (hard-wired);
- Water heating systems and equipment; and
- Water fixtures and water-consuming appliances.

States have the flexibility to adopt amendments to the model codes as long as the state code meets or exceeds the model code baseline. Although states often amend the model codes to align with regional building practices or specific energy-efficiency policies and goals, only a handful of states have developed their own code rather than using the model code or an amended model code.[16] In some cases, municipalities have adopted codes that are substantially more stringent than the state code.

2.3.1.1. Residential Buildings

The 2009 IECC is the current national model energy code for residential buildings. The IECC is developed through a consensus process, with a cycle of hearings in which stakeholders are allowed to introduce amendments for a vote. The code is written in enforceable language that can be adopted and implemented directly by states and municipalities. In July 2011, U.S. DOE issued a final determination that the 2009 IECC would "achieve greater energy efficiency in low-rise residential buildings than the 2006 IECC, with site energy savings estimated at 14%," so, as of this writing, the 2009 IECC is the current national model code (U.S. DOE, 2011c).

U.S. DOE has accelerated its efforts to review revised codes, to reduce the lag time between publication and final determination. In October 2011, U.S. DOE issued a preliminary determination that the 2012 IECC would achieve greater energy efficiency in low-rise residential buildings than the 2009 edition (U.S. DOE, 2011b). The initial estimate of whole-building energy savings from the 2012 IECC is 30% relative to the 2006 IECC. The final determination regarding this code could be published in 2012.

The magnitude of savings achieved by the 2009 and 2012 IECCs indicates that these codes were more aggressive than the codes published prior to 2006, which resulted in very small incremental

[16] California, Florida, Oregon, and Washington have developed their own codes.

improvements (typically 1% to 2%). Figure 2-3 summarizes energy savings over the history of U.S. building codes.

In January 2013, the ICC will begin developing the 2015 IECC. Efficiency proponents, working together under the auspices of the Energy-Efficient Codes Coalition, plan to put forward proposals designed to yield whole-building energy savings of 50% relative to the 2006 IECC (i.e., an additional 20% improvement over the 2012 IECC). Final adoption hearings for the 2015 IECC will be held in October 2013.

2.3.1.2. Commercial Buildings

ASHRAE develops and publishes ASHRAE Standard 90.1: Energy Standard for Buildings, Except Low-Rise Residential Buildings (i.e., buildings other than single-family buildings and multi-family buildings three stories or less above grade). The standard is developed in accordance with American National Standards Institute practices following a consensus process guided by a committee of ASHRAE members. The IECC adopts ASHRAE 90.1 by reference as the IECC standard for commercial buildings.

On October 19, 2011, U.S. DOE issued a final determination regarding ASHRAE Standard 90.1-2010. The determination concludes that "the quantitative analysis of the energy consumption of buildings built to Standard 90.1–2010, as compared with buildings built to Standard 90.1–2007, indicates national source energy-savings of approximately 18.2% of commercial building energy consumption. Additionally, DOE has determined site energy-savings are estimated to be approximately 18.5%" (U.S. DOE, 2011d). This determination establishes ASHRAE 90.1-2010 as the national model code for commercial buildings, superseding the 2007 version. Similar to recent revisions of the IECC, recent revisions of ASHRAE 90.1 have been more aggressive and have resulted in significantly higher energy-savings than earlier versions of the code (see Figure 2-3).

The ASHRAE 90.1 Committee began work on Standard 90.1-2013 in the fall of 2010. For the 2013 standard, ASHRAE has established a target efficiency improvement of 50% for regulated end uses (i.e., 40% whole-building improvement) relative to ASHRAE 90.1-2004. The final revised standard is scheduled for adoption in 2013.

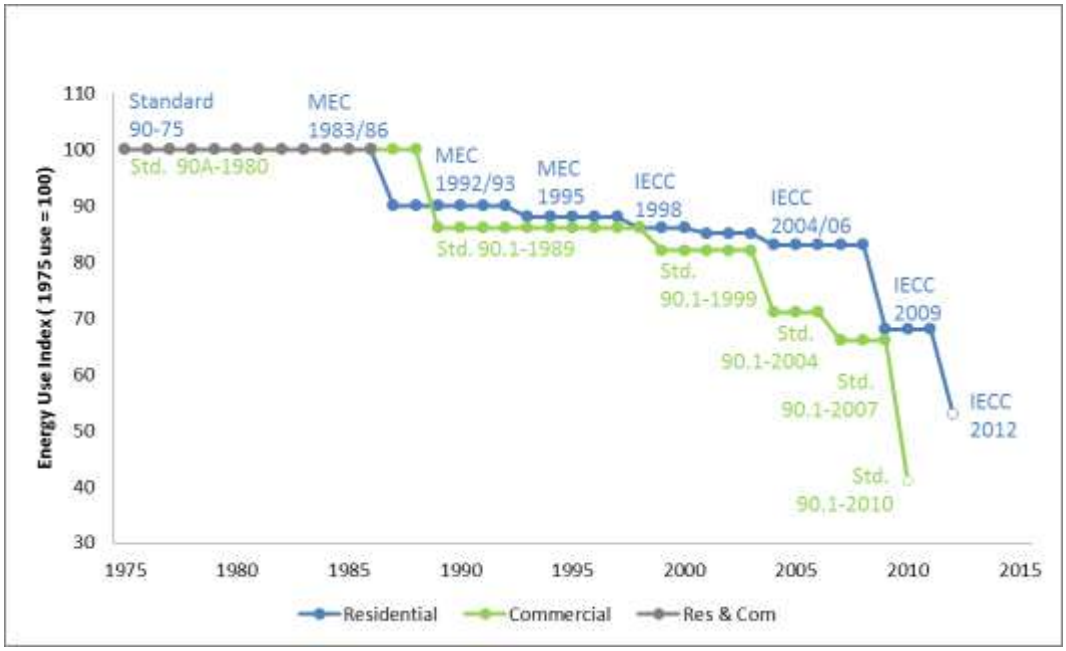


Figure 2-3. History of Code Revisions

Source: (Building Energy Codes Program, 2010b)

2.3.2. Code Adoption

In general, states adopt codes by legislative action or by regulatory action of administrative agencies or boards charged with code adoption; a similar process takes place at the municipal level in states where local governments have the authority to adopt codes. As noted above, code adoption activity has accelerated and is expected to continue in response to ARRA requirements. Figure 2-4 shows current and anticipated state codes for residential and commercial buildings. In general, an interested agency or lawmaker must take steps to initiate adoption of a code. Exceptions are Massachusetts and Maryland where each state has enacted a trigger requiring action to adopt the latest version of model code when U.S. DOE issues a determination.

States may also allow local jurisdictions to adopt more stringent code requirements. Cities may elect to adopt a more recent version of the model code or specific provisions to address particular issues. In recent years, states and cities have adopted some novel approaches, using codes to encourage innovative building practices and to pave the way for next-generation building technologies. Of particular note, Massachusetts was the first state to adopt an above-code appendix to its state code – the 120 AA "Stretch" Energy Code.[17] The "Stretch" Code is an enhanced version of the 2009 IECC with greater emphasis on performance testing and prescriptive requirements (e.g., blower doors, duct leakage). It was designed to be approximately 20% more efficient than the base energy code for new construction (at this time, the 2009 IECC). As of November, 2011, the stretch code has been adopted by

[17] A summary of the Massachusetts "Stretch Code" provisions can be downloaded from : http://www.mass.gov/eopss/docs/dps/inf/summary-of-the-ma-building-code-appendix-120.doc

104 of Massachusetts' 351 cities and towns. Another example is the City of Austin, Texas, which has committed to requiring that all new homes be zero-energy capable by 2015.[18] In accordance with this commitment, the city has developed local amendments to the IECC as well as a set of incremental targets for each code through 2015 to ensure that homes will meet the energy-efficiency levels required for zero-energy-capable homes.

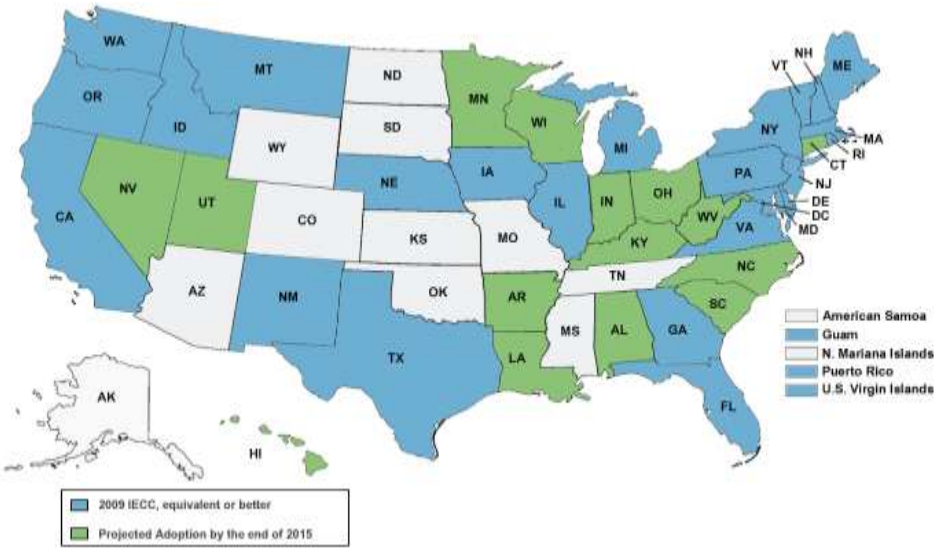


Figure 2-4. State Code Adoption: States that are Expected to have Residential and Commercial Energy Codes Meeting or Exceeding the 2009 IECC or ASHRAE 90.1-2007 by the End of 2015[19]

Note: Indiana, Kentucky, Ohio, Utah, and Wisconsin already have commercial codes in place that exceed ASHRAE 90.1-2007

2.3.3. Code Compliance and Enforcement

Though many states have adopted or will soon adopt the latest model energy codes, compliance is the key to achieving energy savings. Code implementation typically falls to state and local agencies that are responsible for compliance, enforcement, and training, including plan review and construction inspection. Currently, most funding for energy code enforcement comes from permit fees collected by local or state building departments.

The federal government offers support for state and local agencies. U.S. DOE grants provide substantial support for state and local training, and the agency has developed training curricula for local use. U.S. DOE also funds the development of tools for use in energy code compliance and enforcement. For example, U.S. DOE developed and disseminates the widely used code compliance software packages

[18] 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 (i.e., 82,499 thousand British thermal units [MBtu]).

[19] This and other maps on the status of code adoptions and other code-related activities are available on the U.S. DOE website at http://www.energycodes.gov/states/maps/residentialAdoptionActivity.stm

REScheck and COMcheck. These tools make it easier for code officials, prior to issuing building permits, to assess the extent to which building plans comply with code.

To date, there has been no coordinated or comprehensive effort to assess building energy code compliance with in the United States. During the past few decades, a number of studies using a wide range of methodologies have attempted to determine compliance for individual jurisdictions or at the national level, but few have yielded robust data on the percentage of buildings complying with codes or the amount of energy that non-compliant buildings could save if they were compliant. This lack of data makes it difficult to assess the impact of compliance lapses on overall energy savings from codes (Misuriello, Penney, Eldridge, & Foster, 2010). Despite the shortcomings identified in code compliance studies conducted to date, it is widely believed that code compliance falls well below 90% in most jurisdictions and that typical levels of compliance in finished buildings are 50% to 60% (Yang, 2005; Code Compliance Task Force, 2010a).

The recent ARRA requirements calling for states to demonstrate 90% compliance with codes by 2017 has invigorated efforts to develop a uniform methodology for measuring code compliance. The Pacific Northwest National Laboratory (PNNL) developed a methodology to measure compliance and has recently completed a nine-state pilot study using the methodology; a final report is expected soon. The goals of the PNNL study included assessing compliance and determining compliance patterns in each pilot state, creating comprehensive protocols for measuring compliance, and producing best practices for state building departments to follow when designing training programs. An additional nine states have launched their own code compliance studies.

State and local governments are responsible for code enforcement, and there are a number of different models of accountability and coordination among agencies. Four common code enforcement models are used, individually or in combination, in the United States:

- **State agency enforcement.** State inspectors enforce a statewide code by conducting inspections to supplement the efforts of local code officials. The effectiveness of this model depends largely on state resources, including the number of state staff relative to the size of the state.
- **Local enforcement.** City or county officials, often from the building department, conduct code enforcement activities, including plan reviews and inspections. Enforcement is typically carried out by the same officials that enforce fire and safety codes.
- **Third party enforcement.** Independent parties approved by the local building department or relevant state agency carry out code enforcement tasks (generally plan review and/or field inspections). Typically, the builder is responsible for hiring the third party and bears the cost of the inspection.
- **Self-certification**. Builders are required to submit proof of compliance to the state or local agency in charge of enforcement. Although this model reduces staffing needs, it is the easiest to game and yields great uncertainty regarding compliance.

Just as the federal government provides financial and technical assistance to states for building code implementation and enforcement, states in turn provide resources and assistance to municipalities. Local funds often augment these funding streams to conduct outreach and education for code officials and builders.

State and local governments face widespread challenges because of insufficient funding of code enforcement activity. A recent study conducted by the Code Compliance Task Force[20] estimated current energy code compliance expenditures at $200 million annually but identified the need for funding at $810 million per year, i.e., a funding gap of $610 million (Code Compliance Task Force, 2010b). Table 2-1 summarizes estimated funding needs and activities. In the current U.S. economic and political environment, it will be challenging to find a source for these funds, particularly from federal, state, or local coffers. Potential revenue sources include increased permit fees and/or improved collection of existing fees, system benefit charges, integrated resource planning, and other ratepayer funds. Another option to reduce the large shortfall in the funding needed for plan review and inspection is to make greater use of third-party inspectors paid for directly by the builder.

Allocating sufficient funding to code compliance and enforcement would yield significant returns. The task force analysis estimates that each dollar spent on code compliance and enforcement activities would achieve a six-fold payoff in energy savings and that full funding would save American consumers $2.7 billion in annual energy costs in 2020, growing to $10.2 billion in 2040 (Code Compliance Task Force, 2010b).

Table 2-1. Estimated National-Level Funding Needs for U.S. Code Compliance Activities

Category	Funding Need	Activities
Plan Review and Inspection	$660 million	• Staffing for plan review, permitting, inspection, and approval
Implementation and Training	$125 million	• Training of building code inspectors, builders, subcontractors, and design professionals • Outreach to stakeholders • Distribution of code books and compliance manuals; compliance evaluation • Development of alternative/pilot compliance methodologies
National Support	$25 million	• Support for code adoption and code development • Development of training tools and manuals • Public awareness campaign on the importance and benefits of building energy code compliance

Recent experience demonstrates how greater use of third-party inspectors can reduce the burden on local building departments and improve compliance. The City of Austin, Texas, has adopted performance testing requirements including blower door, duct leakage, airflow, and system static pressure tests for

[20] Led by the Institute for Market Transformation, the Code Compliance Task Force consisted of more than 40 representatives from the Building Codes Assistance Project, Natural Resources Defense Council, American Council for an Energy Efficient Economy, Alliance to Save Energy, and a broad range of other local, regional, and national stakeholder groups.

all single- and multi-family homes to ensure compliance with enhanced code requirements. Recognizing the burden that these testing requirements would place on the city's Planning and Development Review Department, the city is requiring the use of third-party contractors to perform the tests. The performance testing program has an annual budget of $131,200; registered third-party technicians are paid directly by the builder. Austin originally allowed a batch-testing process, following the U.S. Environmental Protection Agency (U.S. EPA) ENERGY STAR batch-testing guidelines, for builders constructing groups of homes using the same contractors but discontinued the process after a field audit found that some builders were gaming the system and two-thirds of homes that were not tested under the batch-testing protocol failed to meet the code. With adoption of the 2009 IECC, Austin requires performance testing in all single- and two-family homes; compliance verification shows that most new homes now exceed the code requirements by 4-5%.[21] Other states allow builders to submit home energy ratings (see discussion of the Home Energy Rating System [HERS] Index below) by certified third-party raters to demonstrate code compliance.

2.3.4. Energy Savings

A recent study from PNNL estimates that building energy codes will save more than 14.8 exajoules of energy between 2009 and 2030, with annual savings of 1.8 exajoules in 2030 (Belzer, Halverson, & McDonald, 2010). This translates to more than $15 billion in annual savings on energy bills in 2030 and a substantial decrease in the cost of meeting pollution reduction and carbon emissions goals.

2.3.5. Costs

The availability of data documenting federal, state, and local government expenditures on building energy codes is somewhat mixed. At the federal level, the 2010 appropriation for U.S. DOE's Building Energy Codes Program was $9 million, and the department has requested an increase to $10 million for 2012 (U.S. DOE, 2011a). This supports U.S. DOE activities such as the submission of code proposals; upgrading of model codes; financial and technical assistance to states for code adoption, implementation, and enforcement; and promulgation of standards for manufactured housing. The budget includes funds for U.S. DOE staff as well as funds allocated to states and building code research carried out by PNNL.

Drawing from a survey of building code officials, the Building Codes Assistance Project (BCAP) (2008) developed a set of budget calculations that can be used to estimate funding levels and staffing requirements for local residential building energy code enforcement. The calculations were updated based on feedback from the building codes community in 2010 and expanded to include residential and commercial code enforcement. The calculations take into account local wage rates; the expected rate of compliance at the first round of plan reviews; inspections and the number of buildings requiring follow-up or repeat review and/or inspection; time to meet continuing education requirements; and the time

[21] The Institute for Market Transformation recently published a detailed case study on Austin's third-party compliance program (Institute for Market Transformation, 2011a).

required for plan review, inspections, and other typical code official duties. BCAP provides default estimates for many of the input values in the calculator based on survey results and other research but also outlines each calculation so that users can customize with their own inputs.

Beyond the public-sector costs of building code implementation, the private sector also bears costs associated with code compliance, primarily increased construction costs. The perceived increase in costs to upgrade construction practices to meet more stringent code requirements has been a substantial barrier to adoption of state energy codes. Recent analysis from BCAP indicates that actual incremental construction costs yield relatively short paybacks for homeowners. Specifically, the study found that upgrading to the 2009 IECC resulted in a weighted average incremental cost of $840.77 per new home and average annual energy savings per home of $243.37; this translates to a simple payback for homeowners of 3.5 years (Paquette, Miller, & DeWein, 2011). When advanced techniques or performance tradeoffs were included, costs were lower, energy savings increased, and cost effectiveness improved. Anecdotal evidence compiled for new commercial construction found typical paybacks of four years or shorter, but additional research is needed (Building Codes Assistance Project, 2010a)

2.4. Building Energy Labeling

Building labeling in the United States is characterized by a diverse set of programs and players pursuing a wide range of approaches for improving the amount and clarity of information available about actual and potential building energy performance. There is not yet a mandatory building label or a common approach to labeling or other means of communicating building energy performance in the United States. However, many of the key elements needed for a comprehensive labeling infrastructure are in place or under development, a few voluntary labels have gained significant market share, and new labels have been introduced at the state or local level or are in the pilot stage.

2.4.1. Residential Programs

The Sections below describe three residential building labeling programs in the United States: the Home Energy Rating System, ENERGY STAR for Homes, and the U.S. DOE Home Energy Score.

2.4.1.1. Home Energy Rating System

The Residential Energy Services Network (RESNET) developed the Home Energy Rating System (HERS) (Figure 2-5) to provide an asset rating based on a home as designed and built. A HERS rating gives homeowners and prospective buyers a way to assess a home's energy performance and helps identify improvements in existing homes. HERS is the most well-known and widely accepted home rating in the United States. A HERS rating is required for a home to qualify for an energy-efficient mortgage, for ENERGY STAR labeling, and for many energy-efficiency programs that target new construction.

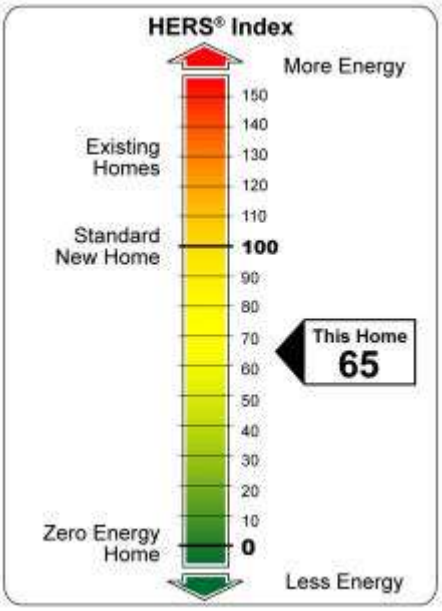


Figure 2-5. HERS Index

Under the HERS Index scoring system, the lower a home's score, the more energy efficient it is in comparison to the HERS Reference Home. A home built to the specifications of the HERS Reference Home (based on the 2006 International Energy Conservation Code[22]) is awarded a HERS score of 100, and a net-zero-energy home scores 0. Each 1-point decrease in the HERS Index corresponds to a 1% reduction in energy consumption compared to the HERS Reference Home. Thus, a home with a HERS Index of 85 is 15% more energy efficient than the HERS Reference Home, and a home with a HERS Index of 80 is 20% more energy efficient (RESNET, 2011).

[22] Unlike the IECC, the HERS Index is based on a whole-house energy use assessment. The HERS Reference Home specification includes assumptions about the efficiency of lighting, appliances, and miscellaneous end uses in addition to the heating, cooling and water heating energy use based on the 2006 IECC.

In support of HERS, RESNET has adopted standards for home energy audits conducted for HERS ratings, provides training and auditor certification, and approves energy modeling software eligible to calculate a HERS rating. Currently, four software programs are accredited by RESNET. As of 2009, there were more than 3,000 HERS raters nationwide, 88 accredited rating providers, and 29 rater training providers. More than one million U.S. homes have received HERS ratings, many in conjunction with the ENERGY STAR for Homes program and federal new home tax incentives. A rating typically costs anywhere from $300 to $800 and may be paid for by a builder, homeowner, or other interested party.

2.4.1.2. ENERGY STAR for Homes

U.S. EPA launched the first version of the ENERGY STAR for Homes (Figure 2-6) specification in 1995. Since then, nearly 1.2 million new homes have earned the ENERGY STAR label, including more than 126,000 homes in 2010 alone (108,000 single-family homes plus multi-family homes and manufactured housing) (U.S. EPA, 2011b). In 2011, U.S. EPA began to phase in ENERGY STAR for Homes version 3. Each new version of the ENERGY STAR guidelines has introduced new features and more stringent guidelines to ensure greater savings than under previous versions. When version 3 is fully implemented in 2012, qualifying homes will exceed the 2009 IECC by at least 15%. U.S. EPA allows specific regional variations in the ENERGY STAR guidelines to account for unique climate conditions or stronger state code requirements. Table 2-2 summarizes the main features of each version of the ENERGY STAR for Homes specification.

Figure 2-6. ENERGY STAR

In 2010, 25% of single-family homes built in the United States earned the ENERGY STAR rating. Sixteen states met or exceeded national market penetration, including several of the states that have the largest numbers of new home starts. The highest market penetrations are in Hawaii (77%), Nevada (66%), Iowa (57%), Arizona (52%), and Ohio (50%). The largest number of ENERGY STAR labeled homes was constructed in Texas, where 66,244 new homes representing 44% of the market earned the label in 2010, more than six times the number of ENERGY STAR homes built in any other state (U.S. EPA, 2011b).

Table 2-2. ENERGY STAR for Home Specifications

Version 1: 1995-2006	Version 2: 2006-2011	Version 3: 2011-
• High-performance windows • Tight construction and ducts • Efficient HVAC system • 3rd-party verification (HERS rating)	***Version 1 requirements, plus:*** • Thermal bypass checklist • Visual inspection of insulation installation • Right-sized HVAC systems • Promotion of efficient lighting and appliances	***Version 2 requirements, plus:*** • Thermal enclosure system rater checklist • HVAC system quality installation checklists (rater and contractor) • Water management system builder checklist Prescriptive and performance paths

2.4.1.3. Home Energy Score

U.S. DOE recently completed an initial pilot testing of its Home Energy Score and associated label. The intent of the label is to allow comparison of a home's energy consumption to that of other homes using a simple metric, similar to a vehicle's mile-per-gallon rating. Scores are on a scale from 1 to 10, with 10 representing a home that has excellent energy performance and 1 representing a home needing extensive energy improvements or upgrades. The Home Energy Score (Figure 2-7) is an asset rating and may not reflect how a home performs as used by current occupants.

To calculate a Home Energy Score, a qualified assessor briefly walks through the home and collects approximately 45 data points. The assessor uses U.S. DOE's Home Energy Scoring Tool (an on-line free software program) to estimate a home's energy use, convert that into a score, and develop recommendations for energy improvements. The assessor gives the homeowner a list of recommended energy improvements and the associated cost savings estimates as well as the Home Energy Score label.

Figure 2-7. U.S. DOE Energy Score Label

In summer 2011, U.S. DOE completed a set of pilot studies to test homeowner response to the energy score, home energy assessor training and reaction to the scoring tool, quality assurance methods, and climate adjustments of the scoring tool, among other issues. The studies were conducted in partnership with counties, utilities, and non-profit organizations in nine states representing varied climates and regions and urban and rural communities as part of a range of program designs (e.g., comprehensive retrofits, public information campaigns, etc.). The pilot studies demonstrated the value of specific recommendations for homeowners, the influential role of the energy professional/auditor, the ability of

the home energy score to engage homeowners, and the importance of incorporating the score into a comprehensive process that identifies opportunities, involves the homeowner in the assessment, and provides information on cost savings and other benefits. Based on input from the pilot studies, U.S. DOE has simplified the label and score, improved the scoring tool, revised assessor training and testing, and is planning to launch the Home Energy Score nationally in the first quarter of 2012 (Glickman, 2012).

2.4.2. Commercial Building Programs

The Sections below describe rating and labeling programs for commercial buildings in the United States: ENERGY STAR portfolio manager, ENERGY STAR buildings, ASHRAE building energy quotient, and green building ratings.

2.4.2.1. ENERGY STAR Portfolio Manager

In 2000, U.S. EPA introduced a new on-line tool designed to allow users—primarily commercial building owners and building managers—to compare the operational energy performance of their buildings to that of similar buildings from across the country. ENERGY STAR Portfolio Manager is a free interactive energy management tool that allows the user to track and assess energy and water consumption and generate a benchmark score from 1 (the worst) to 100 (the best). The tool is widely used by building owners and managers to understand the energy performance of individual buildings or of an entire portfolio of buildings, identify underperforming buildings in need of attention, and verify efficiency improvements including savings from changes to operations and maintenance (O&M) practices. The most widely used commercial building benchmarking tool in the United States, Portfolio Manager has been used to benchmark more than 1.95 billion m^2 of space. Originally designed for commercial office buildings, Portfolio Manager can now be used to benchmark 15 non-residential building types.

Portfolio Manager uses basic building characteristics, such as size, location, operating hours, and number of occupants, along with 12 months of consecutive utility bill data to compute a set of performance metrics. These metrics are then normalized for climate, vacancy, and space use to generate the operational rating.

2.4.2.2. ENERGY STAR Buildings

Commercial buildings earning a rating of 75 or higher using ENERGY STAR Portfolio Manager are eligible for the ENERGY STAR Buildings Label (Figure 2-8). Since the first building was labeled in 1999, more than 12,600 buildings representing more than 185 million m^2 of space have earned the ENERGY STAR label. Program participation continues to increase. In 2010, more than 6,200 buildings earned the ENERGY STAR label, an increase of almost 60% over 2009 (U.S. EPA, 2011a). The ENERGY STAR label can signify dramatic energy savings relative to typical buildings; 10% of all ENERGY STAR-certified

Figure 2-8. ENERGY STAR Buildings Label

buildings use 50% less energy than typical buildings. See the case study of the ENERGY STAR Buildings Program in Chapter 6 for a more in-depth discussion.

2.4.2.3. ASHRAE Building Energy Quotient

ASHRAE has developed a voluntary certification program for buildings that compares the labeled building to other buildings based on energy use intensity (energy use per square foot (ft^2)). The Building Energy Quotient (EQ) label (Figure 2-9) is also intended to illustrate how closely the building's performance aligns with its technical potential. In developing the label, ASHRAE drew on successful features of other building labeling and certification programs in the United States and Europe.

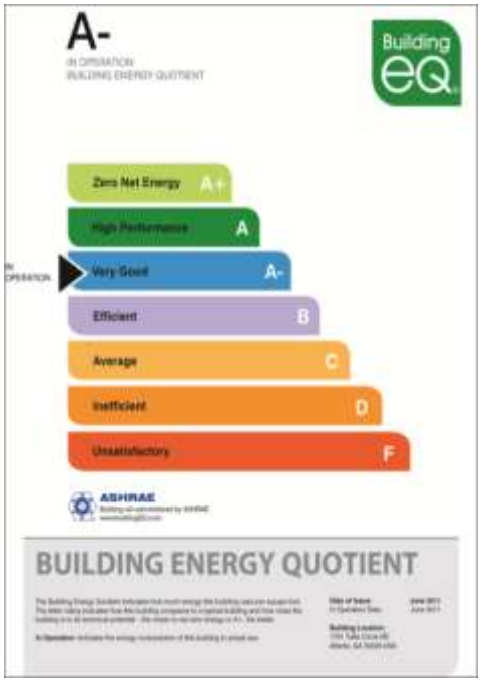


Figure 2-9. ASHRAE Building EQ Label

The Building EQ label was designed to provide both asset ("as designed") and operational ("in operation") ratings for a building's energy performance. In conjunction with the label, ASHRAE has developed two professional certifications that are required for individuals who rate properties under the program: the Building Energy Modeling Professional certifies "as designed" ratings, and the Building Energy Assessment Professional certifies "in operation" ratings. Table 2-3 gives specifics on each rating and certification.

Table 2-3. ASHRAE Building EQ Ratings and Professional Certification

Building Energy Quotient Ratings	
"As Designed" Rating	**"In Operation" Rating**
• Based on components specified in design • Rates quality of building • Based on energy model • Rates new or existing buildings	• Based on measured energy use • Rates combined effect of design and operation • Requires 12-18 months of operation for new buildings
Building Energy Quotient Certified Raters	
Building Energy Modeling Professional	**Building Energy Assessment Professional**
Certifies ability to evaluate, choose, use, calibrate, and interpret results of energy modeling software as applied to building and systems energy performance	Certifies ability to audit, analyze, and interpret information including project scope, data collection, building performance, systems alternatives, and energy-conservation measures

Source: (ASHRAE, 2011)

ASHRAE piloted the Building EQ "in operation" rating from May to September 2010 and planned to launch the full program in fall. The assessor certification was launched in January 2011. The pilot of the "as designed" rating was scheduled for completion in December 2011 with plans to launch the full "as designed" rating element of the label in 2012. Given the complexity of the rating process, only two buildings will participate in the "as designed" rating pilot project. Modeler certification was launched in January 2010.

2.4.3. Green Building Rating

Green building ratings and labels have a growing presence in the United States with a number of programs operating at the national, state, and local levels. By far the most widely adopted system is Leadership in Energy and Environmental Design (LEED), developed and administered by the U.S. Green Building Council. There are currently nine different LEED rating systems:

- New Construction (commercial construction and major renovations): LEED-NC;
- Existing Buildings: Operations & Maintenance: LEED-EB;
- Commercial Interiors (covering tenant improvements): LEED-CI;
- Core & Shell: LEED-CS;
- Schools: LEED for Schools;
- Retail: LEED-NC Retail;
- Health care: LEED-HC;
- Homes (new construction): LEED for Homes; and
- Neighborhood Development: LEED-ND.

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 rating system was slated for update in 2012 but has been postponed for more consideration until 2014.

As a green rating system, LEED awards points to a project for a wide variety of green attributes. Table 2-4 summarizes points available under the LEED for New Construction system, which was the first of the LEED rating systems to be developed. Several levels of LEED rating are available depending on the project's total point score: LEED Certified (40–49 points); LEED Silver (50–59 points); LEED Gold (60–79 points), and LEED Platinum (80 points or higher).

Table 2-4. Points Available under the LEED for New Construction System

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

Given the broad range of green features covered by LEED scoring, the rating system has not resulted in guaranteed superior energy performance; early experience with the system yielded mixed building energy performance results. In each revision of the LEED rating system, the U.S. Green Building Council has taken steps to improve the energy-related credits to ensure that LEED rated buildings exhibit better energy performance in operation.

Since its introduction in 2000, LEED has garnered significant market attention. As of November 2011, more than 55,000 projects had been LEED registered in the United States including more than:

- 21,000 LEED-NC;
- 15,000 LEED for Homes;
- 7,200 LEED-EB;
- 5,400 LEED-CI;
- 2,900 LEED-CS;
- 1,500 LEED for Schools; and
- 50 LEED-HC.

In December 2011, commercial building space certified under the LEED for Existing Buildings rating system surpassed that of LEED for New Construction by a cumulative 1.4 million m^2 (USGBC, 2011).

2.4.4. Emerging Policies Ratings and Disclosure

To date, mandatory building labeling has not gained traction at the national level in the United States. However, there has been growing interest in and movement toward mandatory benchmarking and disclosure of building energy performance ratings at the state and local levels. Since 2007, two states (California and Washington) and five large cities (Austin, New York City, San Francisco, Seattle, and Washington DC) have passed legislation requiring benchmarking and disclosure of building energy ratings covering an estimated 60,600 buildings and more than 371 million m^2 of space (Burr, Keicher, & Leipziger, 2011). Each of these jurisdictions requires benchmarking using the ENERGY STAR Portfolio Manager tool. The specifics of each policy differ to some degree, particularly with regard to the size and type of buildings covered, whether disclosure is public or only available to transactional parties, and the timing of disclosure.

State and local governments are pursuing benchmarking policies as a way to: verify the energy savings from publicly funded retrofit programs; develop a database of the energy performance of their building stock to guide decision making regarding programs and investments; and encourage greater consideration of building energy performance in purchase, lease, and financing transactions.

Of the policies enacted, only a few have so far been implemented; most will phase in during the period 2011 to 2015.[23] Variations in policy requirements and implementation methods are already providing useful lessons about unanticipated challenges and barriers, opportunities, and best practices that can be used by other jurisdictions and in the development of a federal program in the future. For example, in New York City, vendors played a critical role in achieving a high rate of compliance (more than 70%) with the initial reporting deadline for private building benchmarking data. Auditing firms, consulting engineers, and others have begun offering benchmarking as a new service to clients and are using benchmarking to engage owners in further audits and upgrade projects (Burr, IMT, 2011).

[23] The Institute for Market Transformation and the Natural Resources Defense Council maintain information and resources on the latest developments in building energy rating and disclosure at www.BuildingRating.org.

2.5. Incentives for Improved Building Performance

Recent studies estimate that cost-effective energy-efficiency improvements in the U.S. building sector have the potential to reduce annual electricity and natural gas consumption by 20-30% over the next 10 to 15 years, which would save American consumers and businesses more than $100 billion annually (Eldridge, Elliott, & Vaidyanathan, 2010; Granade, Creyts, Derkach, Farese, Nyquist, & Ostrowski, 2009). Efficiency improvements of this magnitude translate into annual electricity savings of more than 695 billion kilowatt hours (kWh) and natural gas savings of almost 51 billion cubic meters (m^3), for a combined savings of approximately 4.5 exajoules each year. Despite the potential for savings, numerous barriers impede building owners from making greater investments in efficiency, including higher first costs; split incentives; and lack of information, education, and training on new technologies and practices available to deliver energy savings.

Financial incentives in the form of direct payments (e.g., rebates) or low-cost financing play a key role in driving homeowners and businesses to invest in energy efficiency. Public-sector, utility, and private-sector investments in improving buildings' energy efficiency can take the form of direct financial incentives (e.g., tax credits and rebates), market development activities, and financing. The following subsections cover incentive programs and new financing mechanisms targeting the new construction and existing buildings.[24]

2.5.1. Utility and Ratepayer-Funded Programs

Efficiency program spending increased more than threefold in the U.S., from $900 million in 1998 to about $3.4 billion in 2009 for electricity programs. In 2010, total budgets for electricity efficiency programs reached about $4.5 billion, and natural gas program budgets were $1 billion; the American Council for an Energy-Efficient Economy estimates a combined total of $5.5 billion dedicated to efficiency programs in that year. Figure 2-10 shows the trend in ratepayer-funded energy-efficiency program spending from 1993-2010. Although these utility programs target the residential, commercial, and industrial sectors, residential and commercial buildings receive the largest share of program funds. In its annual report on the efficiency program industry, the Consortium for Energy Efficiency reports that 2010 electricity program budgets were split among commercial and industrial efficiency programs (39%), residential efficiency programs (23%), and low-income programs (8%), with the remainder going to load management and other programs (CEE, 2010). In contrast, a higher percentage of gas program budgets was directed to the residential sector (41%) followed by low-income (27%) and commercial and industrial sectors (24%).

[24] The discussion in these subsections focuses on existing building (retrofit) programs targeting whole-building energy performance rather than programs targeting specific product types or end uses (e.g., lighting, HVAC).

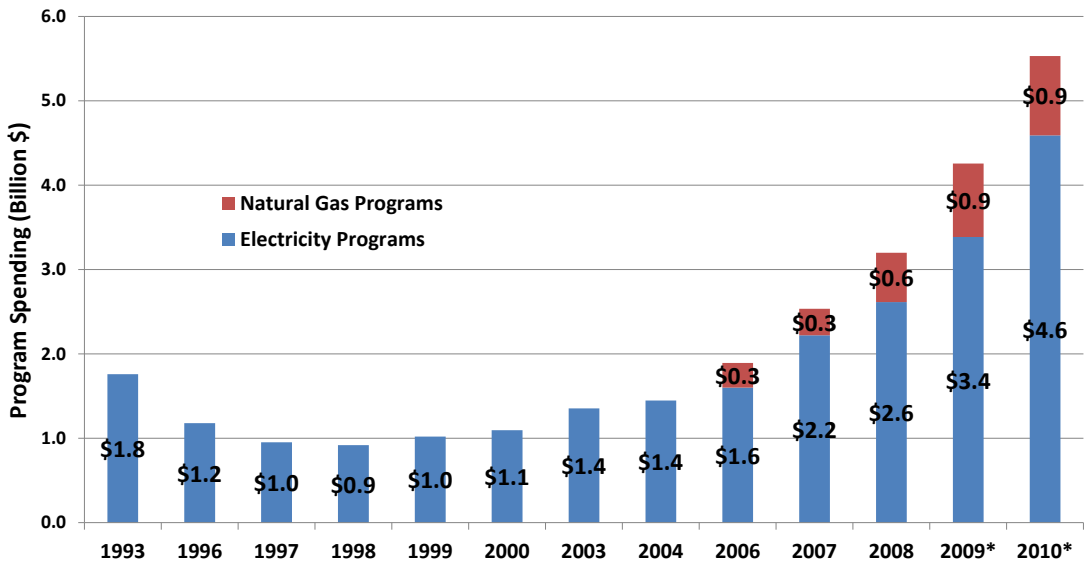


Figure 2-10. State-Level Energy-Efficiency Program Spending or Budgets by Year, 1993–2010

Source: (Sciortino, et al., 2011)

Much of the increase in program spending can be attributed to increasing state-level regulatory commitments to energy efficiency. Twenty-four states now have policies in place that establish specific energy-savings targets that utilities or related organizations must meet through customer energy-efficiency programs. This type of policy, called an "energy-efficiency resource standard" (EERS), is analogous to the "renewable portfolio standard" that is in place in a majority of the states. An EERS sets multi-year electricity or natural gas efficiency targets (e.g., 2% incremental savings per year or 20% cumulative savings by 2020), presented as a percentage of retail sales.

EERS policies accelerate and expand the scale of energy savings achieved through utility and related energy-efficiency programs. The widespread adoption of EERS policies represents a significant evolution in utilities' treatment of energy efficiency. An EERS explicitly focuses on quantifiable energy-savings results, which directly reinforces the categorization of energy efficiency as a real utility system "resource" and helps utility system planners anticipate and project the effects of energy-efficiency programs on utility system loads and resource needs. Moreover, EERS targets are generally set at levels that push programs to achieve higher savings than they previously targeted. EERS policies have strict requirements that measures adopted must be cost effective to ensure that programs provide overall benefit to customers. Not only does an EERS drive utilities and program administrators to achieve greater levels of savings, but it also helps ensure a long-term commitment to energy efficiency as a resource, build essential customer engagement, and develop the workforce and market infrastructure necessary to sustain high savings levels.

Increases in spending on energy-efficiency programs result in higher levels of energy savings. According to Consortium for Energy Efficiency (CEE), in 2010, cumulative annual U.S. electricity savings from ratepayer-funded efficiency programs were estimated at 112,468 gigawatt hours (GWh) (CEE, 2012),

more than double the estimated savings in 2005, of 47,384 GWh (CEE, 2006). Natural gas savings have increased even more dramatically, growing more than fourfold from an estimated 182 million therms in 2005 (CEE, 2006) to 808 million therms in 2010 (CEE, 2012) (annual cumulative savings).

Utilities and other energy-efficiency program administrators use rebates to reduce the initial cost of energy-efficiency investments, which encourages higher levels of energy efficiency in the construction, renovation, and replacement markets than if purchasers had to pay the full initial costs themselves. Early rebate programs (from the 1980s into the 1990s) focused largely on appliances and equipment, to reduce the initial cost of a single product or system (e.g., lighting). As an increased focus on product efficiency led to an increased market share of higher-efficiency products and, in turn, more stringent minimum efficiency standards, programs began to look for new opportunities to save energy. During the past 10 to 15 years, a growing number of programs have augmented their traditional equipment rebate programs with initiatives targeting comprehensive whole-building approaches that combine high-efficiency equipment with sophisticated construction techniques and installation and operations practices. These have yielded energy savings as well as better building performance in terms of occupant comfort, safety, and productivity.

2.5.1.1. Residential Sector

In the residential sector, the U.S. EPA has developed ENERGY STAR-branded programs targeting the new home construction and existing home retrofit markets.[25] Both programs specify home energy performance, improvement, and quality assurance requirements, providing program administrators a platform for their own customized program offerings. Individual programs build off the ENERGY STAR platform to meet the needs of their local markets for contractor training, certification, marketing, and incentives.

The ENERGY STAR for Homes program, described previously in Section 2.4.1.2, is offered by more than 100 utilities as the basic platform for their new homes programs although many utilities add other components or requirements. For example, the largest California utilities require minimum energy-efficiency levels in their new homes programs to be 15% greater than the California Title 24 code requirements. In addition to marketing the benefits of ENERGY STAR-labeled homes, program sponsors often offer financial incentives to increase participation and help transform the market. Incentives offered by new homes programs range from less than $1,000 to $12,500 (CEE, 2010).

According to the U.S. EPA, the four most common utility program incentive structures, used alone or in combination, are:

- **Tiered incentives**: Incentives offered to builders, with increasing value for increased efficiency. ENERGY STAR qualification is typically a prerequisite for all tiers.

[25] In mid-2011, the existing homes program (Home Performance with ENERGY STAR) transitioned from U.S. EPA to U.S. DOE.

- **Equipment incentives**: Additional incentives may apply to specific high-efficiency equipment (e.g., HVAC equipment, lighting, or on-site energy generation) installed in a new ENERGY STAR-qualified home.
- **Rating incentives**: Paid to the builder or directly to the rater, these incentives cover the cost of the rating required for ENERGY STAR certification.
- **Homeowner discounts**: The utility pays a percentage or flat-fee discount on utility bills to owners of ENERGY STAR-qualified homes (U.S. EPA, 2011c).

For existing homes, the Home Performance with ENERGY STAR (HPWES) program takes typical residential audit programs to a new level by coupling a thorough diagnostic assessment with a clear pathway for the homeowner to complete the recommended retrofit measures. Program sponsors in 32 states recruit contractors who are qualified to perform comprehensive home assessments. The assessments include the heating and cooling systems, windows, insulation, air infiltration/ventilation, and a safety check on any gas-fired appliances. Upon completion of the home energy upgrades, the contractor is required to assess the home's performance again to document that specified improvements were properly installed to achieve the promised energy savings. All participating contractors are subject to quality assurance reviews by a third-party sponsor to ensure that projects meet program standards, and homeowners are assured of high-quality work. To date, more than 110,000 homes had been enrolled in the program, including more than 35,000 in 2010. Program sponsors offer a wide range of incentives to contractors and homeowners through the HPWES program, including cash rebates and interest rate buy-downs on project financing.

In an HPWES project improvements typically include increasing attic insulation; insulating crawl spaces or rim joists; sealing, repairing, and insulating ducts; air sealing cracks; and installing programmable thermostats, energy-efficient replacement water heaters, heat pumps, air conditioners, furnaces, boilers, lighting, or windows. For the program sponsor’s planning purposes, program guidance suggests potential annual savings ranging from 1,400 kWh electricity and 400 therms natural gas in the northeast United States to 4,600 kWh electricity and 200 therms natural gas in the southern United States. Based on results from the longest-running HPWES programs, U.S. EPA and U.S. DOE estimate average per-home energy savings of 20% (U.S. EPA, 2011d). Savings are typically higher in homes where heating, cooling, or water heating equipment is replaced as part of the project. An HPWES program requires a much higher investment of program resources at start-up when the sponsor is typically supporting infrastructure development (e.g., contractor training and certification, marketing, inspections, etc.), but the costs decrease over the long-term. U.S. EPA estimates the levelized cost of saved energy for a mature HPWES program at $0.05 per kWh. Programs including gas savings are typically much more cost effective because gas savings in most climates are significant.

In addition to HPWES, other whole-house programs that administrators have rapidly been developing include home assessments, diagnostic test-in and test-out, and incentives for a comprehensive set of efficiency measures including air sealing, insulation, and duct sealing, in addition to equipment rebates. Many of these programs are similar to the HPWES program. Rebates in these programs typically range

from $1,000 to as much as $4,000 depending on the size of the project and the anticipated energy savings.

2.5.1.2. Commercial Sector

Incentive programs for new commercial construction and building energy performance improvements are more customized than residential-sector offerings and are often based on the level of savings achieved. For commercial buildings, there is no single leading national specification or platform for energy-efficient new construction comparable to ENERGY STAR for Homes. Many programs incorporate LEED certification in recognition of the popularity of LEED in many markets; others use the New Buildings Institute's Advanced Buildings protocol. Common elements in new commercial construction programs include technical assistance, training and education, design incentives, and measure incentives. Many programs require and/or offer assistance for building commissioning. Incentives can range from less than $50,000 to more than $450,000.

For existing facilities, programs offering a whole-buildings approach may target more comprehensive retrofit projects that encourage customers to upgrade multiple building systems together (often with a bonus incentive) or take a building performance approach that focuses on retro-commissioning (or "building tune-up") and O&M practices and, when warranted, equipment upgrades. Both approaches can yield savings far exceeding those from traditional single-system retrofits. Studies indicate that savings from comprehensive retrofit programs range from 11% to 26% of whole-building energy use; savings from retro-commissioning and O&M improvements range from 8% to 20% (Amann & Mendelsohn, 2005).

In May 2010, the U.S. EPA launched a new pilot program for commercial buildings, Building Performance with ENERGY STAR (BPwES). The program offers a framework for efficiency programs to work with business customers to pursue whole-building energy improvements by aligning financial incentives and technical assistance to make comprehensive upgrades more attractive. Program elements range from benchmarking with ENERGY STAR Portfolio Manager to whole-building assessments to identify opportunities and prioritize projects with the greatest savings. BPwES sponsors can work with customers to develop a package of technical assistance and incentives that maximize energy savings. Seven pilot efforts are initiating the program in the Northeast, Midwest, and California.

2.5.2. Tax Incentives

Although ratepayer-funded and state-led efficiency programs account for the bulk of incentives for improved building energy performance, tax incentives can augment other incentive funding or provide a unique source of support in regions of the country where there is limited (or no) program activity by utilities or other program administrators.

The Energy Policy Act of 2005 (EPAct 2005) established energy-efficiency tax incentives in the residential, commercial, and transportation sectors to increase the market share of advanced energy-

efficiency products and encourage homeowners and business owners to undertake energy-efficiency improvements. For the most part, these tax incentives were designed to cover the very highest levels of efficiency sold in 2005 (e.g., equipment and practices that had less than a 5% market share at the time), to minimize costs to the Federal Treasury and "free riders" (tax credit participants who would have purchased eligible products even if the tax credits weren't available).

2.5.2.1. New Homes

The new homes provision gives a credit of $2,000 to builders of homes that use 50% less energy for space heating and cooling than homes built according to the 2004 IECC. EPAct 2005 established this credit for 2006–2008, and subsequent legislation extended it through 2011 but has not updated the reference code to the 2009 IECC (i.e., the requirement is still 50% energy savings relative to the 2004 IECC). The tax credit has successfully shifted the new homes market toward more energy-efficient homes. As shown in Table 2-5, the number of homes participating in the credit grew fourfold between 2006 and 2009. In addition, energy-efficient homes gained a greater market share; the number of homes certified as eligible for the tax credit rose to 10% of new homes sold in 2009; however, because of the economic recession in 2009, the total number of new homes declined substantially (Gold & Nadel, 2011).

Table 2-5. Number of New Homes Certified as Eligible for the Federal Tax Credit

Year	Number of Homes Certified as Complying with the Credit	Total US Homes	% of Market
2006	8,141	1,051,000	0.8%
2007	23,702	776,000	3.1%
2008	21,939	485,000	4.5%
2009	37,506	375,000	10%

Source: (Gold & Nadel, 2011)

In addition to the credit for site-built homes, the provision includes a $1,000 tax credit to the builder of a new manufactured home achieving 30% heating and cooling energy savings compared to the 2004 IECC and its supplements (at least one-third of the savings must come from building envelope improvements) or to a new manufactured home meeting ENERGY STAR requirements. The number of new manufactured homes with the ENERGY STAR designation increased from 8.3% in 2006 to 9.6% in 2010. Although these percentages do not represent the actual number of tax incentives used by consumers, this industry is highly sensitive to costs, and consumers tend not to demand high-performance homes. As a result, the growing market share is probably largely attributable to the manufactured homes tax incentive. In addition, this credit has helped utilities gain market share with ENERGY STAR-based rebate programs (Gold & Nadel, 2011).

2.5.2.2. Residential Retrofits

Under the residential retrofits provision, homeowners are eligible for tax credits for upgrading building envelope components (windows, insulation, metal roofs, etc.) and installing energy-efficient new equipment. From 2006 to 2011, the amount and availability of the tax credit changed, creating some confusion and uncertainty in the market (see Table 2-6).

Table 2-6. Summary of Residential Retrofit Tax Credits

Year	Tax Credit	Maximum Tax Credit
2006-2007	10% of equipment/materials cost	$500 per household
2008	No tax credits	
2009-2010	30% of equipment/materials cost	$1,500 per household
2011	10% of equipment/materials cost	$500 per household

A preliminary report on the residential retrofit tax credits found that three types of improvements accounted for most of the credits claimed in 2006 and 2007: windows, insulation, and exterior doors. See Table 2-7.

Table 2-7. Residential Retrofit Tax Credit Spending on Improvements in 2006 and 2007

	Total Spending on Eligible Improvements (in millions)	
Type of Improvement	2006	2007
Insulation	$2,492	$2,276
Exterior Windows	$2,913	$4,102
Exterior Doors	$1,848	$1,816
Metal Roof	$324	$508
Energy-Efficient Building Property*	$197	$288

Source: (U.S. Government Accountability Office (U.S. GAO), 2010a; U.S. GAO, 2010b)

**Energy-efficient building property includes high-efficiency heating, cooling, and water heating equipment meeting efficiency performance specifications in the enabling legislation.*

2.5.2.3. Commercial Buildings

Tax incentives for new and existing commercial buildings provide a deduction per ft^2 for owners and tenants who reduce HVAC and interior lighting energy use by 50% relative to ASHRAE standard 90.1-2001. The same incentive applies to new buildings and retrofit projects. Although data are limited, anecdotal evidence suggests that few whole-building deductions were taken between 2005 and 2010. Low participation is credited to delays in guidance and software approval from U.S. DOE and the Internal Revenue Service, as well as the failure of the agencies to develop the contractor certification standards that the legislation requires (Gold & Nadel, 2011).

Commercial lighting deductions account for the vast majority of the incentives claimed because they proved the easiest to understand and with which to comply. In addition, as part of outreach efforts, the lighting industry designed a website, http://lightingtaxdeduction.org/, that gives information about how to best take advantage of the tax credit. The HVAC and building envelope industries did not undertake similar educational campaigns. As a result, the commercial buildings tax deduction was more successful at increasing the market share of advanced commercial lighting products and less successful at increasing the number of whole-building, HVAC, and building envelope improvements (Gold & Nadel, 2011).

The commercial buildings tax deduction has been extended through 2013. In general, tax incentives such as these should be implemented with a longer lead time that was the case with this deduction, which originally took effect immediately after it was enacted in 2005 and expired January 1, 2008. Because of the time necessary for U.S. DOE to issue advice and for the IRS to create rules regarding qualifying for and claiming the deduction, as well as the time required to conduct an education campaign, high levels of participation were achieved only in the past two years.

2.5.3. Financing Mechanisms

Meeting aggressive energy savings and climate protection targets requires private investment in energy-efficiency upgrades by building owners and occupants. Incentives alone will not be sufficient to meet the needs for building retrofits. Despite the benefits of energy-efficient investments, high up-front costs continue to be a significant barrier to leveraging retrofits to achieve potential monetary and energy savings across the building sector. During the past several decades, a number of innovative energy-efficiency financing program designs have emerged that are designed to reduce the up-front costs of energy-efficiency improvements and assist owners in the residential and commercial building sectors in achieving maximum energy savings.

2.5.3.1. Loan Programs

Financing programs offering loans to cover the costs of energy-efficiency upgrades have been available in the U.S. residential and commercial sectors for many years. Although a few federal programs offer efficiency financing products (mostly for the residential sector), there is no widely used national energy-efficiency loan program, so state programs are particularly important. States across the country have implemented loan programs with varying degrees of success. Although several programs have many years of experience and have issued thousands of loans, this market has yet to come to scale. It has been difficult to attract large levels of private capital into this market because lenders find it hard to evaluate the risk presented by these types of loans.

2.5.3.2. On-bill Financing

“On-bill” financing generally refers to a financing for energy-efficiency improvements that is serviced by, or in partnership with, a utility company and is repaid by the customer through his or her monthly utility

bill. In many cases, energy savings are sufficient to cover the monthly payment (in other words, utility bills are less than or equal to what they were before the efficiency improvement even though the bill includes the monthly installment to repay the cost of the improvement). Programs can be tailored to the commercial or residential sectors. At present, 14 states have on-bill financing programs, with another six running pilots or having programs in the works. Nine of these states (California, Georgia, Hawaii, Illinois, Kentucky, Michigan, New York, Oregon, and South Carolina) have legislation in place supporting adoption of on-bill financing, and regulators in a number of other states are exploring the feasibility of on-bill financing programs.

On-bill financing programs can leverage a utility's unique relationship with energy customers to provide convenient access to funding for energy-efficient investments. In many cases, as noted above, these programs' customers to pay back the cost of their energy-efficient improvements with the money saved on their utility bills. Financing can be extended to previously underserved markets in the form of a service charge or, in the case of on-bill loans, through modified underwriting that takes bill payment history into account. Other advantages of on-bill financing include:

- Convenience of a single bill for program participants;
- Bundling of rebates and other incentives with financing to increase the attractiveness of efficiency projects;
- The perception that on-bill programs are a more secure investment that can attract additional private capital;
- A mechanism for financing improvements in rental properties and for individuals who might not stay in their homes for a long time (because investment and repayment are linked to the utility meter account rather than to a specific customer/person).

2.5.3.3. Property-assessed Clean Energy Financing

Property-assessed clean energy (PACE) financing allows property owners to finance energy-efficiency and renewable energy projects through an assessment on their property tax bills for up to 20 years. This arrangement addresses two key barriers to energy-efficiency investments: long-term financing eliminates the first cost barrier and provides for low-interest payments that are more than covered by energy savings; and the repayment obligation transfers to the new property owner upon sale, along with the energy bill savings from the project, thus eliminating the risk that an owner is unable to recoup the investment at the time the property is sold. Once a municipal government establishes the PACE financing district, funds are raised from bond issues, which brings in private capital rather than government subsidies or taxpayer funds. This makes PACE an attractive tool for local governments working to meet energy savings or carbon reduction goals.

PACE is a relatively new option for financing energy-efficiency projects. Since the first states adopted enabling legislation in 2008, PACE has been authorized in 24 states and the District of Columbia. In mid-2010, most PACE programs for the residential sector were put on hold as a result of actions by the Federal Housing Finance Agency. Despite these actions, several municipalities have continued to offer

PACE to local homeowners. PACE advocates are pursuing federal legislation to address the Federal Housing Finance Agency's concerns and allow municipalities to move forward with PACE programs.

In the commercial sector, PACE programs are beginning to ramp up as private capital flows into programs that are operating initially with federal grant money. Commercial programs have not been subject to the same regulatory constraints as residential programs; many new programs have been launched within the past year so more data to analyze their impact should be available in the near future.

2.6. Best Policy Practices in the United States

This section summarizes key indicators of best practices in U.S. building energy-efficiency codes, building labeling programs, and incentives.

2.6.1. Building Energy Codes

The subsections below identify key indicators of best practices in U.S. building codes.

2.6.1.1. Best Practices

Transparency: The IECC and ASHRAE code development processes are open and transparent, allowing diverse stakeholders an opportunity to participate. This open process increases acceptance of the final product, which can be incredibly important to state-level adoption efforts.

Regular and frequent code revision cycles: The regular and frequent U.S. code revision cycles improve the stringency of codes and keep codes up to date with advances in technology and construction practices. The result is that building energy efficiency and energy savings continue to increase, and codes become tools for market transformation.

Flexibility in code design and compliance pathways: While far from universal in the United States, there are states and cities that allow for technology advances and provide tools and alternative compliance paths for meeting the standards. Two well-known examples are California at the state level and Austin, Texas with its zero-energy-capable-buildings code.

Local "stretch" codes: U.S. provisions for local governments to adopt codes that exceed the statewide requirements give flexibility to progressive municipalities, those with more resources, and those facing specific energy-related constraints who wish to enact more stringent minimum codes. More stringent codes at the local level result in energy efficiency beyond the minimum levels specified in state codes, which helps to increase the overall efficiency of the building stock.

Utility involvement: The U.S. practice of providing utilities with incentives to incorporate building code support into their program portfolios (i.e., allowing utilities to claim savings from code support activities) leverages utility relationships with builders, designers, and contractors; builds on utility expertise in education, training and outreach; and reduces the burden on local building departments.

Support from industry, non-governmental organizations, and governments: In some states, electric and gas utilities are empowered and allowed increased profits to provide technical assistance for customers in meeting standards and/or incentives for exceeding the standards. Some states and cities engage non-profit organizations with technical expertise to assist in design of standards. Local governments often provide support beyond code compliance. These are best practices; they are not, as yet, widespread.

Code compliance software: The use of code compliance software (such as REScheck or COMcheck) simplifies the task of establishing or evaluating designs to assure code compliance. These codes work with the national level (voluntary) codes and with some state-level codes.

Complementary policies: In some states, building codes are coupled with building energy labeling and disclosure policies as well as incentives for exceeding the code.

2.6.1.2. Issues

Code revision lead times: Current lead times for the IECC and ASHRAE code development processes and subsequent U.S. Department of Energy (U.S. DOE) review and certification curtail the aggressiveness of code revisions. By the time revised codes are implemented, technologies and construction practices have evolved, and the underlying cost and cost-effectiveness assumptions are often outdated. In addition, there is often a lag between U.S. DOE's adoption of a new code and states following suit. Establishing mechanisms to trigger automatic state review and adoption of the latest model codes as soon as U.S. DOE adopts them would ensure their timely rollout, which would increase energy savings. This has been the case in the U.S. state of Maryland where a trigger provision led the state to adopt the 2012 IECC before U.S. DOE had issued its final determination on the revised code. Such mechanisms might also reduce politically motivated delays in code review, which sometimes occur despite extensive stakeholder engagement in code development.

Funding and use of third parties: Allocating sufficient funding for code compliance and enforcement initiatives is critical to effective building energy codes. Funding should enhance or, at a minimum, maintain existing budgets for building department training, inspection, and outreach to the building community. One way to reduce the burden on local building departments is to expand code compliance models to include the use of third parties for plan review and inspections. Under a third-party compliance model, most costs are paid by the builder and passed through to homebuyers. The role of third parties will be of increased importance with the increased performance testing requirements in the 2012 IECC.

2.6.2. Building Energy Labeling

2.6.2.1. Best Practices

Robust rating system: U.S. experience with the Home Energy Rating System (HERS) and more recently with LEED demonstrates the importance of rater training and certification and adequate tools for modeling and/or calculating a building's rating. These features increase the credibility of ratings and facilitate their use in mandatory programs and labeling policies.

Stakeholder involvement: The U.S. practice of engaging stakeholders in updates to rating and labeling improves the usefulness of these programs, increases buy-in and support for labels, and enhances marketing.

Consumer/user research: U.S. building energy and rating labels that have been based on consumer research incorporate designs and features that have made them effective in practice and facilitated implementation.

Public education and awareness: Campaigns to educate the public and prepare key market players have been critical to the success of new building labels and implementation of building rating policies in the United States. Education and awareness builds demand for voluntary labels and engages the market. Training for building owners and vendors has had a marked impact on early compliance with mandatory rating and labeling.

Program coordination among federal and state governments and utilities: Working with existing programs has leveraged the impact of U.S. labeling programs by taking advantage of existing program infrastructure and utilities' relationships with homeowners, building owners and managers, and other relevant stakeholders (e.g., contractors and real estate agents).

Detailed recommendations for building improvements along with ratings: The time when a building is rated or assessed for a label is a prime opportunity to engage owners in potential energy-efficiency upgrades. Providing recommendations as part of the rating package helps U.S. building owners understand their opportunities and options.

2.6.2.2. Issues

Need for broad mandatory labels and enforcement: To date, much of the activity on building energy labeling in the United States has focused on development of rating and labeling systems for adoption on a voluntary basis by builders and building owners, use in ratepayer-funded and other efficiency programs, or incorporation into lending programs. The recent emergence of mandatory building labeling requirements in a number of states and municipalities will increase the reach and impact of these rating and labeling schemes. Broader adoption of mandatory labeling requirements at the local, state, and federal levels is needed, coupled with strong enforcement.

2.6.3. Financing and Incentive Programs

Driving investments: Energy-efficiency resource standards, energy savings targets, and other policies can drive investment in energy efficiency. Targets, particularly when coupled with performance incentives or other measures that reward entities that exceed their goals, have been demonstrated to increase spending and to expand the breadth and depth of program offerings in the United States.

Stakeholder engagement: Engaging a broad range of stakeholders in policy and program development and implementation in the United States has helped create better-designed incentives and with increased participation rates.

2.6.3.1. Best Practices

Incentives that match the market: Incentives can be matched to the market by adjusting their timing, amounts, and delivery mechanisms. Where program administrators have the flexibility to monitor the market and make midstream adjustments to their programs, programs are more effective in yielding energy savings and driving market transformation.

Education and outreach: The U.S. experience demonstrates the importance of funding program budgets and plans that are adequate to cover education and outreach to market participants, ensuring that participants understand incentive and program rules. The U.S. commercial buildings tax incentive was much more successful in driving lighting upgrades than other types of retrofits. The lighting industry's public outreach efforts played an important role.

Targeted programs: U.S. commercial-sector programs targeted to specific market segments maximize participation and savings as demonstrated by ratepayer-funded programs and ENERGY STAR efforts targeted toward the commercial real estate, office, retail, hospitality, food service, and health care sectors.

Evaluation: Tracking and evaluation mechanisms are built into the majority of U.S. programs. Those that also have the flexibility to make midstream corrections and improvements in response to needs revealed through program evaluation have been the most effective.

Policies to address barriers: In the most successful programs, program designers research potential barriers and objections to new energy-efficiency program approaches and work with stakeholders to address or pursue policy mechanisms to remove barriers before introducing programs.

Savings mechanisms: U.S. programs—particularly emerging on-bill financing initiatives—often include mechanisms to ensure that savings exceed payments (e.g., robust audit procedures). Effective project financing provides positive cash flow for the home or building owner while reducing the risk of default for the lender.

Mechanisms to facilitate repayment: Emerging U.S. programs have demonstrated early success by incorporating mechanisms for facilitating customer repayment of costs for energy-efficiency measures. Based on this experience, policy guidance and legislation that encourage the use of available financing (e.g., requiring that utilities offer on-bill financing with a revolving loan fund or loan-loss reserve from federal or ratepayer funds) is a best practice.

Investor risk: The chances of attracting private-sector capital are increased when the government establishes loan-loss reserves or covers on-bill programs in existing loan-loss reserves, an approach used in a number of programs in the United States. Loan-loss reserves differ from loan guarantees by only assuming a portion of the risk—enough to make programs more attractive to investors.

Financing linked to the building, not the owner: Initial experience with the Property-Assessed Clean Energy (PACE) program and similar financing options in the United States indicates that financing mechanisms that associate repayment with the building rather than with the current owner are promising ways to reduce the perceived risk that dissuades many owners from pursuing retrofit projects. These mechanisms also encourage installation of energy-efficiency measures at properties that the owner does not plan to retain for a long period.

2.6.3.2. Issues

Lead times and engaging other stakeholders: Experience to date demonstrates the importance of creating market certainty by allowing sufficient lead time for the market to prepare for a new program, and by establishing a program duration that makes it worthwhile for all parties to invest in marketing the incentive. As states and utilities with limited experience begin to offer incentive programs—which is happening in many previously lagging areas of the country—it is crucial that they heed the lessons learned over the past two decades, including the need to increase program impact by engaging other stakeholders in selling the program and its benefits to their customers and clients.

Support for comprehensive retrofits: Comprehensive retrofit projects maximize energy savings as well as other non-energy benefits by offering building owners an opportunity to consider interactive effects among building systems or system components, system design issues, and the role of operations and maintenance practices. Incentive and other programs that focus on specific individual building components, such as lighting, improve energy efficiency, but programs that encourage comprehensive retrofits produce the greatest overall savings and are most cost effective in the long run. Utility cost-effectiveness tests should be amended and updated to remove barriers to comprehensive retrofit programs. Among other issues, it is important to recognize that customers are often pursuing (and paying for) non-energy benefits as part of a retrofit. Cost-effectiveness tests should be applied so that participant costs associated with non-energy benefits do not distort the cost effectiveness of the program energy savings.

2.7. Conclusions

The United States has established a robust infrastructure of policies, programs, and tools energy-efficient buildings. Recent code revision cycles have produced increasing levels of energy savings with some leading jurisdictions working toward very low and net-zero energy capable new construction. The number of states adopting or updating building codes has increased significantly in recent years, and new efforts are under way to better evaluate code compliance and improve understanding of compliance deficiencies. Energy rating and labeling programs are generating a high level of interest and are viewed as trusted sources of information, increasingly influencing purchase and retrofit decisions. In the commercial sector, building rating and labeling has become a core component of many ratepayer-funded efficiency programs and is part of emerging mandatory energy-use-disclosure programs. In the residential market, ratings and endorsement labels are a growing presence, particularly for new homes. New rating programs targeting existing homes are being introduced to spur greater investment in energy-efficiency retrofits. State-level energy-efficiency policies and energy-savings targets are driving ever greater investment of ratepayer funds in efficiency and encouraging innovation in program design. Beyond ratepayer-funding, federal, state, and local policies are increasing public investment and encouraging greater private financing of efficient new construction and retrofit projects.

Despite excellent success in establishing a strong U.S. policy and program infrastructure, challenges remain. Among the areas where U.S. policy and programs could be improved are: timing of code updates and new programs, funding and other support for compliance, and developing programs to encourage comprehensive or “deep” retrofits to maximize savings.

In sum, the significant and laudable advances in code development and adoption in the U.S. sometimes fail to deliver their savings potential because of significant deficiencies in code compliance and enforcement; moreover, U.S. rating and labeling programs, while trusted and in many ways effective, must be updated and better utilized to identify and promote advanced performance and the most efficient buildings and homes—both new and existing. In a mature building market like the United States, existing buildings represent the greatest opportunity for energy savings but also present the greatest challenges technically, economically, and in terms of program delivery and implementation. To meet increasingly aggressive energy and carbon-reduction goals, the United States must build on and expand its program and policy infrastructure and incorporate best practices to accelerate the rate of building retrofit and deepen the level of energy savings in each retrofit project.

Chapter 3 - Review of Building Energy Efficiency Policies: the European Union

3.1. Introduction

Europe is most remarkable for the political will that resulted in a collective mandate across 27 member states to adopt the Energy Performance of Buildings Directive (EPBD) (Directive 2002/91/EC, 2002) in 2002 and to codify it as national law by January 2006.

EPBD covers many aspects of building energy performance. It mandates minimum energy performance requirements not only for new construction but also for existing buildings undergoing major renovation. Furthermore, the directive requires building energy performance certificates (EPCs) when a property is sold or leased. For heating, ventilation, and air-conditioning (HVAC) systems specifically, the directive requires either mandatory inspections of larger boilers, air-conditioning plants, and heating systems older than 15 years of age; or advice on the efficient use and replacement of these systems.

The European Union (EU) adopted a revised version of EPBD in 2010, which strengthened the required energy performance levels. The revised directive also requires that performance be set at a cost-optimal level over the economic life cycle of a building or building element. A key provision of the revised directive is that all new buildings after 2020 (or after 2018 for public authorities) must be near-zero-energy buildings (nZEBs).

EPBD is part of a broader menu of actions by the European Parliament and Council to achieve an energy-savings target of 20% below 2020 projections. Other key measures include:

- The Directive on Energy End-Use Efficiency and Energy Services (2006/32/EC), which requires that each member state achieve energy savings of 9% across all sectors by 2016 and publish national Energy-Efficiency Action Plans (NEEAPs) every 3-4 years;
- The Eco-design Directive (2005/32/EC, replaced by 2009/125/EC), which establishes a framework for code design requirements for energy-related products;
- The Energy Labeling of Domestic Appliances Directive (92/75/EEC, replaced by 2010/30/EU) on labeling provide standard product information on energy and other resources consumed by energy-related products;
- The Combined Heat and Power (CHP) Directive (2004/8/EC) on the promotion of cogeneration including amending the directive (92/42/EEC) on efficiency requirements for new hot-water boilers fired with liquid or gas fuels.

Currently, a new draft Energy-Efficiency Directive is being proposed by the European Commission (EC) to replace both the Energy Services Directive and the CHP Directive, in response to a gap between the objective of reaching 20% energy savings in 2020 and the savings currently projected from existing

measures. The proposal includes a number of building energy-efficiency measures and related financing. The directive's two most important articles require that energy providers reduce their customers' energy use by the equivalent of 1.5% of final energy consumption per year (EU, 2011a) and that EU member states increase, to 3.0% of total floor area, the annual rate at which publicly owned buildings are renovated. Amendments to the draft directive are being negotiated among the three EU institutions — the Parliament, the Commission, and the Council of member state governments – with the intent to finalize the directive in June 2012. Some targets are likely to be scaled back in the final version, e.g., a public building renovation rate of 2.5% rather than 3% per year.

The EPBD's influence has grown significantly since it was first published in 2002. At that time, there were only 15 EU member states. Since then, the EU's membership has grown to 27 (EU-27), mainly through the addition of Central and Eastern European states. Moreover, numerous non-EU members, including Norway, Switzerland, and countries in Southeast Europe that are part of the Energy Community (www.energy-community.org), have adopted some or all of the provisions in the EPBD and other energy-saving directives. Much can be learned from the promulgation process and initial implementation efforts in the EU. New member states had to undertake major, rapid legislative changes to implement the EU Directives on energy efficiency (as well as many other issues) in order to become part of the European Union. Based on member states' experiences, this chapter identifies best practices from the process of adopting and implementing energy-efficiency policies in the European Union. The sections below highlight best practices, including early adoption efforts, frequency of code revisions, early targets for nZEBs, and inspection regimes.

3.2. Energy Use in European Union Buildings

The Buildings Performance Institute Europe (BPIE) study "Europe's buildings under the microscope" provides information on building stock characteristics in Europe (BPIE, 2011). The EU has a total building stock of 25 billion square meters (m^2), increasing at 1% per year. The existing stock is subject to continual improvement and upgrade, including retrofits to add energy-saving measures. BPIE estimates that energy-saving renovations occur at the rate of about 1.2% of existing building stock floor area per year (BPIE, 2011; EC, 2011a). About 40% of existing buildings were built prior to the 1960s; these generally have very poor energy performance because they were mainly constructed before any mandatory energy-efficiency codes came into effect (BPIE, 2011).

The average household size in Europe's residential building stock is about 2.4 persons. About 42% of the EU-27 population lives in flats, 34% in detached houses, and 23% in semi-detached houses. Seventy-four percent of the population lives in owner-occupied dwellings, 13% lives in dwellings with a market rent, and 14% in reduced-rent or free accommodation (Eurostat, 2012). Average floor space varies from approximately 20 m^2 per person in multi-family apartments in Central and Eastern Europe to 50 m^2 per person in single-family homes in Southern Europe (BPIE, 2011).

Climate conditions vary considerably across the continent, which has three main climate zones: a very cold climate zone with heating degree days (HDD) greater than 4,000 per year, which is home to 4% of the population mainly in Nordic and Baltic countries; a moderately cold climate zone with HDD between 2,501 and 4,000, which is home to 57% of the population; and a warm climate zone around the Mediterranean with fewer than 2,500 HDD, which is home to 39% of the population (Joint Research Centre, 2011).

For information on energy use per end use, the Odysee database contains details at the country level as well as at the EU level (Odysee database, 2011).

Residential space heating represents more than two-thirds of total final energy use in the European Union. Water heating and electric appliances represent 13% each, cooking 4%, and lighting 3% (Odysee database, 2011). The breakdown of energy sources in Figure 3-1 shows natural gas as contributing the largest share, nearly 40%. Coal now represents just 3% of total final energy, mostly in Eastern Europe (IEA, 2011b).

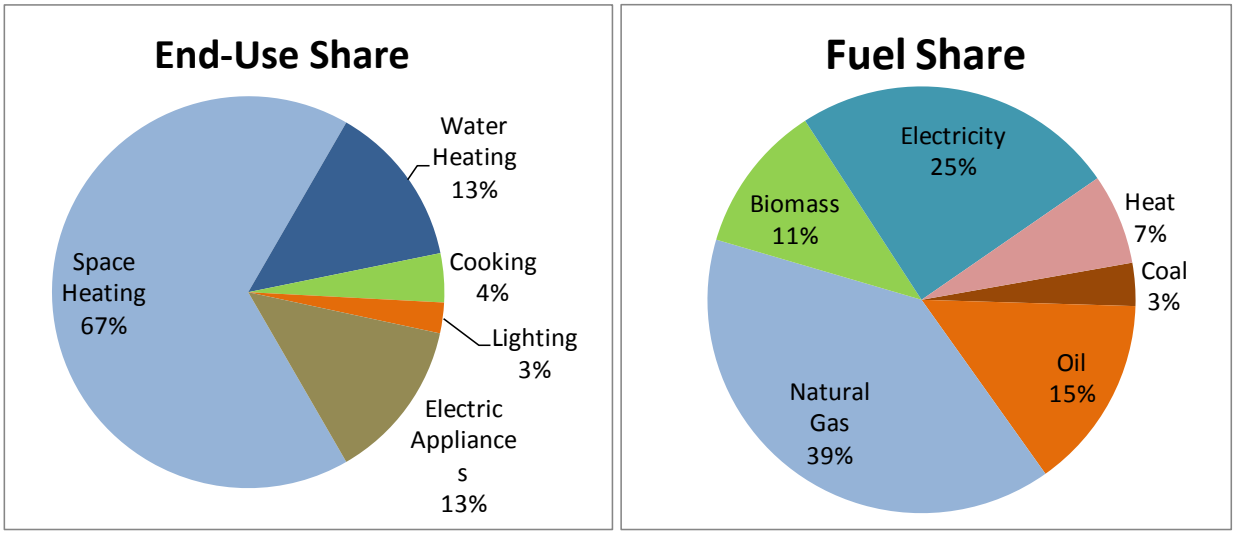


Figure 3-1. EU Residential Building Energy Use, 2009

Source: (Odysee database, 2011; IEA, 2011b)

Although overall final energy consumption in the EU residential sector has increased during the past 20 years, average energy consumed per dwelling decreased between 2000 and 2009 by 1.3% per year. This is due to a combination of improved energy efficiency, reduction in average dwelling size, and in some countries higher energy tariffs and/or reduced comfort. However, actual performance varies significantly among countries, from virtually no change in energy use per dwelling in Hungary and Greece to reductions greater than 2.5% per year for Romania, Slovenia, and Poland. Figure 3-2 shows the breakdown by country according to the Odysee database. The data in this figure also show that most EU member states are exceeding the Energy Services Directive (ESD) average target efficiency improvement rate of 1% per year.

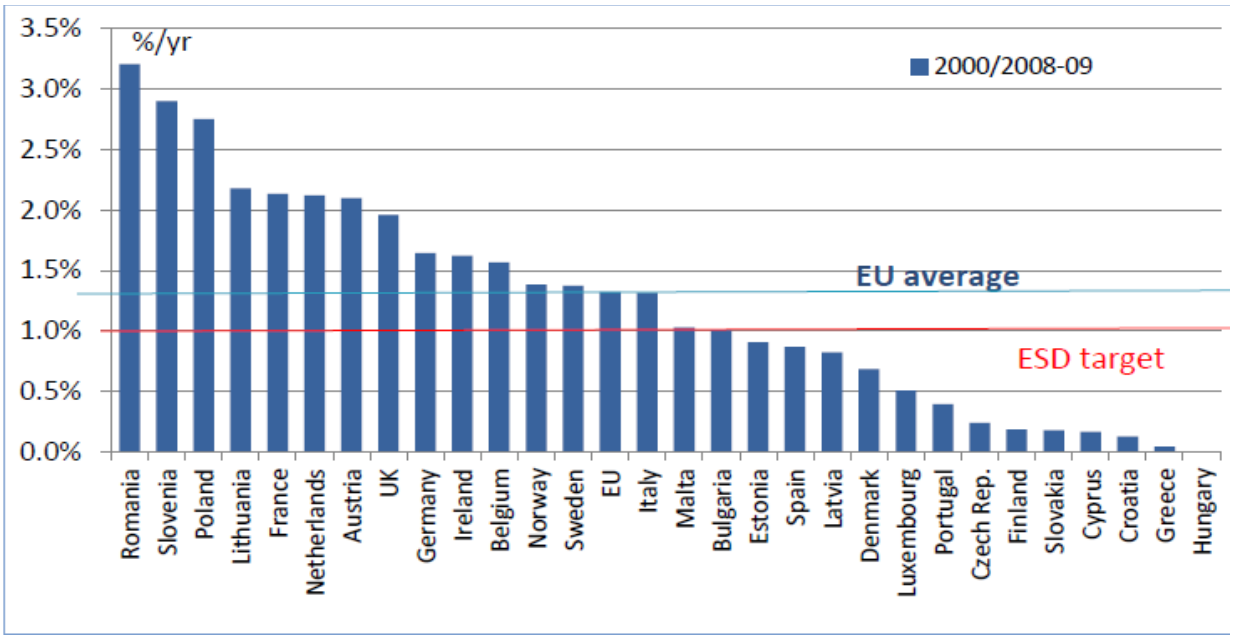


Figure 3-2. EU Energy-efficiency Improvements by Country in the Household Sector

Source: (Odysee database, 2011)

In the EU commercial sector,[26] electricity represents almost half of the total final energy consumption (48%). Natural gas is the second most common form of final energy (30%), followed by oil (14%) and heat (6%) (Odysee database, 2011). Electricity per employee has been continuously increasing by 1% per year on average since 1995, indicative of increased use of information technology (IT) and other office equipment. Use of other fuels has been more or less flat.

Total energy use for all 27 member states, based on data from the International Energy Agency (IEA, 2011b) and total square footage compared to estimates from BPIE (BPIE, 2011), reveals an average baseline building primary[27] energy intensity (2009) of 252 kilowatt hours (kWh)/m^2 for residential spaces and 466 kWh/m^2 for commercial buildings.

[26] Also known as the service or the tertiary sector in European countries, the service sector includes wholesale and retail trade, finance, communications, health care, utilities, and education; International Standard Industrial Classification subsector rev.4 Code G to U (UN, 2010).

[27] Primary energy factor for electricity is estimated at 2.6.

3.3. Building Energy Codes

The subsections below describe the recent history of energy-efficiency directives in the European Union as well as implementation of and compliance with the directives.

3.3.1. The EU Energy Performance of Buildings Directive

The EU BPBD was originally adopted in 2002 and revised in 2010, as outlined in the subsections below, which also describe the process by which member states codified the EPBD into their national laws.

3.3.1.1. 2002 EU Directive

As mentioned previously, the EPBD, which took effect in January 2003, is the main EU legislative instrument for building energy efficiency (DG ENER, 2011). EU member states were required to incorporate the directive's provisions into national law by January 2006.

The original EPBD required three key elements:

- Setting minimum energy performance requirements for new construction and large existing buildings that undergo "major renovation" (Articles 4, 5 and 6)
- Certifying the energy performance of buildings (Article 7)
- Regularly inspecting boilers and air-conditioning systems to guarantee energy-efficient operation (Articles 8 and 9)

By the end of 2006, most member states had incorporated the EPBD into national law. However, practical implementation required more time, and some member states still had to develop complementary legislation (ECEEE, 2008). The directive allowed an additional three years to fully apply the provisions its Articles 7, 8, and 9 in cases where there was a lack of qualified and/or accredited experts. However, some member states were delayed significantly beyond the three-year period (van Eck, 2008).

The directive also stipulates that energy calculation methods be harmonized based on an overall energy performance code. To help with the harmonization process, the European Commission in 2004 mandated the European Committee for Standardization to develop a standardized methodology for calculating the integrated energy performance of buildings in accordance with the EPBD. About 30 EPBD-related standards were then developed. The EPBD also requires that codes be reviewed every five years. In 2010, seven years after the EPBD was first passed by Parliament, the Commission opened a legal process against several member states whose implementation of the directive was still lagging.

Recognizing the challenges posed by some EPBD requirements, the Commission, through its Intelligent Energy-Europe initiative, established a support mechanism to enable member states to communicate and share experiences with EPBD implementation. Concerted Action EPBD was launched in 2007, coordinated by the Portuguese National Energy Agency, and has been extended into a third phase until

2015. Concerted Action EPBD is specifically designed for policy makers; only national representatives in charge of preparing the technical, legal, and administrative framework for the EPBD are involved. Concerted Action EPBD offers member state officials the opportunity to learn from each other and find common approaches to the most effective implementation of the EPBD. Concerted Action EPBD is organized around a number of themes relevant to EPBD codification and implementation. The themes in the first phase of the group's meetings were certification, inspections of boilers and air-conditioning systems, and training and information campaigns. The current phase continues these same themes, minus the information campaigns, and adds four more: cost-optimum methodology, nZEBs, compliance and control, and effectiveness of support initiatives. The Concerted Action EPBD network is organized around meetings between national teams, regularly bringing together more than 100 participants from 29 countries (EU 27, plus Norway and Switzerland) and uses other measures to enhance communication, including a web platform and national update reports. Concerted Action EPBD has been very successful in helping member state policy makers resolve technical issues related to the EPBD implementation process and find common solutions.

3.3.1.2. 2010 Revised EU Directive

Recognizing the significant potential for cost-effective energy savings in the buildings sector and the need for additional measures to meet the objective of reducing the EU's energy consumption by 20% by 2020, the European Parliament published a revised version of the EPBD in 2010. The 2010 EPBD strengthened energy performance requirements and expanded its scope (Directive 2010/30/EU, 2010). Member states must codify the revised EPBD into national law by July 2012.

The revised EPBD's main provisions include:

- A comparative methodology framework to assess the "cost-optimal" level of standards. In January 2012, the Commission published a comparative methodology for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements over their economic life cycle (EC, 2012a). Each member must evaluate its efficiency requirements based upon optimal cost by June 30, 2012.
- A mandate that new buildings occupied and owned by public authorities be nZEBs by the end of 2018 and that all new buildings be nZEBs by the end of 2020. The term "nearly zero energy building" was loosely defined as "a building that has a very high energy performance. [...] The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby." The maximum allowable energy use was not specified in the revised directive.
- Extension of the directive's scope by eliminating the 1,000 m² threshold for renovations, meaning that all existing buildings undergoing major renovations have to meet minimum efficiency levels.
- Encouragement of the public sector to provide an example by establishing more ambitious targets for energy performance.
- Introduction of minimum requirements for components for all replacements and renovations although, for major renovations, the holistic calculation methodology is the preferred method.

In addition to clarifying the provisions of the original EPBD and strengthening energy performance requirements, the 2010 revised directive recommends that each member state verify compliance and penalize non-compliance. Finally, the revised directive recommends that each member state set targets to stimulate investment in low-energy buildings. However, according to principles that apply to all EU directives, the form and method of implementation are left to national governments. The EPBD revision also leaves to member states the choice of determining the minimum energy requirement level to achieve nZEBs. Therefore, even if all member states are pursuing the same goal, differences in the implementation process and ambition levels can lead to different energy-savings results.

3.3.1.3. Member State Code Implementation Process

Because of the long life and low renovation rates of EU buildings, the earlier that tougher energy codes are adopted, the greater the energy and carbon dioxide (CO_2) emissions savings. This is even more important if a building code is implemented before a significant construction boom.

As indicated above, EU member states varied in their level of preparedness and prior experience with energy efficiency when the EPBD was passed. Thermal insulation requirements have existed in some northern countries for a long time – since 1948 in Sweden and the 1960s for Denmark and the Netherlands. By the time the EPBD was introduced in 2003, most member states had building codes although they varied in the level of performance required. However, some member states had to introduce entirely new legislative frameworks to meet the EPBD implementation requirements. Some countries (Cyprus, Malta, and Estonia) lacked any energy requirements for building construction or renovation; others had some building energy codes and implementation structure, but these rarely covered existing buildings and often only pertained to building heating systems (BPIE, 2011). In these countries, the EPBD integration effort typically took place in stages over a number of years. Table 3-1 shows the historical implementation of building codes in a selection of European countries and the percentage improvement since implementation of the EPBD, compared to the previous standards.

Table 3-1. Recent Revisions of Building Codes and Percentage Improvement Compared to Previous Standards

	Initial	...	2003	2006	2007	2008	2009	2010	2011	2012	2015
Austria						13%		15%			
Denmark	1961										43%
England & Wales								25%			
Finland	1976		25%		1%			33%			
Germany	1977						25%			25%	
France	1974			20%						67%	
Ireland	1980				40%			32%			
Italy	1993			27%		8%		12%			
The Netherlands					20%			25%			33% (Planned)
Portugal	1990			19%						To be determined	

Source: Compilation from different sources including Concerted Effort EPBD country reports (EPBD CA, 2011)

As seen in Table 3-1, during the implementation of the EPBD, some countries' standards improved by as much as two-thirds. However, improvements for different countries are not directly comparable because starting conditions varied among countries. Overall, the average increase in energy-efficiency requirements in the 27 EU member states was 25% (Dyrbøl, Thomsen, & Albæk, 2010).

A few member states have for some time demonstrated excellent practice in regularly setting tougher building energy performance standards. Many EU countries have regularly updated standards (Jagemar, Schmidt, Allard, Heiselberg, & Jurnitski, 2011). In Germany research and development, as well as demonstration projects that far exceed the prevailing minimum standards, are used to provide leading indicators of potential future targets for energy performance. In some countries, building codes are announced well in advance to prepare the industry for the next round of regulation (Laustsen, 2008). For example, when the Danish Parliament promulgated the 2010 energy performance standard, it also decided that this standard would be strengthened by 25% to 30% in 2015, and by a similar amount again in 2020.

Other member states have used the opportunity of codifying the EPBD into national law to set very ambitious reductions in their energy performance requirements, as shown in Table 3-1. This is the case in Ireland where energy consumption limits have been reduced by a total of 60% over three years. France also shows impressive reduction of its energy consumption limits. With the new regulation referred as Regulation Thermique 2012, passed in France in 2011, the permissible energy consumption limits for new construction as of 2013 will be 67% lower than the previous limits.

3.3.2. Minimum Energy Performance Standards

The subsections below describe minimum energy performance standards for new and existing buildings in the European Union.

3.3.2.1. Minimum Energy Performance Standards for New Buildings

In Europe, energy-related building codes have historically focused on thermal insulation requirements for building elements (e.g., walls and roofs) and on reducing energy used for heating. Since the introduction of the EPBD in 2002, national building codes have to some extent moved toward a focus on integrated building energy performance. Rather than prescribing minimum thermal properties of building envelopes, HVAC systems, or fenestration, integrated energy performance standards set a maximum energy demand for the whole building. Performance-based codes often integrate trade-offs whereby sub-optimal performance in one area of the building design (for example, fenestration ratios) can be offset by higher performance in another area (such as more efficient HVAC or lighting systems).

A detailed list of the post-EPBD building code requirements in each EU member state can be found in the recent BPIE study (BPIE, 2011). Direct comparison of the building energy use that is expected to result from these requirements is difficult because energy use and strictness of standards are influenced by many variables, such as user behavior, climate, base-case technologies referenced in the code, building types and geometry, and even simple issues like the definition of the reference floor area (Maldonado, et al., 2010). Despite some harmonization in the use of whole-building performance standards, there is still wide variation in the way EU member states have set these standards, and there is no robust, simple, and fair method for comparing the different national requirements. For example, although most national codes are expressed in primary energy units, a few still use final energy units. Additionally, some codes still concentrate on heating energy use while others address a much broader set of end uses. Moreover, each country has a different primary conversion factor that depends on the mix of final energy fuels. The United Kingdom (UK) has a minimum performance level expressed in CO_2 emissions rather than primary or final energy. Table 3-2 shows examples of standards for some member states.

Table 3-2. Examples of Minimum Energy Performance Requirements in Selected EU Member States

Country	Building Type	Year	Performance Requirement (maximum annual energy use)		Final Energy (FE) or Primary Energy (PE)	End Use Covered
Austria	residential	2010	66.5	kWh/m^2	FE	Space Heating
	non- residential	2010	22.8	kWh/m^2	FE	Space Heating
Denmark	residential	2011	52,5 + 1,650 /A *	kWh/m^2	PE	Space/Water Heating and Lighting
	non- residential	2011	713.7 + 1650 /A *	kWh/m^2	PE	Space/Water Heating and Lighting
France	residential	2013	50**	kWh/m^2	PE	Space/Water Heating and Lighting
	non- residential	2012	50**	kWh/m^2	PE	Space/Water Heating and Lighting
Ireland	residential	2010	63	kWh/m^2	PE	Space/Water Heating and Lighting
Italy	residential	2010	71.2	kWh/m^2	FE	
Portugal	(Lisbon)	2006	52	kWh/m^2		
	(Braganca)	2006	117	kWh/m^2		

Source: Compilation from different sources including Concerted Effort EPBD country reports (EPBD CA, 2011)

** A is the gross conditioned area.*

*** This number varies by climate zone and altitude within the range 40kWh/m^2 to 65kWh/m^2.*

Like energy performance standards, member states' new codes often contain selected prescriptive standards traditionally associated with building energy codes, such as maximum U-values, minimum fan power requirements (kW/cubic meter [m^3]), day-lighting and solar heat gain requirements, boiler and/or air-conditioning plant efficiency standards, and renewable energy requirements. For example, the new standard in Spain, called the Building Technical Code (Código Técnico de la Edificación), requires all new or renovated buildings to meet 30%–70% of domestic hot water demand with solar thermal energy.

With the codification of the revised EPBD in 2012, the European Union will begin focusing attention on comparing national energy performance requirements to cost-optimal levels. Member states will have to assess the maximum possible code stringency level based on accounting for all the relevant costs (investment, maintenance, and other operating costs) and lifetime energy savings benefits. Importantly, the cost-optimal methodology considers both investment and the energy cost savings over the economic life cycle of a building. As noted above, in early in 2012, the European Commission published a methodology and guidance to help member states compare current code energy performance levels with cost-optimal levels (EC, 2012a; EC, 2011c). The European Commission has so far not mandated that member states revise existing requirements to the cost-optimal level. Instead, member states have the freedom to set minimum requirements that are more stringent than cost-optimal levels. However, each member state will have to report to the European Commission the results of the comparison and, if the energy performance of the existing standard is more than 15% below the level found to be cost

effective, the member state will need to justify the existing regulations or work out a plan to reduce this gap. The introduction of this benchmarking mechanism for national energy performance requirements will help in assessing the stringency of each member state's requirements.

The 2010 revised directive also required member states to establish strategies to gradually increase the construction of nZEBs so that all new buildings used and owned by public authorities are nZEB from the end of 2018 and all other new buildings are nZEB from the end of 2020. A case study in Chapter 6 (Section 6.2.2) describes how some of the leading countries are progressing toward the target and in some cases have ambitions to exceed the EPBD requirements.

3.3.2.2. Minimum Energy Performance Standards for Existing Buildings

Given that Europe's new construction rate is one of the lowest in the world (about 1% a year) and that the largest energy inefficiencies lie in the oldest building stock, upgrading existing buildings is critical to reaching the European Union's 20%-by-2020 energy reduction target. About 40% of Europe's buildings were constructed before the 1960s, and many of those are plagued by very poor energy performance (BPIE, 2011). Today, an average existing residential building in Europe requires four times as much energy as a new building. The question is how to take advantage of the huge energy savings potential in the existing building stock.

To address energy efficiency of existing buildings, the EPBD mandates minimum energy performance levels for existing buildings that undergo "major renovations." EPBD originally only targeted large existing buildings (1,000 m^2 or larger), but the directive as amended in 2010 covers all buildings that undergo major renovation. Most EU member states had no prior regulation of the energy performance of retrofitted buildings (Beerepoot, 2002). Renovation building permits now often require an Energy Performance Certificate (EPC) showing that the building will achieve at least a defined minimum level of efficiency after renovation. For example, in Austria post-renovation buildings must be projected to achieve at least the minimal performance rating (100 kWh/m^2) to qualify for a construction permit. However, not all EU countries have permit requirements for renovations and, for the ones that do, permits are typically only necessary for major changes in building façades (BPIE, 2011).

A future challenge for European policy makers will be to design policies that not only trigger higher renovation rates but also increase the energy impact of renovations. One possibility, highlighted in the European Commission's impact analysis of the Energy-Efficiency Plan 2011 (EC, 2011a), is to require that buildings in the poorest performance classes be renovated before they are sold or rented. These mandatory renovations would significantly drive up the low renovation rate in the European Union and could, by 2020, achieve about 33 million tonnes of oil equivalent (Mtoe) of energy savings, with CO_2 emission reductions of 65 Mt (million tonnes) in the rental sector, and a further 13 Mtoe and 26 Mt CO_2 emissions reductions in the sales market, compared with baseline primary energy savings. In the UK, the Energy Act 2011 introduced a requirement that, by April 2018, all private rented properties (residential as well as non-residential) be brought up to a minimum energy-efficiency rating (UK DECC, 2011).

Pehnt and Sieberg (2011) describe another approach that would require all existing buildings with energy performance below a defined threshold to undergo renovation to meet a higher energy performance standard. The policy's targeted buildings as well as the energy performance requirements would follow a step-by-step model to reach near-zero emissions by 2050 for all existing buildings. Non-compliant buildings would have to pay a fee that would be pooled into a fund to help finance retrofits for building owners in need of assistance. This plan is being debated at the federal and state levels in Germany.

Although there are many good examples of building renovation, they vary in the level of improvement and associated costs. So-called "deep renovations" can more than halve energy use of a building. However according to BPIE, most current renovation activity is minor, resulting in much more modest levels of energy savings. Minor renovations are frequently the result of government incentive programs that encourage installation of single measures such as more efficient heating plants, renewable energy measures, or additional insulation. Although these individual measures might save significant energy on their own, they are rarely geared toward achieving the maximum energy savings for the building as a whole. A shift to is needed in the European Union to more ambitious levels of energy-saving measures in most renovation activity. Ideally, a "whole-building" approach would be used, in which all building elements and energy systems are considered as a package, and a holistic solution is achieved that delivers the optimal performance, i.e., the lowest energy use.

This report uses the terms "minor" and "deep" renovation although there is no agreed benchmark defining what each level means. Table 3-3 shows the categories of energy savings for different levels of renovation as proposed by BPIE (BPIE 2011).

Table 3-3. Proposed Categories for Different Levels of Renovation

DESCRIPTION (renovation type)	ENERGY SAVING (% reduction)
Minor	0-30%
Moderate	30-60%
Deep	60-90%
Nearly Zero Energy Building	90% +

Source: (BPIE, 2011)

3.3.3. Inspection Regimes

About 10 million boilers in EU residential buildings are more than 20 years old, and replacement would save 5% of heating energy (Bowie & Jahn, 2003). The EPBD requires member states to either require regular inspections of boilers and air-conditioning systems (option A) or provide advice to end users on the benefits of replacing old equipment (option B). Inspection is needed to provide recommendations for upgrades. Member states choosing option B must demonstrate that this strategy achieves a level of savings equivalent to that resulting from option A.

A few countries already had mandatory inspection regimes in place before the EPBD. Large boilers were regularly inspected in Denmark, Italy, Germany, and Austria. In Germany, boiler inspection also covers flue-gas losses and takes place even more frequently than required by the EPBD. Moreover, if a boiler in Germany does not comply with the requirements, it has to be replaced. The boiler operator has to pay a fee that is officially fixed according to the extent of work (e.g., owners of gas boilers with an output of up to 24 kW must pay about 25 euros [€] per year). In this way, thousands of boilers are due for replacement every year, which progressively reduces the average age of the boiler stock in Germany and increases average efficiency ((Schettler-Köhler & Kunkel, 2011).

Germany was able to combine energy-efficiency inspections with a previously existing scheme, thereby saving implementation costs. For many years, chimney sweeps have inspected all boilers in Germany for safety under a compulsory program. The sweeps' task has now been broadened to include energy-efficiency checks for a minimal extra cost. A review of existing programs in other countries indicates that additional boiler energy inspections will cost much more (€50–€130) than in Germany, and, in many cases, these costs are higher than the value of expected energy savings for customers (Antinucci, 2008).

According to a BPIE survey, 21 countries have chosen option A (inspections), and 7 countries have chosen option B (advice) (BPIE, 2011). Sweden chose option B and established a national information campaign to replace boilers with heat pumps or other renewable thermal energy sources. The overall cost of the program is €1 million allocated over five years. Program monitoring will be provided by chimney sweeps and results will be evaluated based on the decreased number of oil boilers in use. The program will also include surveys of building owners, occupants, and construction industry professionals.

For space heating systems, the Netherlands provides an interesting programmatic example. When heating systems there reach 15 years of age, they are inspected, and advice is provided regarding boiler substitution and system improvement.

3.3.4. Compliance and Enforcement Procedures

Compliance and enforcement are essential to deliver the full potential savings from any regulation (Janssen R. , 2010). An impact analysis conducted by Ecofys and Fraunhofer in 2010 estimated EPBD compliance rates between 45% and 55% for existing buildings and 70% for new buildings (Wesselink, Harmsen, & Eichhammer, 2010). Compliance with the EPBD takes place at two levels: national governments codifying the EPBD into national law, and the building industry complying with codes.

For member states that do not comply, the European Commission can open an infringement procedure (EU, 2011b), sending a formal request (a "Reasoned Opinion") for the member state to comply with EU law. The member state then has two months to do so. If the member state does not comply, the Commission may decide to refer the member to the European Court of Justice. Eight infringement procedures were open in 2010 for incomplete or incorrect codification of the EPBD requirements for EPCs and boiler and air-conditioning system inspections (EC, 2011c). Most of these procedures were

resolved quickly. However, in November 2011 the European Commission referred Spain to the European Court of Justice for failure to fully comply with the directive because Spain's requirements for an EPC apply only to new buildings and existing buildings undergoing major renovation whereas the EU legislation requires a methodology and certificates for all building types (EC, 2011d).

Responsibility for granting permits and enforcing compliance with building codes in the European Union generally falls on local authorities, and verification and enforcement procedures vary widely, from systematic to random, among member states (ASIEPI, 2009). Enforcement is systematic in Denmark, Finland, Netherlands, Belgium (Flanders Region), and Norway. State or federal employees may check the completeness of documents and invoices, analyze plans and energy performance calculations, and/or visit buildings during construction or after completion. In Norway and Belgium (Flanders), energy performance declarations are generally submitted and checked electronically. In Belgium (Flanders), systematic enforcement is complemented by random checks. In France, enforcement is based on an annual check of a representative sample. In general, random checks are used because of a lack of expertise among local employees and lack of funds for compliance and control. In most instances, inspections are done by a government agent, but more and more countries, such as the UK and Sweden, are relying on independent third-party assessors to conduct final inspections. In a few countries, such as Poland, inspection is through self-certification by the owner, builder, or architect. Ireland uses EPCs for compliance and verification; a certificate must be submitted to the district council within five days of completion of a building.

Enforcement procedures also vary greatly among member states. In some countries, a building cannot be sold or brought into use until an EPC has been issued and a final inspection has taken place.

The most powerful compliance enforcement measures are withholding building permits or withdrawing builders' or assessors' accreditation (ASIEPI, 2009). These measures have a direct effect because they constrain the use of a building or the right to construct or assess buildings or apply for permits. In Denmark and Finland, if the building does not comply with the energy performance requirements, its use can be denied, and assessors can lose their accreditation. In other cases, local authorities can impose a penalty for non-compliance after an inspection or a consumer complaint. The ASIEPI project, funded by the European Commission, surveyed how 13 EU member states deal with compliance and enforcement of building codes. Table 3-4 shows the enforcement strategies used in the member states in ASIEPI study.

Table 3-4. Overview of Enforcement Categories in 13 EU Countries

Control categories	Implementation schemes 13 MS														
	BE			CZ	DE	DK	FR	FI	GR	HU	IT	NO	NL	PL	ES
	B	F	W												
Requirements; new buildings, major renovation															
Withhold the building permit	◐				●	●	◐	●	✕			○	●	●	✕
Withhold the utilization permit						●		●	✕		●				
Impose fine / active control	●	●	●	○	●		●				●				✕
Impose fine/ passive control					●					○					
Issuing building certificates; existing buildings															
Withhold the sale of the building							◐				◐				
Withhold the renting out of the building							✕				◐				
Impose fine / active control		●				●					●				
Impose fine/ passive control					●					✕			●		
Accreditation of assessors															
Withdraw the assesors accreditation		●	✕	●		●	○		✕		●		●	◐	

● applied
◐ partly applied
○ unspecified application
✕ intended application

Source: (ASIEPI, 2009)

*Note *BE = Belgium (B = Brussels Region; F = Flanders; W = Wallonia); CZ = Czechoslovakia; DE =Germany; DK = Denmark; FR = France; FI = Finland; GR = Greece; HU = Hungary; IT = Italy; NO = Norway; NL = Netherlands; PL = Poland; ES = Estonia*

Overall, the strategy for compliance and enforcement varies a lot by country, and data are lacking on compliance rates by country. Compliance is a very important subject but also a sensitive issue in Europe. Even countries that have the longest experience in building code implementation, such as Denmark and Sweden, described difficulties in achieving a satisfying compliance rate at an International Energy Agency workshop on the subject (IEA, 2008b). Moreover, definitions of non-compliance vary significantly among country studies, from submitting the right documents to checking calculation methods, to possibly comparing measured energy performance to calculated values. As a result, compliance rates vary from country to country as well.

A comprehensive study is needed to assess compliance with building energy codes in the European Union. In support of improved performance in this area, Concerted Action EPBD included two themes related to compliance as part of its program for the period 2011-2015:

- Compliance with Regulations, which will provide the opportunity for EU member state policy makers to exchange experiences and best practices and gather information on member states' practices;
- Compliance with Inspections, to explore issues and improve performance related to the EPBD requirements for inspection of heating and air-conditioning system.

3.3.5. Voluntary Standards

The subsections below review member states' experience with three voluntary standards in Europe: Passive House, Minergie, and Effinergie.

3.3.5.1. Passive House

Passive House (Passivhaus in German) is the oldest voluntary standard for super-efficient buildings in Europe. The first Passive House was built in Darmstadt, Germany in 1990 and consumed 90% less space-heating energy than a standard new building of the time. Since then, many more passive houses, as well as non-residential buildings have been constructed in Europe, mostly in Germany and Austria, as well as in various countries worldwide. An estimated 32,000 buildings have been built to the Passive House Standard. There is also a Passive House Standard for renovations. (Passive House Institute 2011).

Energy Requirements

To be formally certified as a passive house, a building must be designed to consume not more than 15 kWh/m² net living space per year for heating and 15 kWh/m² net living space per year for cooling energy, or be designed with a peak heat load of 10 W/m² (Enerbuild 2009). Moreover, the building's total primary energy-specific consumption should not exceed 120 kWh/m^2/year, including household appliance electricity use. Finally, the building must not leak more air than 0.6 times the house volume per hour (n50 ≤ 0.6 / hour).[28]

Cost

The European Commission funded a project called CEPHEUS (Cost-Efficient Passive Houses as European Standards) that resulted in the construction of 221 housing units to passive house standards in five European countries: Germany, Sweden, Austria, Switzerland, and France. The final project report (Feist, Peper and Görg 2001) gives details about the economics of constructing passive houses. Incremental costs (capital and operating) were estimated to be, on average, less than 10%[29] higher than current construction practices , resulting in a payback period of 21 years (Feist, Peper and Görg 2001). Incremental capital costs ranged from €0/m² to €337/m² (17% of total building cost), and average operating costs were very low, at €0.37/m² on average. Energy savings led to operating cost savings of 74% for space heating (in the range €162-616/house). Averaged across 12 projects, the cost of the kWh saved in heating energy use in passive houses averaged 6.2 €cents.[30]

[28] At 50 Pa (N/m²) as tested by a blower door.

[29] The International Passive House Association estimates the average incremental cost of a passive house to be on the order of 3% to 8% and points out that the investment in higher-quality building components that is required by the passive house standard is mitigated to some extent by the elimination of expensive heating and cooling systems (IPHA 2010).

[30] The cost of conserved energy for efficiency technology and solar thermal installations is calculated as an extra investment discounted over 25 years of service life at 4% real interest, plus the additional operating costs of the passive house components divided by the annual fuel savings.

Another EU-funded project, Passive On, examined how to expand the passive house concept, especially in Southern Europe. The Passive-On project estimates the range of additional up-front costs among five countries (UK, France, Portugal, Spain, and Italy) to be in the range of 3%-10% for newly constructed buildings (EC DG TREN 2009).

The CEPHEUS project also demonstrated high user acceptance of the passive house standard, which suggests that passive house ventilation systems, which some have concluded are complicated to maintain, is not a deterrent. The project also highlighted the importance of architect and project planner qualifications and the need for user manuals in local languages.

Further information on the uptake of passive houses in Europe is provided in a case study in Chapter 6 (Section 6.2.2).

3.3.5.2. Swiss MINERGIE Standards

Minergie is a private, non-profit organization in Switzerland that has developed several certifications for new buildings and retrofits. The most common is simply called "Minergie" and certifies buildings that consume no more than 75% of the energy used on average in Minergie-benchmarked buildings. This results in a maximum primary energy intensity of 38 kWh/m^2/year for residential buildings and 40 kWh/m^2/year for office, retail, and school buildings. Minergie buildings are also required to consume 50% less fossil fuel compared to standard buildings. The primary energy conversion factors are 2 for electricity, 0.5 for wood, 0.6 for district heating, 0 for solar and ambient heat, and 1 for fossil fuels; the end uses covered are space and water heating and ventilation. The MINERGIE P designation addresses buildings with low energy consumption (especially for space heating) and is similar to passive house requirements. MINERGIE P buildings must be fitted with an automatic air-renewal system that has heat recovery. MINERGIE P focuses on insulation, airtight building shells, comfort ventilation, and freedom in design choices (EC DG TREN 2009). MINERGIE P buildings are 60%–85% more energy efficient than conventional buildings and consume not more than 15 kWh/m^2/year for space heating (Minergie 2010).

Two other voluntary standards co-exist with the Minergie building standard. One is the European Ecolabel, which adds ecological health requirements (such as recyclability of materials, indoor air quality, and noise protection). Another Minergie designation applies specifically to building equipment elements that are certified as exhibiting exceptional energy efficiency (Minergie 2010).

From the Minergie scheme's beginning in 1998 until 2010, more than 18,000 buildings had been certified as Minergie, and 857 as MINERGIE P. Only 9% of all Minergie certifications have been awarded to renovated buildings. In total, approximately 13% of new buildings and 2% of refurbishment projects are Minergie certified, mostly in the residential sector (Vaughan 2009). However, when considering floor space, non-residential buildings represent 38% of the total. One of the main reasons the Minergie standard is popular among building consumers is the fact that Minergie buildings provide a high level of comfort (Minergie 2011), which is made possible by high-quality building envelopes and the systematic renewal of indoor air. Incremental costs of Minergie buildings are on the order of 2%–6% additional up-

front costs (EC DG TREN 2009). The Minergie scheme requires that additional costs must not exceed standard building costs by more than 10% (Minergie 2010).

3.3.5.3. French Effinergie Criteria for Energy-efficient Buildings

In France, building industry professionals and local governments involved in building construction created the Effinergie label to establish criteria for low-energy-consuming buildings. Effinergie is an association in which members participate in a collaborative process, sharing expertise and knowledge to answer complex issues related to the energy performance of buildings. At this point, the Effinergie designation only certifies buildings that consume significantly less energy than the standard but are not nZEBs. One of the very first actions of Effinergie was to develop the BBC-Effinergie designation (BBC stands for Building Basse Consommation, which means "low-energy building"). This designation, established in 2007, is recognized by public authorities (Enerbuild 2009). The main requirement for BBC certification is that the annual energy consumption of the building is equal to or below 50 kWh of primary energy per m^2 of net floor area. [31] Currently, a house corresponding to the 2005 thermal regulations (RT 2005) consumes an average of between 91 and 150 kWh/m^2/year (ConceptBio). The primary energy conversion factors are 2.58 for electricity, 0.6 for wood, and 1 for other fuels, and the end uses calculated on the Effinergie label are space heating, water heating, ventilation, lighting, and air conditioning. The Effinergie standard is mostly for new construction, though in 2009, a label specific to renovation, Effinergie Rénovation, was added. The main requirement of the renovation standard is 80 kWh primary energy per m^2 of net floor area per year. The same climatic correction applies to the renovation label. The Effinergie association is now working on defining the requirements for nZEBs.

The new standard for thermal performance (Regulation Thermique RT 2012) that came into effect for non-residential buildings starting in October 2011 and for all new residential properties starting in January 2013 will be equivalent to the BBC-Effinergie level. In other words, the new standard is built on the foundation of the BBC-Effinergie standards. The gains in knowledge that were achieved through the Effinergie program can now be cemented by these new more-ambitious standards. This is an interesting example of building industry experts and local actors coming together to define the requirements of low-energy building design before energy efficiency was required by government regulations.

As of December 2011, 31,128 buildings were certified with the BBC-Effinergie label for new construction, representing 19,046 multi-family homes, 12,046 single-family homes, and 36 commercial buildings, for a total of 257,000 m^2 (Effinergie 2012). Market demand for the certificate is increasing rapidly. In 2011, 75% of newly constructed multi-family homes and 12% of newly constructed single-family homes had the BBC-Effinergie label. Nonetheless, the number of certified renovated buildings is still very low—only 3,349 as of July 2011, representing 60 single-family homes, 3,286 multi-family homes, and three commercial buildings for a total of 5,500 m^2.

[31] However, the maximum energy consumption requirement varies according to climate conditions, ranging from 40 kWh/m^2 net floor area in the south of France to 65 kWh/m^2 net floor area in the north of France.

Many other EU countries have set their own standards higher than the minimum level set by building codes. Examples include Germany, where “EnEV minus 30” and “EnEV minus 50” designate buildings that perform 30% better and 50% better than the current standard; and Denmark, where low-energy class 2 and class 1 buildings consume 25% and 50% less energy, respectively, than the standard (20 kWh/m^2 final for heating cooling ventilation and hot water).

3.4. Building Energy Labeling

In addition to labels that reflect the voluntary standards described in Section 3.3.5. above, European Union member states use the EPC, a required comparative performance label introduced across the European Union as part of the EPBD. EPCs are mandatory on sale or rental of all properties and indicate a building's energy performance by ranking the building in comparison with peer buildings as well as reference values, such as minimum energy performance requirements. The goal of comparative labels is to raise purchaser and/or renter awareness.

The subsections below describe best practices of EU member states in meeting label policy and program goals, based in part on previous analyses (BPIE, 2010a; P. Ries, Jenkins, & Wise, 2009)

3.4.1. Mandatory Programs

Denmark was the first country in the world to implement a comprehensive mandatory building label program (Dunsky, Lindberg, Piyalé-Sheard, & Faesy, 2009). Since 1997, all Danish homes and commercial buildings have been required by law to obtain and disclose an energy performance rating upon sale or lease. Based in part on the initial successes of this and similar programs, the EPBD now mandates that each member state require EPCs in all building property transactions. An important feature of the 2010 EPBD revision is that certification should also include recommendations on how to improve the building's energy performance. The directive suggests that recommendations should include all cost-effective improvements and should provide an estimate of the range of payback periods or costs and benefits over each measure's economic life cycle (European Parliament, 2010). In 2010, the revised EPBD also required that an energy performance indicator be included in rental or sale advertisements, not just in the final transaction documents.

3.4.1.1. Energy Impacts

The subsections below describe the calculation methodology for estimating a building's performance for labeling, for certification for apartments, and for reporting.

Calculation Methodology

The approach to data collection and processing has a significant impact on an EPC as well as on its acceptance by industry and the broader market. Two basic methodologies to estimate the energy performance of a building are: calculated (also called asset) energy performance and measured (also called operational or metered) energy performance. The calculated method relies on modeling the energy-consumption characteristics of the building and its equipment. The measured method uses post-occupancy metered energy consumption data gathered from utility/energy provider bills. There are several differences between the two approaches, the main one being that the measured approach includes the effect of building occupant behavior and needs to be adjusted to a standard energy use metric. Adjustment of bill-derived energy use is based on correction factors and knowledge about the

climate. The calculated method, by contrast, requires careful inspection of the building and a reliable computation engine, with standard energy performance and default values based on building physics. The minimal training and low cost of the measured method are advantages, but the results can be less objective than the calculated methodology or a combined methodology. Figure 3-3 shows how these methods as well as mixed methods compare to one other, based on cost and quality (Jensen, Hansen, Thomsen, & Wittchen, 2007).

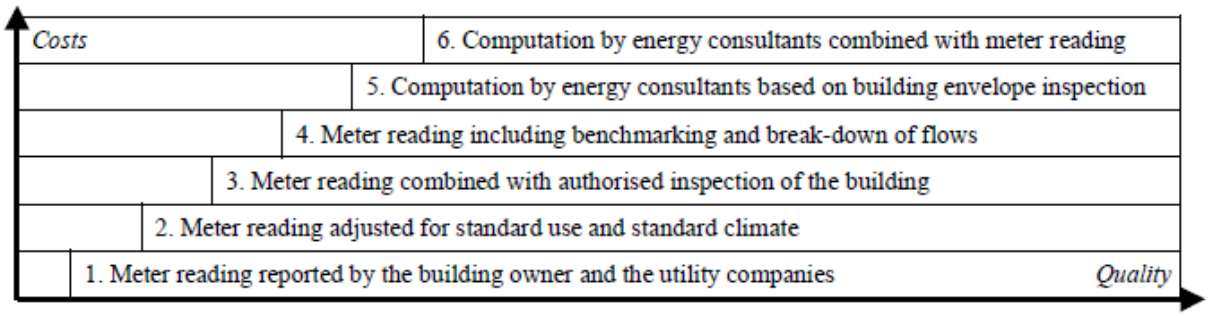


Figure 3-3. Combination of Measured and Calculated Methods and the Six Levels of Complexity

Source: (Jensen, Hansen, Thomsen, & Wittchen, 2007)

When the EPBD was finalized in 2002, Denmark modified its EPC scheme to what it calls the "second generation" of energy certification. In the first generation, the calculated method was used only for small buildings, and the measured method was used for large buildings. It was found that a combination of both methods provides the best estimates (Jensen, Hansen, Thomsen, & Wittchen, 2007), but the combination requires significantly more effort to carry out. One of the objectives of the second-generation modification included the merging of the two methodologies to improve energy performance estimates for large buildings.

In many EU member states, the choice of methodology depends on the building type (BPIE, 2010a). As illustrated in Figure 3-4, the calculated method is the most commonly used in all sectors.

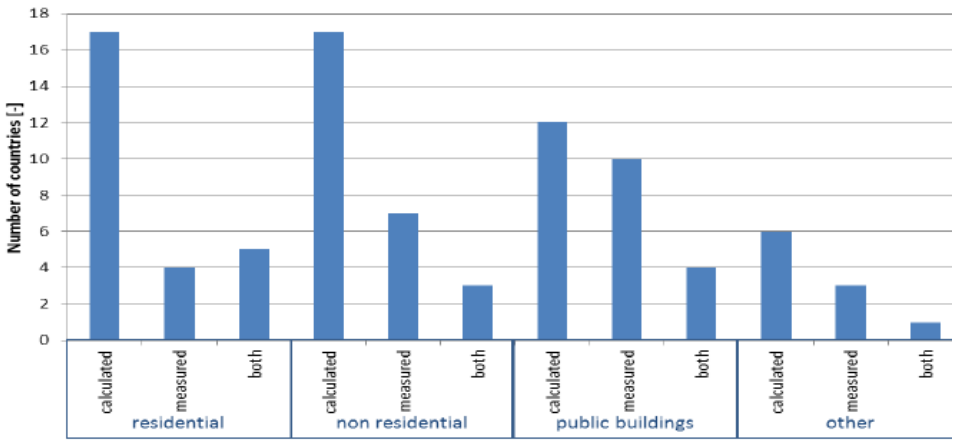


Figure 3-4. EPC Building Energy Performance Verification Methods Used in Member States, by Building Type

Source: (Engelund Thomsen & Wittchen, 2010)

Certification of Apartments and Apartment Blocks

A topic of much discussion among policy makers at the Concerted Action meetings was the certification of apartments in multi-family houses and apartment buildings (Engelund Thomsen & Wittchen, 2010). In some apartment complexes, energy performance characteristics are identical throughout the whole building, but, in others, performance varies among units (e.g., between top- and bottom-floor apartments). Challenges arose in determining when it is appropriate to use the characteristic of one flat to estimate all other identical apartments. Another important decision is whether an EPC covers the entire building or individual apartments, a particularly challenging issue because some apartment building retrofits, such as roof insulation, can only be undertaken at the whole-building scale. Moreover, whole-building heating systems are widespread in some EU countries, making it difficult to determine the energy use of a single apartment. Therefore, the choice between whole-building or individual apartment certification depends heavily on the type of building. Some countries have adopted different approaches depending on building characteristics (e.g., age, ownership, and type of heating system). In nine member states out of the 19 surveyed by Concerted Action on Certification, certificates are issued for the whole building, and, in eight member states, certificates are issued at the individual apartment level. Two member states, Austria and Hungary, issue EPCs for both individual apartments and whole buildings (Engelund Thomsen & Wittchen, 2010) .

Guidelines, Reporting Forms, and Computer Software for Certification in the European Union

Instruction manuals and computing tools are important elements in the successful implementation of an EPC scheme. These tools help building energy professionals conduct high-quality building energy assessments in a uniform, transparent, and objective manner (Jensen, Hansen, Thomsen, & Wittchen, 2007). Instruction manuals should clearly define methodologies and, to the maximum extent possible, detail the default values, correction factors, and standard input data that experts need to carry out the

energy assessment. Standardized reporting forms are important to ensure that information is recorded and estimated in a consistent fashion by all experts. Finally, a computing tool is a key instrument for energy experts, allowing them to speed up building assessments and use a uniform methodology. Most tools allow simple checks of the input data. Computing tools allow information to be centralized and used for assessing building energy performance in other countries and regions.

Certification Databases

Some member states require that energy experts register certificates in a web-based centralized database system (BPIE, 2010a). This provides a valuable resource to policy makers who wish to assess the energy performance of the existing building stock and the savings potential of new efficiency programs and policies. The information could also be used to benchmark buildings and estimate energy performance gaps. A national database can be used to monitor progress toward widespread building certification and to estimate energy savings under different policy and program scenarios.

As described in Jensen et al. (2007), a study of a sample taken from the Danish national database of 200,000 energy certificates for small buildings allowed researchers to understand and identify real energy savings potential for those buildings and to design policies that targeted measures with the greatest savings potential. The sample was also used to benchmark some categories of buildings. For example, the research resulted in the development of a benchmarking tool for schools that allows anyone, from energy officials to school caretakers, to visualize the energy performance of a school compared to other schools. The tool ranks the building's performance, which can help stimulate the building owner's interest in improving the building's standing. The tool could also include energy-saving measures and their costs and simulate the savings that would result from selected options.

Ireland recognized at an early stage the benefits of a computerized system to make the most use of a building energy rating scheme (ECEEE, 2009). The Sustainable Energy Authority Ireland uses national databases not only to register certificates but also to register certified assessors. After passing a national exam to become certified assessors and signing the Code of Practice to guarantee their independence, assessors register in the national database, which is available on the Sustainable Energy Authority Ireland website and is accessible to anyone wishing to find a building energy rating assessor (Sustainable Energy Authority Ireland, 2011). Another database registers all building energy ratings and provides monthly status reports, available on the Sustainable Energy Authority Ireland website.

3.4.1.2. Enabling Legislation for Mandatory Labeling in the European Union

When the EPBD came into effect in 2003, member states were given three years to incorporate it, through legislative action, into each member state's regulatory framework. However, at the end of 2005, more than 70% of member states reported difficulty in implementing the directive because of a lack of qualified and independent assessors (van Eck, 2008). It took another three years for most countries to put functional EPC schemes in place. After the initial EPC program development, a major hurdle for many countries in implementing the directive was to build or increase the ranks of qualified and

independent energy assessors. Beyond the need for labor force development, substantial effort is needed to ensure that accredited assessors are qualified and independent. EPCs and other building labels need to be widely perceived as both trustworthy and useful. Therefore, specifying assessors' qualifications, delivering assessor training, proving assessors' independence, and assuring the quality of their work were among the most important criteria considered by member states in the program development and implementation process (BPIE, 2010a).

Number of Certification Assessors

The exact number of assessors necessary to implement the EPC scheme in each member state is not known but can be estimated based on the number of buildings in the country, the time needed to audit a building, and the number of buildings going on the market every year. For example, the European network for the energy performance certification of buildings project estimates that Greece (population 11.1 million) will require 3,600 auditors to implement EPCs, assuming that about 50% of Greece's 4,000,000 existing buildings will need to be certified within the next five years and that an auditor can assess 110 buildings per year (two working days for each building) (ENFORCE, 2010). Denmark, which has a population of 5.4 million, has about 2,000 inspectors. However, most inspectors do not work full time on issuing EPCs.

Training of Assessors

General training requirements for assessors are established by national legislation and detail different levels of academic and professional experience, accreditation by professional associations, enrollment in specific energy certification training courses, and/or exam-based certification (van Eck, 2008). Specific training lasts on average between five and 10 days and can be voluntary or mandatory, depending on a country's requirements.

In countries where no specific training is required, accreditation is automatic or self-recognized. For example, in Germany, because of the large number of EPCs required, there was a need to quickly increase the number of assessors. To expedite the process, Germany's Energy Saving Ordinance does not require certification, only relevant field experience and academic degrees. More than 70% of Germany's assessors have a university degree (Schettler-Kohler & Hunkel, 2010). This is an interesting example, but the results suggest that it is not best practice because the quality of certifications has been a problem in Germany.

Traditional academic educational programs can be expensive and time consuming, creating a bottleneck in implementation of energy certification programs. As an alternative, specific energy certification training courses can be developed to quickly train competent assessors. Training in EU member states is delivered through a government body, a third-party private company or, in some cases, professional associations (Maldonado, et al., 2010). Accreditation is given at the end of the training, often on the basis of a required examination. Different models range from formal to informal education and experiential criteria. In France, no specific education or previous experience is required to become an energy assessor; rather, assessor accreditation is based solely on a theoretical exam that includes

multiple-choice questions and a practical example in which the energy performance of a building is assessed and certified using assessment software (Remesy, Bonnemayre, & Menager, 2010).

Other member states have incorporated flexibility by relying on other actors to organize and accredit assessors. In Denmark, for example, private companies can be certified as building assessors, which allows for work sharing between more and less experienced individuals within a company and places responsibility for training and staff accreditation on the company. A similar program operates in Scotland where the government has entered into a memorandum of understanding with a professional body that is responsible for ensuring that its members are qualified, perform quality assessments, and are independent (i.e., have no conflicts of interest) (Woods, 2010).

Independence of Assessors

It is vital that energy assessors be independent and free from conflicts of interest, given the economic interests of companies involved in construction, preparation of engineering plans, and real estate sales. Effective implementation of EPCs requires that EU member states seriously consider and evaluate the independence of energy assessors. Some member states require that experts sign a “code of conduct” guaranteeing strong, verifiable professionalism and independence. More than 60% of member states have also implemented codes of conduct for experts involved in the certification process to help them avoid conflicts of interest and assure high-quality certification. In many member states, real estate companies are forbidden from providing EPCs for buildings.

Quality Assurance of Certification Programs

EPC programs must be evaluated regularly to ensure their quality. In certain EU member states, building accreditation training must be renewed regularly, e.g., every five years, and in other training programs are continual. For example, in England all accredited energy assessors must undertake continuing professional development training that includes information on updates on and revisions to the EPBD (Communities and Local Government, 2008).

Portugal provides a good example of well-organized quality control guarantees for EPCs (IEA, 2010a). Before an EPC is used in sales or leasing documents, the data it contains are entered into specialized software that stores the information in a centralized database and runs standard checks to avoid potential mistakes. Two forms of subsequent random sample checks are conducted. About 2% of issued certificates are randomly checked to verify that the contents follow methodology guidelines, and about 4% (2009) are subject to a more detailed quality control check. The more detailed check includes a full review of the calculations and a building audit to verify that the certificate complies with calculation and audit methodologies and that the building energy performance is consistent with the certificate. This triple-checking mechanism results in high level of overall compliance (ENFORCE, 2010).

3.4.1.3. Building Energy Performance Rating Systems

Development of a labeling system entails resolving a number of issues: the nature of the rating scale (e.g., how grades are set, whether different scales are needed for different types of buildings, etc.), the manner in which a rating is communicated, the process by which the necessary data and other information are collected and shared with program participants, whether recommendations for improving building performance are included with a rating, and the costs and duration of the validity of a rating. EU member states have developed several approaches, which are briefly described in the subsections below.

Building Energy Labels

All EU member states have adopted building energy labels based on rating systems. Many member states have developed certificates that show building energy performance on a scale from A to G, similar to the system already in place for appliances and equipment. Only a few (for example Germany, the Flanders region of Belgium, and Poland) have chosen to display building energy performance using a speed bar, with colors that shift from red (poor performance) to green (good performance). Other countries, such as The Netherlands, show the rating on a performance staircase. Norway's label uses houses of different colors and places them on a matrix with two dimensions: the level of energy efficiency ranked from A to G and the degree to which renewable energy resources are used to provide space and water heating. Figure 3-5 shows examples from Poland, France, The Netherlands, and Norway. Most labels also indicate the specific energy performance of the building as well as the standard for new buildings and renovated existing buildings. Units of measurement differ among member states; some labels show building performance in kWh per m^2; others use gigajoule per m^2, and still others use CO_2 emissions. Countries report energy use in primary units, but the primary energy factor used to convert final energy to primary energy is rarely mentioned.

France's label provides an interesting example of how detailed information can be provided. On the French label, the building's performance is provided in both annual primary energy (kWh/m^2) and in annual CO_2 emissions (kg/m^2). The label also gives details on the total annual energy consumption of key end uses, such as water heating, space heating, cooling, and ventilation. This information is given in primary and final units by fuel type, and the annual cost by end use is shown as well.

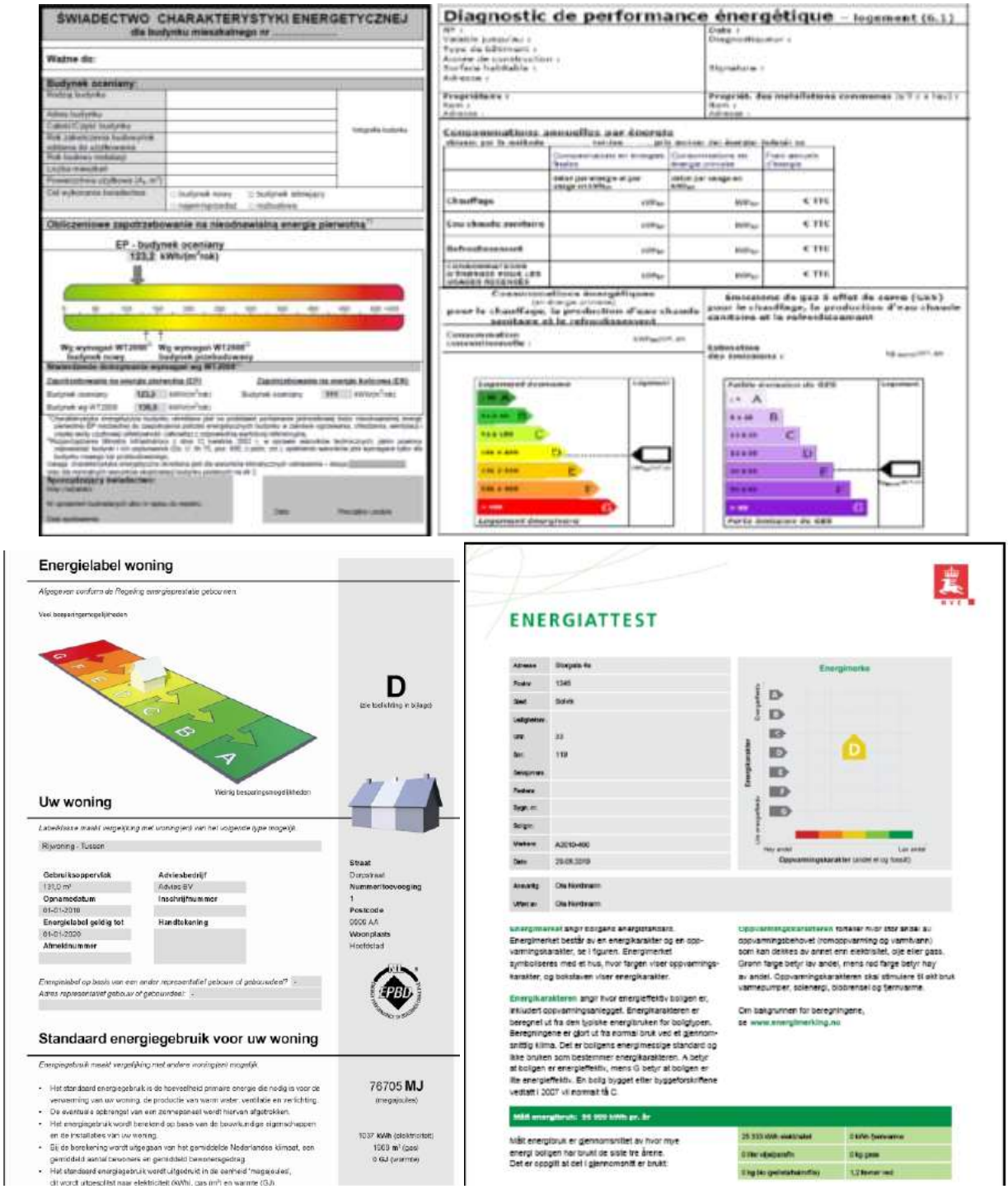


Figure 3-5. Example of a Speed Bar Label from Poland, a Bar Chart Label from France, a Staircase Label from the Netherlands, and a Matrix from Norway

Source: Compilation from Concerted Action EPBD country reports (EPBD CA, 2011).

Although some countries, e.g., Germany and Ireland, conducted field testing and asked consumers' opinions before selecting the final format of the EPC label, more research is needed to assess how different labels are accepted and understood by consumers.

Expanded High-Performance Categories

Most countries use the same rating format for both new and existing buildings within the same functional class. A few countries (e.g., Spain, Denmark, Ireland, and Portugal) that use the seven-category A to G rating system have expanded the categories for the highest-performing buildings, incorporating designations such as A1 and A2 or A+ and A++ for buildings that are built to a higher standard than the minimum requirements of the building code. Increasing the number of categories that exceed the standards encourages builders to strive for greater energy efficiency to achieve a higher rating.

Different Building Types

Most EU member states' energy-efficiency labeling programs utilize a number of different scales associated with different building types. However, the Danish program has only two scales, one for residential buildings and one for commercial buildings. Denmark chose this approach to try to keep the labeling scheme as simple as possible.

Required Efficiency Improvement

The EPBD requires that EPCs include recommendations for cost-effective building energy-efficiency measures. In some countries, standardized reports are provided to experts to estimate energy-savings potential, and, in other countries, experts can use their own approaches. Standardized reports that refer to common building types can help reduce the costs of assessing efficiency improvements.

Denmark and Portugal have established obligations to implement measures that are identified as cost effective in selected building types. For example, for non-residential buildings with ratings lower than a certain threshold in Portugal, all recommended efficiency improvements that have a simple payback time shorter than eight years must be implemented during the first three years after certification. In public buildings in Denmark, recommendations with a simple payback time shorter than five years must be implemented in the first four years after certification (Engelund Thomsen & Wittchen, 2010). Buildings in Denmark's public sector must be assessed every five years; compliance with recommended improvements is verified when the building is reassessed.

Cost of Certification

Certification costs vary according to the size of the building and the method chosen (calculated or measured) to estimate the building's energy performance. EPC costs are also influenced by the detail and complexity of the recommended efficiency improvements. The costs of certification for single-family buildings that have been reported by EU member states to the EPBD Concerted Action on Certification vary from €100 to €1,250 per EPC; in 50% of the cases, the costs fell within the narrower range of €200

to €600 per EPC (Engelund Thomsen & Wittchen, 2010). The most recent BPIE study provides detailed information on the price of certificates among countries (BPIE, 2010a). The building owner pays the cost of certification before any property transaction. This creates strong political pressure to keep the price of EPCs as low as possible, especially for rentals and small transactions. In most countries, the price is determined by the market, but, in some cases, as in Slovenia, the price is fixed by legislation. In Denmark, the maximum price for an EPC for residential buildings up to 299 m^2 is fixed by legislation (Engelund Thomsen & Wittchen, 2010).

Duration of Certificate Validity

The EPBD requires that the certificates not remain valid longer than 10 years, and most member states have chosen this time frame for mandatory recertification. However, a few states opted for shorter periods, typically between five and 10 years. For example, the Netherlands has opted for six years and Bulgaria for seven years.

3.4.1.4. Disclosure, Compliance, and Enforcement in Certificate Programs

The subsections below describe regulations on the timing of disclosure of a building's EPC status, specific disclosure requirements for public buildings, and enforcement and compliance including penalties for assessors for deficient certifications.

Timing of Energy Performance Disclosure in Transactions

The timing of the disclosure of the EPC is very important to maximizing the certificate's impact in a transaction. If the disclosure takes place during the final stage of the transaction when the participants have already made a decision regarding buying or renting a building, the EPC plays only an informational role and generally does not change the decision or negotiations. However, if disclosure is required at the time a building is advertised, this timing allows buyers and lenders to understand and value the energy performance of the building as part of their decision making and negotiations. Initial experiences with the timing of disclosure resulted in calls for the EPBD to include a clause requiring that EPC data be displayed at the earliest stage during a transaction. As a result, since January 2011, a building's energy label and class must be displayed as soon as the building is advertised for sale or rent.

Compliance in Public Buildings

Publicly owned or occupied buildings represent approximately 12% of the building stock in Europe but are rarely sold or rented (EC, 2011a). Therefore, EPBD documents contain a special clause for public buildings, requiring them to display their energy certificates at the building entrance or in a prominent place clearly visible to the public. The 2010 EPBD reduced the original 1,000 m^2 threshold for public buildings to 500 m^2, and the floor area minimum drops again to 250 m^2 in 2015. The display location for energy certificates and the information that they include vary considerably among countries. For example, public building certificates are available on the internet in Portugal and show only general information, not recommendations. England and Wales go significantly beyond the EPBD requirements

and require that all public buildings (about 42,000 buildings) display their certificates and update them each year to show the previous year's rating. Regular measurements were established to reflect the usage pattern of the building over time (Engelund Thomsen & Wittchen, 2010).

Enforcement and Penalties for Non-compliance

For EPCs to be meaningful, they must be verified to ensure that their content is accurate. And, for an EPC scheme to be effective, every building that comes on the market for rent or sale must receive a valid EPC prior to being advertised. Verification of compliance with both of these criteria is essential.

The revised 2010 EPBD recognizes the importance of compliance by introducing penalties for non-compliance that are effective and proportionate. Many member states have implemented penalties for non-compliant building owners. For example, the region of Flanders in Belgium has an enforcement scheme the entails random checks to verify the availability of the certificates in real estate agencies, on websites, and in newspaper advertisements. If no certificate is available, the owner will be summoned to a hearing and risk a fine of between €500 and €5,000.

Certificate Quality

Good quality assessment is an essential part of successfully implementing an EPC regime. If a quality check finds that a certificate was poorly or deficiently estimated, the assessor can be penalized by withdrawal of his/her accreditation or by a fine. In Denmark, where EPCs are valid for five years, assessors must carry professional liability insurance to cover the full five years after a certificate has been issued.

3.4.1.5. Impact of Certification Programs

One of the main goals of implementing a building EPC scheme is to inform customers of the energy performance of the building they are about to purchase or rent as well as of the options to improve its rating. A legitimate question is how to determine whether higher-rated buildings are sold or leased at a cost premium. Two countries in Europe have investigated the impact of the EPCs on market prices: the Netherlands and Poland (Engelund Thomsen & Wittchen, 2010). The Netherlands study was based on sales of 180,000 houses, 40,000 of which had an energy label. This study found a positive cost premium of 2.7%. The Polish study was an opinion survey done before Polish EPC implementation and illustrated that 60% of companies interviewed believed that the EPC would have a positive effect.

3.5. Incentives

In addition to the standards and labels discussed in the previous sections of this chapter, a number of incentive schemes have been developed across Europe to harness the huge potential to reduce energy use in the existing stock as well as in new construction. BPIE screened 333 different financial schemes in 27 member states plus Norway and Switzerland (BPIE, 2011). Databases are also maintained by the International Energy Agency (IEA, n.d.) and MURE (Mesures d'Utilisation Rationnelle de l'Energie) (EC, n.d.). Meanwhile, the "bigEE" (Bridging the Information Gap on Energy Efficiency in Buildings) project is currently developing an international, internet-based knowledge platform on energy efficiency in buildings to provide a comprehensive source of information on this and related subjects for policy makers (Thomas, 2010).

BPIE found that the most common form of incentive in European countries is financial (grants and other subsidies). All EU member states as well as many non-EU countries have financial incentive programs. Some incentives target existing buildings, and others address new buildings. Some target residential buildings, and some target non-residential. Most member states also have loan and tax incentives. Less frequently used forms of support are obligation schemes (sometimes structured in the form of white certificates), audits, third-party financing (including financing offered through energy service companies) and, for buildings with integrated renewables, feed-in tariffs.
Table 3-5 summarizes four of the largest incentive programs currently in operation. However, energy savings and CO_2 emissions reductions should not be compared among countries because the metrics vary, and not enough information is available to harmonize the results. Therefore, these reductions are shows as indicative of the scope of the scheme in each country.

Table 3-5. Energy-Efficiency Financing Schemes for the Four Largest EU Member States

Country	Year	Type of Incentive	Program participation /year	Gov. Budget /year	Final Energy Savings* / year	Source of Funding	Source of data
Italy	Since 2007	55% Tax credit	250,000 households (2009)	2.5 (average2007-2009) B €	0.13 Mtoe** in 2009	Taxpayer	(Italy NEEAP, 2011) and (Pistochini & Valentini, 2011)
France	Since 2005	Tax credit	1,500,000 households (2009)	2.6 B € (2009)	0.32 Mtoe** in 2009	Taxpayer	(France NEEAP, 2011)
Germany		Subsidized loan and grant	617,000 households (2009)	1.4 B € (2010) (Table 6-7)	0.21 Mtoe** (average 2008-2010)	Taxpayer	(2011b; KfW Bankengruppe, 2011a) (German NEEAP, 2011)
UK	Since 1994	EEO	700,000 insulation (average 2008-2011)	1.4[32]B € (average 2008-2012)	0.77 Mtoe** (average 2008-2010)	Ratepayer consumers via EP	(DECC, 2012); Ofgem, 2011; and (UK NEEAP, 2011)

**Source: Individual MS 2011 National Energy Efficiency Action Plans.*

*** Million tonnes of oil equivalent*

[32] Exchange rate of €1.23 per 1 pound sterling (GBP).

3.5.1. Program Design

This subsection aims to answer the question of which policy designs best address the market barriers faced by each of the actors involved a decision to construct an efficient building or retrofit an old building to improve its efficiency.

3.5.1.1. Manufacturer Incentives

Energy-efficient homes require innovative technologies that usually cost more than standard technologies. Some energy-efficiency programs have focused on accelerating the learning-by-doing phase in component manufacturers to support long-term growth and technological maturation of this market.

Technology Procurement Programs

The goal of technology procurement is to bring down the price of new energy-efficient technologies by guaranteeing a market for a specified quantity of product sales.

Sweden has the most experience with technology procurement in Europe. The Swedish National Energy Administration has for many years formed buyer groups to demand products that are more energy efficient than those already on the market and negotiate the price down. Recently, the approach has evolved to issuing tenders that include provisions for innovation in energy-efficient technology.

Examples of large private procurements include the buy-down of compact fluorescent lamps (CFLs) by the home furnishings retailer, Ikea. Because of Ikea's large purchasing power, the company has been able to acquire CFLs at a low cost from a selected producer and has passed the savings on to consumers around the world. Ikea is such a large retailer that this program has an important impact on its supplier manufacturers as well as on consumers by providing energy-efficient technology at an attractive price (Ten Cate, Harris, Shugars, & Westling, 1998).

Market Transformation

The development of the Swedish heat-pump industry is a very interesting case study of how continuous support can radically transform a market. The Swedish government started supporting research and development programs for heat pumps in 1975 (Kiss, Neij, & Jakob, 2008), complemented by household subsidies in the 1970s and 1980s. Then, in 1993, a technology procurement process for heat pumps was instigated by a purchaser group that included two large property owners and four energy suppliers. This group's procurement process specified a heat pump that was 30% more efficient and 30% cheaper than the existing models on the market. The process resulted in two winning models meeting the procurement requirements. The two winning companies were given an initial market of 2,000 units. The procurement program was further supported with investment subsidies as well as educational programs to increase the penetration rate of heat pumps. After the first year, sales exceeded expectations.

Moreover, shortly after the procurement, interest in heat pumps started to increase from abroad, and Swedish manufacturers started to export them in 1996. In the 2000s, government subsidies were given to replace oil-based heating systems and to reduce electrically heated houses. Today, Sweden has the largest market (number of installations) for ground-source heat pumps in Europe, with more than 300,000 installed. Ground-source heat pumps represent 40% of heat pump sales. Manufacturers annually produce 40,000 ground-source heat pumps, some of which are exported (Kiss, Neij, & Jakob, 2008). Moreover, all large Swedish heat pump manufacturers have their own R&D laboratories and continue to conduct research with universities and institutes to improve the quality and efficiency of their products.

3.5.1.2. Incentives for the Construction Industry

Monetary compensation might not be the most persuasive incentive for the building industry to build or design more energy-efficient houses. Builders themselves need to be convinced that consumers will be willing to purchase more efficient houses, particularly if the homes have a price premium. Although some niche players will focus on the high-energy-performance market, most construction firms, architects, and others in the building supply chain tend to be conservative and resist change in well-established practices. For this reason, standards are the most important driver of higher energy performance although incentives and other support schemes can facilitate the process. An important element of the overall approach is to educate the building industry about what can be done and at what price.

Demonstration Projects

In this regard, the Danish government recently established a Center for Energy Savings in Buildings (Videncenter for Energibesparelser i Bygninger) to help the construction sector increase its knowledge of both possible energy savings in buildings and of building regulations. A sum of Danish krone 32 million (€4.3 million) was allocated between 2008 and 2011 to establish and operate the Danish Center for Energy Savings in Buildings. This center is financed by the Danish government, partly by a public fee through the revenues from the EPC scheme (Danish Energy Saving Trust, 2009).

Information-sharing Associations

France provides an interesting example in which building and energy-efficiency experts came together in an association (Effinergie) to establish a standard and national label to recognize best practices in the energy performance of new construction and retrofits, as described in Section 3.3.5.3.

Tax Reductions for Energy-efficient Products

Applying a reduced valued-added tax rate to environmentally preferable products while taxing less preferable ones can help to increase the penetration of cleaner technologies. For example, building on

its very successful bonus/malus[33] (also called feebate) scheme for cars, France has recently developed a similar scheme for furnaces. The UK has a reduced value-added tax rate for (professional) installation of energy-saving materials. However, uptake has been estimated to be low. There is a question about the effectiveness of this type of policy because energy savings are dependent on how materials are incorporated in a building, not just the sum of the materials used.

3.5.1.3. Owner Incentives

Up-front cost is the most significant barrier to owner investment in energy efficiency, which is why most incentives are financial in nature.

Tax Credit s

Income tax credits or tax deductions are popular financial incentives that many governments have implemented. These are generally proposed by energy ministries, government environmental agencies, or other public agencies. The programs offer tax credits or deductions for the purchase of energy-efficient equipment. Tax credits reduce the amount of tax the consumer pays, and tax deductions lower the consumer's taxable income. The percentage of the credit or deduction varies by country and generally has a maximum limit. Another popular type of tax incentive is a reduction in sales tax on energy-efficient equipment purchases, either directly or via a refund. Europe has several examples of tax credit schemes implemented by governments to stimulate the penetration of more efficient equipment.

Italy's government offers a generous tax credit that reduces by 50% the price of purchasing energy-efficient equipment. The program's penetration rate has been estimated to be very high, greatly exceeding the expectations of the Italian Energy Ministry (Pistochini & Valentini, 2011). About 250,000 households have benefited from the scheme every year since 2007. This program represents a cost of €7.5 billion to taxpayers. Window upgrades have been the most popular energy-efficiency measure installed by households under this program, followed by heating system replacements and solar panel installations. Insulation installations and overall building redevelopments amounted to only about 5% of total measures under the program even though these two measures are the most cost optimal; total building retrofits, followed by insulation installations, have the lowest costs relative savings achieved over the lifetime of the measures. The cost of conserving energy by retrofitting houses was estimated to €0.03/kWh in 2009, around half the price of energy used for heating purposes. More information on this Italy's program is available in a study by the Climate Policy Initiative (Neuhoff, Amecke, Novikova, Stelmakh, Deason, & Hobbs, 2011).

Since 2005, French households have also benefited from a tax credit for the installation of more efficient equipment. The tax credit is less generous than the Italian one, but the program penetration rate is higher. In 2009, the measure benefited 1.5 million households, representing €2.6 billion in tax credits. (French Environment Ministry, 2011). An estimated 6.6 million tons of CO_2 equivalent has been saved

[33] An incentive program designed to give a negative bonus (or malus) for poor performance and a positive bonus for good performance.

with the introduction of this tax credit. However, part of the successful penetration of the tax credit in France is its complementary relationship with the white certificate scheme implemented in France in 2006. Under the white certificate program, energy providers are obliged to save energy through their customers. White certificates can be generated from the installation of efficient equipment, so companies such as Electricité de France (EDF) and Gas de France (GDF) have heavily promoted the tax credit because it encourages customers to save energy at minimal cost to the energy company. Therefore, in it is hard to isolate the energy-savings effect of the tax credit from the effect of the white certificate program. Energy-efficient heating systems are the measure most commonly installed by consumers under the white certification program.

Low-interest Loans

Germany has designed a very successful incentive scheme, the Kreditanstalt für Wiederaufbau(KfW) program, which provides low-interest loans, which is described in detail in the case study in Chapter 6, Section 6.2.1.

Grants

The Czech Republic's Green Investment Scheme (GIS) is a good example of a grant program to stimulate energy-efficient new home construction as well as retrofits. The Czech GIS grants subsidize 30%-50% of the investment costs for residential-sector energy-efficiency measures (the grant percentage depends on the total savings of a measure). Measures eligible for grants are: insulation retrofits, new passive building construction, and use of renewable energy for heating and hot water (Tuerk, Frieden, Sharmina, Schreiber, & Urge-Vorsatz, 2010). Payments are made after the measures have been installed, so building owners pay up front and then are reimbursed. Despite recent oversubscription of the subsidy fund, the World Bank's 2011 review concluded that the program is succeeding and will likely be completed before the end of 2013. The Czech GIS is expected to result in 1.1 million tonnes of reduced CO_2 emissions by 2012, 6.3 petajoules of heating energy savings, and an increase of 3.7 petajoules in heat generation from renewable energy sources (Usporam, 2011). However, this success in the Czech Republic is due in large part to funding from Kyoto Protocol-generated carbon credits, which resulted from the collapse of the Czech economy during the 1990s. The high participation rate in the GIS program was dramatic and unexpected. Distribution of funds under the program has only recently begun. A key lesson may be learned from how the Czech Republic handles the oversubscription of the fund as well as verification of grant recipients' energy savings.

3.5.1.4. Incentives Available to Low Income

Another good example of program design comes from the United Kingdom where special attention is being paid to priority distribution of grants to segments of the population that need them most. The UK Fuel Poverty Strategy, published in November 2001, lays out the government's policies for ensuring that to the maximum extent possible, no one will be living in "fuel poverty" in England by 2016. A household is considered to be fuel poor if it would need to spend at least 10% of its income to heat the home to an acceptable level of warmth (DECC, 2011d). In 2007, approximately 4 million households were in the fuel

poverty category, which was 0.5 million more households than in 2006 as a result of increases in energy prices (DECC, 2011c). A number of policies and schemes are in place to help those vulnerable to fuel poverty, including the Carbon Emissions Reduction Target (CERT), which is covered in detail in Section 3.5.3.1., and heating and insulation improvements from the Warm Front scheme and the Decent Homes program. Since 2000, the UK Department of Energy and Climate Change (DECC) estimates that more than £25 billion has been spent in these programs to assist more than 2 million households in the UK (DECC, 2011c).

The UK's low-income household grant approach has the benefit of ensuring that cross-subsidies resulting from financial incentive programs do not negatively affect populations that suffer the most from energy costs. In addition, the program targets residences where the energy savings potential is typically the largest because low-income households often have the least energy-efficient homes. Moreover, low-income households have historically not undertaken energy-efficiency measures supported by incentives, so free ridership is very low in this income category. Therefore, a program that provides grants directly to low-income households can be a good strategy to address one of the largest savings potentials.

3.5.1.5. Renters' Incentives

The split incentive that exists between landlords and renters is a large barrier to the penetration of energy efficiency in European buildings. A considerable share of the residential building stock in Europe is rented (although this varies among nations from 65% in Switzerland to 5% in Romania) (BPIE, 2011). The high percentage of rentals poses a significant challenge in some countries because neither the tenants (who do not own the property) nor the landlords (who do not pay the energy bills) have sufficient incentive to invest in such measures.

The British Government is developing new policy measures to address this barrier. The Green Deal, to be launched in October 2012, establishes a framework that enables private firms to offer consumers energy-efficiency improvements to their homes, community spaces, and businesses at no up-front cost; the firms recoup payments through an installment charge on consumer's energy bill. This is an approach that has already proven successful in the United States and is often referred to as Pay-As-You-Save.[34] This strategy attaches the energy-efficiency loan to the property, not to a person. This type of program can not only address the split incentive between landlords and tenants but can also increase participation by homeowners who might not invest in a measure that has a long payback period if they think they might sell the property before the investment is recouped.

3.5.2. Funding

The estimated investment to achieve the estimated cost-effective energy savings potential in the building sector in the European Union (65 Mtoe) is €587 billion for the period 2011-2020, or €60 billion

[34] PAYS implies that the cost of loan repayment is equal to or less than the cost savings.

per year (EC, 2012b). Funding sources vary among countries. The following subsection describes funding source for energy efficiency programs and starts with government funding and then cover more innovative approaches such as using a portion of EU structural funds[35] for energy-efficiency programs, funding through energy provider rates, and use of government funds to leverage bank investments. The following subsections describe some of these funding resources.

3.5.2.1. Government-funded Programs

Government programs fund energy-efficiency investments in many European countries. Examples include tax credits in Italy and France and subsidized loans in Germany. Government programs are generally funded by taxpayers. Politically, these programs are supported by the argument that they save energy, reduce consumers' bills, and create jobs. A study in France estimates that for every €1 million of investment in building thermal renovation, 14.2 jobs are created (EC, 2012b). Moreover, a study of the German KfW[36]program shows that for every Euro spent by the government, €2-5 is returned to the government in the form of additional tax revenue, social security contributions, and a reduction in unemployment costs (EC, 2012b), as mentioned in the German case study section (Chapter 6, Section 6.2.2).

However, a disadvantage of government funds is that they depend on macro-economic health and can be reduced in times of financial crisis. For example, in Hungary, a program to support deep retrofits has been put on hold because of the financial crisis in that country. Moreover, a change in the political arena also can mean a change in the budget allocation for this type of program. These types of changes can result in an unstable foundation for long-term planning for energy efficiency in some countries.

Germany's success in mobilizing funding is in part because the KfW constitutes a colossal fund. In 2009, KfW had a balance sheet total of €400 billion, second only to the China Development Bank (€465 billion) among national or "development banks" and more than the holdings of the European Investment Bank (€362 billion) (UK Parliament, 2011).

3.5.2.2. Ratepayer-funded Programs

A number of countries apply a small levy or charge—a fraction of a cent per kWh—on sales of energy (de la Rue du Can, Shah, & Phadke, 2011). These levies create a fund that supports energy-efficiency programs. The rationale is that the total cost to customers from the increased energy tariff is more than compensated for by the aggregate savings on energy bills from the efficiency programs. The revenues from the levy are redirected entirely to customers. Efficiency investments eventually result in lower rates by preventing or delaying capital investments in costly new generation capacity. In other words, customers invest at the time of energy purchase but recover the extra costs through the dual benefit of energy savings and reduced future capital investment.

[35] Structural funds are composed of the the European Regional Development Fund, the European Social Fund and the Cohesion Fund and aim at reducing development disparities between the EU regions.

[36] KfW stands for Kreditanstalt für Wiederaufbau (in German) or Reconstruction Credit Institute.

In Europe, these funds are usually referred to as "earmarked funds," and public benefits charges themselves are commonly called "taxes" instead of charges. A number of countries, including Denmark and Belgium, have implemented a public-benefit charge on electricity rates to fund energy-efficiency programs. The Danish Energy Saving Trust is financed by a special energy savings charge of Danish krone 0.006/kWh (0.0011 USD/kWh) payable by households and the public sector. Total annual proceeds amount to approximately Danish krone 90 million (USD 16.4 million) (Danish Energy Saving Trust, 2009). In the Netherlands, a tax on electricity was accompanied by a tax rebate for buyers of energy-efficient appliances under the Energy Premium Scheme. The cost for the Energy Premium Scheme amounted to €65 million in 2000 (USD $88 million) and €135 million Euros in 2001 (USD $184 million) (Siderius & Loozen, 2003).

Ratepayer-funded energy efficiency programs also include programs implemented by EP such as the UK CERT scheme. However, in this case where price is set free, the cost recovery mechanism is implicitly paid for by gas or electricity ratepayers: no specific charge is defined as part of the consumer's electricity or gas tariff; instead EP spend a share of their profits on energy efficiency. In both case, the costs of measures are to some degree recovered through tariffs

3.5.2.3. Carbon Incentive Program in Czechoslavakia

The Czech GIS beneficially uses incidental carbon credits for financing improvements in the buildings sector, a sector that is typically very difficult to reach through the Kyoto Protocol's Joint Implementation (JI) and Clean Development Mechanism (CDM) carbon trading schemes. Energy-efficiency measures in the buildings sector are not a good fit for JI or CDM financing because these programs require rigorous savings validation and verification before trading of carbon emissions rights can take place. Moreover, building-efficiency-related savings potential is widely dispersed over a highly variable landscape of projects, individual project savings are relatively small, and transaction costs are often very high, making bundling of projects difficult; this creates a high barrier to JI and CDM funding (Urge-Vorsatz, Tuerk, & Sharmina, 2009). However, the Czech Republic and other Central and Eastern European countries have generated a surplus of government emissions rights (assigned amount units) under the Kyoto Protocol (Valentova, 2010) due to economic transitions in the 1990s. These incidental carbon credits have been sold to create GIS that are used for environmental improvement efforts, particularly those that further reduce greenhouse gas emissions (Tuerk, Frieden, Sharmina, Schreiber, & Urge-Vorsatz, 2010). In 2009, the Czech Republic contracted with the Japanese, Austrian, and Spanish governments as well as a Japanese company for a total of €980 million in assigned amount unit sales. The proceeds of the fund are managed by the CSEF and have been primarily applied to a Czech GIS that subsidizes 30%-50% of the investment costs of energy-efficiency programs.

Although the fate of such credits in the post-Kyoto period is uncertain, the market uptake of current green investment schemes indicates promise for building energy-efficiency financing programs that result in carbon emissions reductions in Eastern European and former Soviet Union countries.

3.5.2.4. Revolving Funds

Revolving funds, in which installment payments replenish the principal, are an interesting mechanism for financing energy efficiency. There is growing interest in a revolving fund to finance energy-efficiency projects in Europe. The best example is the German KfW, which has inspired other European countries. For example the UK is developing a new revolving fund called the Green Investment Bank for financing low-carbon investments, including (but not limited to) energy efficiency.

The Joint European Support for Sustainable Investment in City Areas (JESSICA) is a European Commission policy initiative co-developed by the European Investment Bank (EIB) and the Council of Europe Development Bank (CEB). JESSICA uses EU structural funds to create alternative financing vehicles that are often used, to make repayable energy-efficiency investments in urban buildings. Under JESSICA initiative, EU member countries are able to dedicate a certain portion of EU structural funds to help co-finance, with private banks and other government funds, residential efficiency retrofit projects. Of the total EU budget that is contributed by member states, 35.7% or €308 billion is dedicated to structural funds, of which approximately €8-9 billion are for renewable energy and energy efficiency (BPIE, 2011).

3.5.3. Administration of Incentives

This section explores best practices for administering energy-efficiency incentives in the European Union. There are many examples. Energy-efficiency programs are often administered by governments or energy agencies, sometimes trusts or banks, and in a growing number of cases by energy providers (EPs). This section includes examples of how EPs have been administering the UK scheme and describes the resultant savings.

3.5.3.1. Role of Energy Providers

Some countries have chosen to rely on EPs to deliver energy-efficiency measures. The approach is to set energy-efficiency obligations (EEOs) for EPs to save end-use energy for their customers. EPs are then required to meet annual energy savings targets by undertaking activities directly or contracting with energy service companies. In most cases, the targets oblige EPs to achieve a specific level of energy savings, which is calculated based on studies of energy-efficiency potential. Targets are then expressed as a percentage reduction in total energy sales, a reduction in the growth of energy usage, or an absolute value. White certificates are generated in some programs and allow energy obligations to be met by buying or selling energy-saving credits. White certificates assess energy savings in units defined by each country, which vary widely.

Several European countries have implemented an EEO scheme or are seriously considering doing so. In June 2011, the European Commission issued a proposal for a new “Energy-Efficiency Directive” that, if accepted, will make it mandatory for all member states to implement EEOs (EC, 2011b). EPs will be obliged to save 1.5% of their energy sales every year, by volume, by implementing measures such as improving the efficiency of heating systems, installing double-glazed windows, or insulating roofs.

In 1994, the UK was the first EU country to implement an EEO. The current obligation, CERT, requires domestic energy suppliers to save 293 Mt CO_2 from 2008 to 2012 (DECC, 2011a). This represents annual savings, at the end of the scheme, equivalent to 2% of current household emissions. It is expected that suppliers will need to invest around £5.5 billion in energy-efficiency measures to meet this target (DECC, 2012). EPs must abide by strict constraints in meeting the target: 1) at least 40% of the carbon savings have to be in "priority group" households (households that are on certain national benefits schemes and/or whose residents are more than 70 years old), and 2) at least 25% (74 Mt CO_2) must be delivered through professionally installed insulation measures. The CERT scheme will be replaced by the energy company obligation (ECO) in 2013. ECO obliges energy suppliers to support household energy efficiency and focuses on vulnerable and poor households and specific higher-cost measures, in particular solid wall insulation. ECO will work alongside the Green Deal, described in Section 3.5.1.4.

The energy suppliers obligated under CERT/ECO update the energy regulator (the Office of Gas and Electricity Markets) every three months with cumulative progress toward each of their carbon emissions reduction obligations (Ofgem, 2011). Office of Gas and Electricity Markets figures show that more than two million households received roof insulation through CERT schemes between April 2008 and June 2011, and 1.6 million households received cavity wall insulation. Energy suppliers generally contracted with partners to deliver professionally installed home insulation measures by setting an explicit price per tonne of carbon saved. Although CFLs have not been eligible under CERT since March 31, 2011, 300 million CFLs were distributed under the CERT scheme, accounting for 50.9 Mt CO_2 (24.6% of total savings). Heating measures, such as more efficient boilers and fuel switching (for example from oil to gas), represent 7.3% of total savings. Figure 3-6 shows the breakdown of the CO2 savings by measure type.

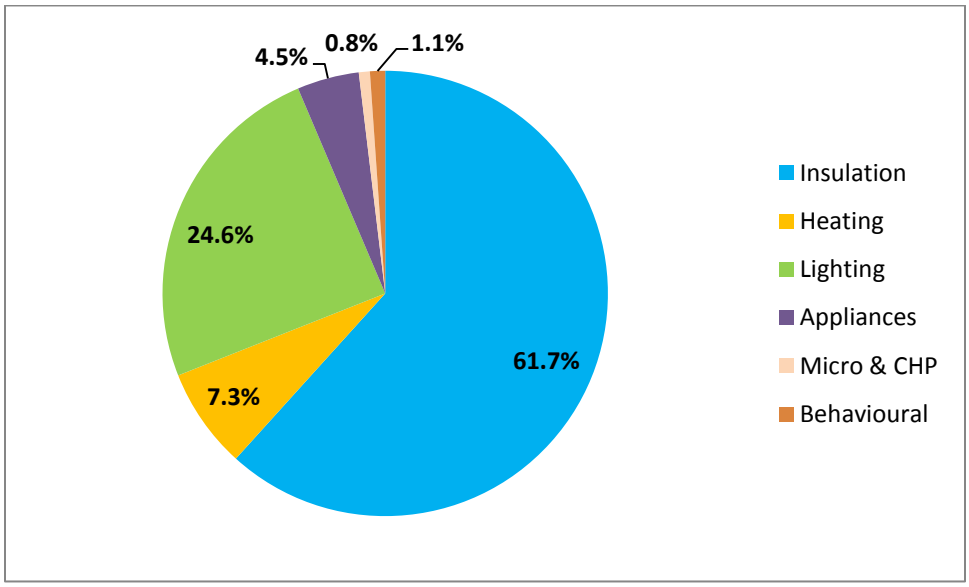


Figure 3-6. UK CERT Total CO_2 Savings by Measure Type

Source: (Ofgem 2011)

The costs of energy-efficiency measures undertaken to meet targets are passed on to consumers via rate increases on energy bills. DECC estimates that the average supplier cost per consumer bill will be £50 per year under CERT, largely offset by reductions in bills from energy savings for households that benefit from measures. Average rate increases in the UK have been estimated at approximately 1.5% (Eyre, Pavan, & Bodineau, 2009). Balancing costs and benefits, DECC estimates that the CERT scheme has a net present value to society of approximately £17 billion (DECC, 2011b).

Positive results of the scheme and its predecessors are evidenced in the decrease in residential natural gas consumption. Since 2005, gas demand in Britain has decreased approximately 15% despite significant increases in the number of gas customers. This reduction is the result of combined effects, including increases in insulation, increased penetration of condensing boilers, and increased energy prices (Lees, 2011).

Other examples of EEOs are found in Italy, Denmark, the Flanders region of Belgium, and France (Lees, 2011). These schemes differ widely in their scope, the sectors they cover, the energy providers included, the provisions set by regulators, and the metrics by which savings are calculated.

Although EEOs have been successful in saving energy for large numbers of customers, EEOs have been criticized by some because the incentive on energy providers is generally to meet the obligation at lowest cost, which is a disincentive to the higher costs of deep renovation, which typically produces greater and more cost-optimal savings over the building's lifetime. The UK is addressing this concern to some extent through the new ECO in 2013, which will be specifically targeted at higher-cost measures although there is no requirement to undertake a "whole-house" approach.

As a result of the proposals in the draft Energy-Efficiency Directive, EPs are likely to play a much bigger role in energy efficiency in Europe than they have in previous years. The main rationale behind this shift is a push to integrate energy efficiency as an energy resource in the EPs' planning strategy. Many U.S. states have had experience with this approach, known as integrated resource planning, because U.S. regulators have used it to compare the benefits and costs of additional generation with the benefits and costs of saving energy. Energy utilities need to be provided with an incentive to invest in energy efficiency and to potentially make profits through energy savings.

3.6. Best Energy Policy Practices in the European Union

3.6.1. Building Energy Codes

3.6.1.1. Best Practices

For many years, building codes have been a central driver of energy efficiency in new buildings. As a result of the EU Energy Performance of Buildings Directive (EPBD), and particularly with the requirement to achieve nearly zero energy buildings (nZEB) starting in 2020 (2018 in the public sector), the importance of building codes has been further enhanced. EPBD has moved EU member states toward integrated building energy performance-based codes as opposed to prescriptive, element-based requirements. The EU experience highlights the following best practices:

Regular and transparent code revision cycles: A few EU member states (Denmark, Germany, and others) have regularly set tougher building energy performance standards, with two to five years between updates, and with revisions announced well in advance to prepare the industry for the next round of regulation. Research, development, and demonstration projects that far exceed the prevailing minimum standards have also been useful in providing leading indicators of potential future targets for energy performance.

Voluntary standards: Voluntary standards provide a means to go beyond the minimum national requirements and demonstrate the practical experience of constructing or renovating buildings to higher energy performance levels. In Europe, the Passive House and MINERGIE standards demonstrate good practice. As the number of buildings meeting such voluntary standards has grown, so policy makers increasingly see them as defining the next iteration of mandatory performance codes. However more effort is needed to define low-energy buildings and nZEBs in term of energy performance, to share experience among all member states, and to possibly harmonize definitions.

Learning by sharing: A unique feature of the EU region is that it deals with 27 member states that have different cultures, languages, backgrounds, and experience. Nevertheless, the European Union has been successful in establishing a platform for communication among professionals and practitioners, which has helped them share experience and has proven to be an effective way to converge on some harmonized definitions, methodologies, and standards. The access to a network of experienced actors on specific topics has brought invaluable resources to the process. Communication networks have been most successful when organized for specific actors. Here are two successful EU examples:

- Concerted Action (CA) is a European network restricted to policy makers in charge of preparing technical, legal, and administrative building energy-efficiency policy. This network has created a gateway for country representatives to learn from others on different aspects of energy performance of buildings policy implementation.

- An example at a national level is the French Effinergie, where experts and constructors come together and work on developing standards for low-energy buildings. Participants use the network to share knowledge about construction of such buildings.

3.6.1.2. Issues

Compliance with building codes: The strategy for control and enforcement varies a lot among EU countries, and data are lacking on compliance rates by country. Compliance is a very important subject but also a sensitive issue in Europe. Moreover, definitions of non-compliance and therefore compliance rates vary significantly among country studies. The definition of compliance can range from simply submitting the right documents to checking the energy performance calculation method to comparing measured energy performance values to calculated values.

Comparing building code stringency: Despite some harmonization in the use of whole-building performance standards, there is still wide variation in the way member states have set these standards, and there is no robust, simple, and fair method available to compare the different national requirements. Early in 2012, the European Commission (EC) published a methodology and guidance for calculating cost-optimal levels of minimum energy performance requirements for buildings. These documents will help each country to compare current code energy performance levels with cost-optimal levels. This will also allow evaluation of progress toward cost optimal policies within each member state.

Low-energy building cooling and lighting standards: Voluntary low-energy building standards, such as Passive House, have so far been adopted mainly in colder regions of Europe. There is a need to develop suitable standards for warmer regions in the south and to increase deployment of low-energy buildings. Passive House has been successful in demonstrating how it is possible to significantly reduce the need for space heating, but the standard does not include cooling or lighting. A low-energy standard for cooling and lighting needs to be developed, and buildings using this performance standard need to be constructed as examples that can be replicated.

Gaining more experience with nZEBs: With the requirement for all new EU buildings to be nZEB within a decade, there remains a major learning curve for practitioners across Europe regarding the technical specifications, construction practices, and costs of such buildings, both residential as well as non-residential.

3.6.2. Building Energy Labeling

3.6.2.1. Best Practices

The Energy Performance Certificate (EPC) was introduced in all EU member states as a requirement within the EPBD. Examples of EPC and other labeling best practices in Europe include:

Labeling including recommendations: In 2002 the European Union required all member countries to design national systems for energy certificates and labels for buildings in the next four years (by 2006). Subject to criteria that were established, each country could design the certificates and labels for their own circumstances. The use of certificates was mandatory. By 2008 labeling and certification programs were widespread throughout the EU. Evaluations have been carried out since 2010 using a common methodology across EU member countries.

The EU program for certifying and labeling energy use in buildings is unique among large regions for being both widespread and mandatory. It may turn out to be the most effective policy approach for encouraging retrofit of buildings in general and at point of sale.

Building an information pyramid: The use of a centralized database that registers information on building labels issued is an important tool to understand the energy performance of the building stock and how it changes over time. Such a database can be used to develop benchmark tools and other supportive materials. The information in the database provides an important feedback loop for building assessors to continually improve the quality of EPCs and to ensure that the recommendations that accompany EPCs are relevant and up to date.

3.6.2.2. Issues

A few areas for more research have been identified to help improve the impact of labeling programs in the European Union:

Methodology: More research is needed to understand factors leading to differences between measured and calculated estimates of a building's energy performance. Such research requires an approach that depends on a variety of techniques—from the behavioral sciences, engineering, and statistics at a minimum.

Evaluation: Because each EU country has adopted its own label design, evaluation of the rate of public acceptance of labels among EU countries could help us understand how different designs affect consumer behavior. Research is also needed to identify how best recommendations can be presented to positively affect a building owner's decision to invest in improving a building.

Control and enforcement: Research is needed to identify countries that have successfully used EPCs in control and enforcement procedures.

3.6.3. Financing and Incentive Programs

3.6.3.1. Best Practices

Mobilizing private investors from banks: Policy makers need to leverage private funding to invest in energy saving measures. The German KfW development bank is a very successful example of a public –

private partnership that encourages banks to promote investment in the energy performance of German buildings. Policy makers need to develop mechanisms and a conducive environment for such investments to be recognized as a financial asset class for banks as well as building owners (households and commercial owners).

Targeting deep renovation: German programs not only increase renovation rates but target deep renovation. The financial incentives are set proportionally to the depth of the retrofit (i.e., the resulting energy savings). The German example is further studied in the case studies in Chapter 6.

A palette of incentive programs: Across the European Union, a large array of incentive programs has been implemented. Some of the high-impact programs, such as tax incentives, energy-efficiency obligations (EEOs) and loan schemes, are the result of several years of evolution and refinement to meet changing market conditions while absorbing experience from other territories. Member states need to increase the size and participation rates of successful programs in order to increase savings. Challenges remain for policy makers in designing incentive instruments that motivate consumers to use less energy in buildings and for the construction industry to produce, offer, and use more energy-efficient technologies.

3.6.3.2. Issues

Comparing incentive programs: The critical question about which incentive scheme results in the most savings at the least cost remains unanswered. This is true for several reasons. The most important is the large variety of methodologies used to calculate energy and CO_2 savings in different countries or even among different schemes within countries. A variety of metrics are used, including primary energy versus final energy and lifetime savings versus first-year savings. Even when lifetime savings are considered, countries use different lifetime and discount rate assumptions. These would need to be harmonized for a thorough and accurate comparison. In addition, not all countries systematically evaluate their programs.

3.7. Conclusions

The European Union is actively engaged in realizing the energy saving potential in building improvements and considers the building sector crucial to meeting its climate change strategy goals. Despite shortcomings and delays in its implementation, EPBD remains perhaps the most ambitious, transformative, and influential policy worldwide that addresses energy use in buildings. EPBD has succeeded in overcoming political and technical differences among member states and has established a common goal to improve building energy performance in the European Union.

All 27 EU member states and numerous non-member countries with a combined total population of more than half a billion people are subject to the EPBD's requirements. Its comprehensive scope includes building codes for new construction and renovation, certificates for energy performance, inspection of heating and cooling systems, and a target of permitting only the construction of nZEBs starting in 2020 (2018 for public authorities). Many EU member states also see improving building energy performance as a way to boost their economies and improve energy security (reducing reliance on energy imports) as well as to reduce consumer energy bills, especially in low-income households. Some countries also value the competitive benefits of encouraging homegrown technological solutions that help the transition to low-carbon economies.

Among the lessons learned, the EU experience demonstrates how long the process is to train the work force necessary to implement a labeling program. It took member states from a few to up to six years to implement the EU directive on labeling, in part due to the need to establish a political consensus. Government and industry associations can facilitate training and ensure future high-quality energy assessments by providing well-designed training and guidance tools and software. European experience also shows that labeling program benefits are enhanced when these programs operate in tandem with other policies and as part of a package of measures. Many countries have financial incentive schemes in which the performance criteria are determined by a label requirement.

Overall, a wide variety of incentive programs has been implemented in Europe. Some yield measures with large savings but that last for only a limited time (five to fifteen years) while others yield fewer short term savings but that continue much longer (50 to 100 years). Moreover, not all policies yield immediate energy savings that are directly measurable; nonetheless, these policies may be instrumental in transforming the market and changing behavior. We believe that all measures should be considered and implemented to spur both immediate and long-term incremental changes. Challenges remain for policy makers to design packages of incentive instruments that produce immediate as well as long-term savings. Importance should also be given to implementing measures that spur learning effects and reduce the price of renovating and constructing more energy-efficient buildings.

Although the European Union has demonstrated a degree of political will in enacting energy-efficiency policies among its member states, many challenges remain, and execution is often hampered by other national political considerations. Moreover, even if all EU member states have the same general aim, Europe is composed of geographically and climatically diverse countries that have very different cultures

and resources. The differences in approach to and aggressiveness of implementation programs and policies result in different degrees of energy savings. Despite these differences, there are some encouraging developments in which experience and best practice have crossed national borders, and countries that have historically been lagging are catching up with their European counterparts.

The EU Parliament and Council are about to pass a new energy-efficiency directive that will complement the EPBD by involving private-sector actors in realizing energy efficiency improvements in the building sector, accelerate renovation rates, and deepen the scope of retrofits and thus overall and cost-effective energy savings. This will also spur learning effects that will lead to reduced costs for renovating buildings.

Energy use per dwelling in the EU residential sector (which accounts for 75% of the EU building stock and approximately two-thirds of building energy use) is gradually decreasing thanks to a combination of improved energy performance and reduced average property size. However, energy consumption in the commercial sector continues to increase, driven largely by higher electricity loads for heating, ventilation, and air conditioning (HVAC), lighting, and office equipment. To date, Europe has developed relatively fewer incentive schemes that target and limit growth of energy use in the commercial sector as compared to the residential sector.

At the same time, some EU countries have struggled to increase rates of participation in energy-efficiency programs, particularly in renovation of existing buildings. This is likely the next challenge that EU and European national policy makers will confront. Many barriers prevent building owners and occupants from taking advantage of energy-efficiency programs. Policy makers face resistance and inertia when it comes to changing people's behavior and influencing their willingness to invest in improving the energy performance of the building stock. Therefore, policy makers have much work still to do to translate political will into realized savings.

Chapter 4 - Review of Building Energy-Efficiency Policies: China

4.1. Introduction

China's building code, labeling, and energy-efficiency incentive frameworks have evolved significantly during the past decade.

Distinctive features of China's building codes include provisions tailored to China's wide range of climate zones with their varying heating and cooling needs and a "loop" system of implementation that involves both local and provincial authorities. Although there are some questions about the data, some areas of the country have achieved high code compliance rates.

China's green building energy labeling scheme is notable for requiring minimum performance in each category specified, in contrast to the internationally popular Leadership in Energy and Environmental Design (LEED) program in which low scores in some categories can be offset by higher scores in others, potentially resulting in some building elements performing inefficiently. Low public awareness is a challenge for China's relatively new building labeling programs. In addition, the presence of two labeling schemes, one for green buildings and one for building energy efficiency, creates some confusion among consumers.

China's central government has provided leadership in establishing financial incentives to support heating reform in existing construction as well as adoption of energy-efficient technologies and building-integrated renewable energy technologies. Cost sharing between national and local governments has been a key to the success of building incentives.

As a general approach, China's central and local governments have recognized the need to adopt both regulatory policies (i.e., building codes) and market-based and financial policies (i.e., building energy labels and incentives) to improve building energy efficiency.

The unprecedented rate of growth in new construction in China and the government's relatively recent policy focus on building energy efficiency leaves China's building energy-efficiency codes and labeling and incentive programs facing some major challenges. Insufficient institutional and technical capacity make it difficult to develop more stringent and up-to-date building codes. A particular issue is the use of 1980s-era baseline values against which efficiency improvements are measured even though those baselines may not represent average existing conditions in the building stock today. Another challenge for China's building codes and efficiency policies is uneven enforcement and monitoring. Disparities between urban and rural building energy-efficiency levels and in the levels of policy support between

central and local governments have also limited the effectiveness of all types of building energy-efficiency policies in China. The connections among the three types of building policies (codes, labeling, and incentives) in China have been limited thus far; their effectiveness could be improved significantly with greater cross-cutting policy linkages and adoption of complementary policies (e.g., linking incentives with building energy labels).

4.2. Energy Use in China's Buildings

With continuing rapid urbanization and economic growth in China, buildings are becoming increasingly important consumers of energy.[37] China's building sector has grown at an astounding pace during the past decade, as illustrated Figure 4-1. More than two billion square meters (m^2) of building floor space were added annually in 2007 and 2008, and the construction boom continued with funding from the 2009 stimulus plan (Tsinghua University Building Energy Research Center, 2011). Construction of urban residential buildings has been increasing in particular, driven simultaneously by income growth and China's burgeoning urban population demanding more living space. More than 300 million new residents were added to Chinese cities between 1990 and 2010, and urban residential floor space increased from 9.6 m^2/person in 2000 to 20.3 m^2/person in 2008 (NBS, 2009; Tsinghua University Building Energy Research Center, 2011).

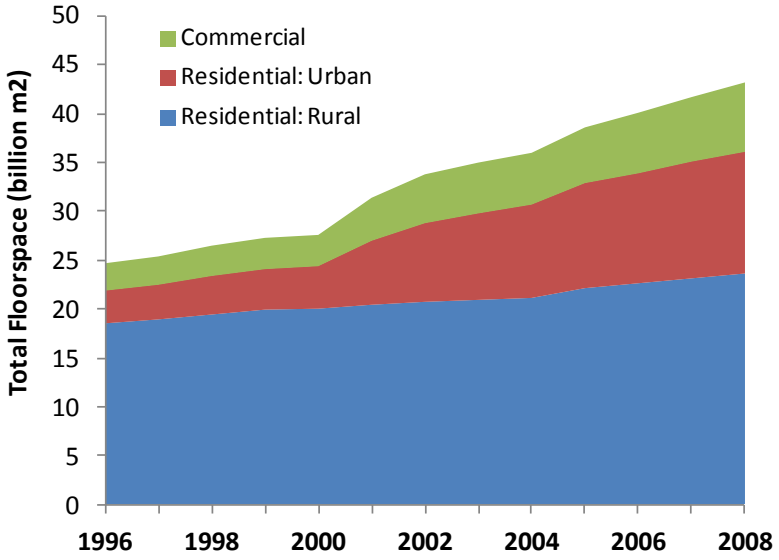


Figure 4-1. China's Reported Historical Total Floor Space by Building Type, 1996 – 2008

Source: (Tsinghua University Building Energy Research Center, 2011).

Over the next four decades, Chinese building floor space is expected to continue to increase, with growth driven by new urban residential and commercial construction. Lawrence Berkeley National Laboratory (LBNL) studies suggest that, by 2050, urban residential floor space could reach 46 m^2/person in China, and total floor space could reach 51 billion m^2, as seen in Figure 4-2 (Zhou, Fridley, McNeil, Zheng, Ke, & Levine, 2011). At the same time, total rural residential floor space would decrease from 22 billion m^2 in 2010 to only 14 billion m^2 as the share of rural population shrinks from the current 47 % to

[37] China categorizes buildings as residential and "public." "Public buildings" refers to nonresidential buildings, including government and office buildings as well as retail buildings, hotels, schools, and hospitals. This definition of public buildings in China is similar to what is commonly referred to as commercial buildings in other countries. For consistency with the other sections of this report, we use the term "commercial buildings" in place of the Chinese term nonresidential "public buildings." China further divides the residential buildings category into urban and rural residential buildings.

only 21% by 2050 (Zhou, Fridley, McNeil, Zheng, Ke, & Levine, 2011). During the same time period, total commercial floor space is expected to double from 11 billion m^2 in 2010 to 22 billion m^2 in 2050 (Zhou, Fridley, McNeil, Zheng, Ke, & Levine, 2011).

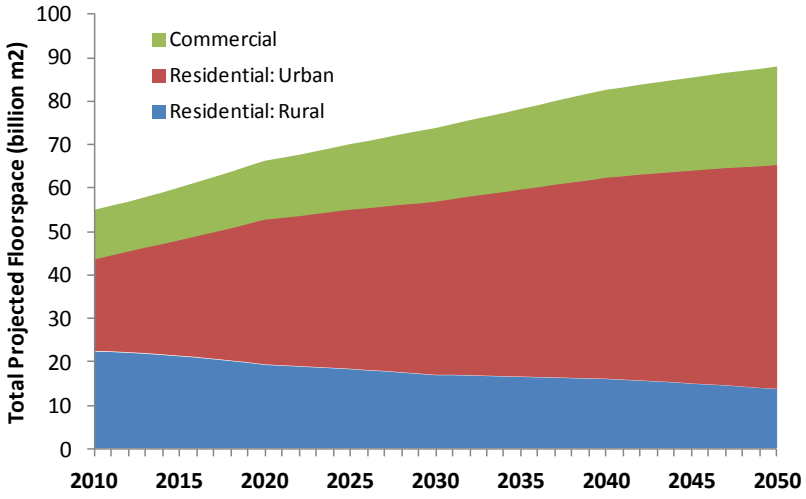


Figure 4-2. China's Projected Total Building Floor Space by Building Type, 2010 – 2050

Source: LBNL China End-Use Model. For details on modeling methodology and underlying assumptions, see (Zhou, Fridley, McNeil, Zheng, Ke, & Levine, 2011).

Increasing demand for energy services in China comes from both residential households with increasing income levels and China's expanding commercial sector although current average energy intensity in China's residential and commercial buildings is still very low compared to international levels. For residential buildings, the urban cooking and water heating intensity was only one-quarter of the average Japanese level in 2000. Average final energy intensity in commercial buildings is only one-third of U.S. and Japanese levels (Zhou & Lin, 2008; Zhou, Fridley, McNeil, Zheng, Ke, & Levine, 2011).

Historically, building energy consumption in China increased sharply after 1990. Total consumption more than doubled between 1980 and 2005. Because Chinese energy consumption statistics are recorded and reported by the sector in which the consumption occurred rather than by the purpose for which the energy was used, official statistics for building energy use might be underestimated (Zhou & Lin, 2008). For example, energy consumption in residential and commercial buildings that are operated by industrial enterprises (e.g., dormitories and office buildings for industrial workers located within an industrial facility) is reported as industrial energy use rather than building energy use. As a result, the Chinese National Bureau of Statistics reported that primary energy consumption for buildings in 2008 was only 17% of total energy consumption; more recently, Tsinghua University and NBS estimated that buildings consume 20% of total primary energy (Shui & Li, 2012). However, other sources have reported buildings' share of total energy consumption at 25% (~350 million tonnes of coal equivalent [Mtce[38]])

[38] Mtce or million tonnes of coal equivalent is the standard unit for energy in China and is equal to 29.27 x 10^{15} Joules (i.e., million GJ).

once sectoral adjustments are made to capture the total energy consumption of all buildings (NBS, 2009; Zhou & Lin, 2008). In industrialized countries, buildings represent approximately 35% of energy consumption, so Chinese buildings' share of total energy consumption is still comparatively low (Kong , Lu, & Wu, 2011). However, by 2050, primary energy use in Chinese residential and commercial buildings could grow to more than 1,500 Mtce (Zhou, Fridley, McNeil, Zheng, Ke, & Levine, 2011).

4.3. China's Building Energy Codes

China's building energy codes and standards were adopted and implemented in phases beginning in the late 1980s. The first standard was adopted for residential buildings in the heating zones (cold and severely cold climate zones) of North China. Subsequent standards in the early 2000s expanded coverage to include residential buildings in two other climate zones, the hot-summer cold-winter zone in Central China and the hot-summer warm-winter zone in Southern China. Figure 4-3 shows a map of China's climate zones. In 2005, a national design standard for commercial buildings in all climate zones was adopted and implemented. Both the residential and commercial building design standards cover only building envelopes and heating, ventilation, and air conditioning (HVAC) systems. China has a separate standard for lighting design in buildings, which was adopted in 2004. The subsections below detail the specific requirements of each design standard.

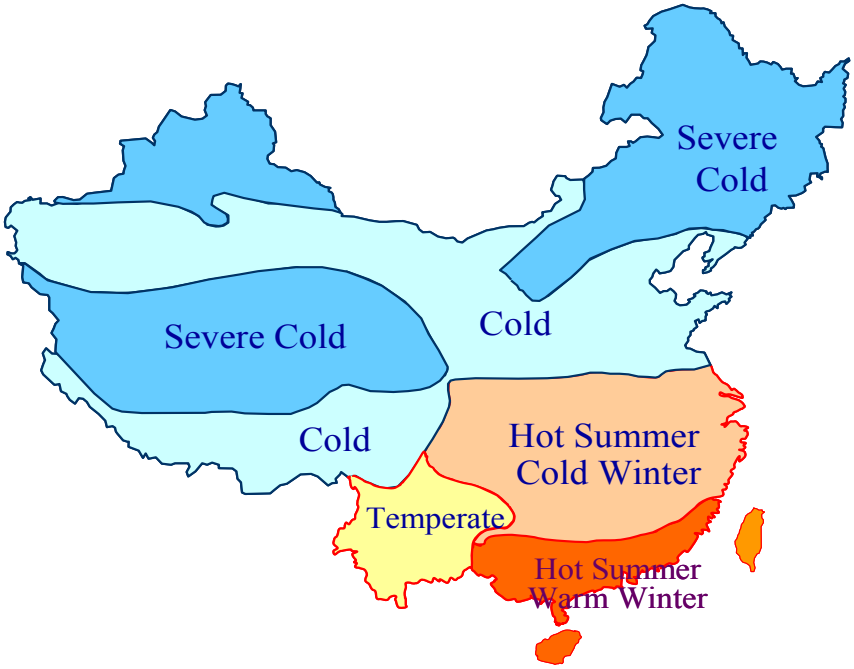


Figure 4-3. Map of Climate Zones in China

Source: (Huang & Deringer, 2007)

China's centralized Ministry of Housing and Urban-Rural Development (MOHURD) is the regulatory agency for building energy code development and implementation. MOHURD is under the State Council, which is responsible for regulating the entire building industry. MOHURD, which was known prior to 2008 as the Ministry of Construction, works with building science research institutes and universities on code development and revision as well as with counterparts in provincial and local governments on code implementation. Specifically, the Department of Standards and Norms within MOHURD works with research institutes (such as the China Academy of Building Research [ABR]), universities, and industries on the technical development of building standards. Two other departments within MOHURD, the

Department of Science and Technology and the Department of Urban Development, are responsible for efforts related to building energy efficiency, such as retrofits and heat supply reform (Levine, et al., 2010). Lastly, MOHURD's Department of Quality and Safety oversees building code enforcement on the national level while working in coordination with local Construction Commissions and Provincial Construction Departments on local and regional implementation. Figure 4-4 shows a structural diagram of the governmental organizations related to building efficiency codes and standards.

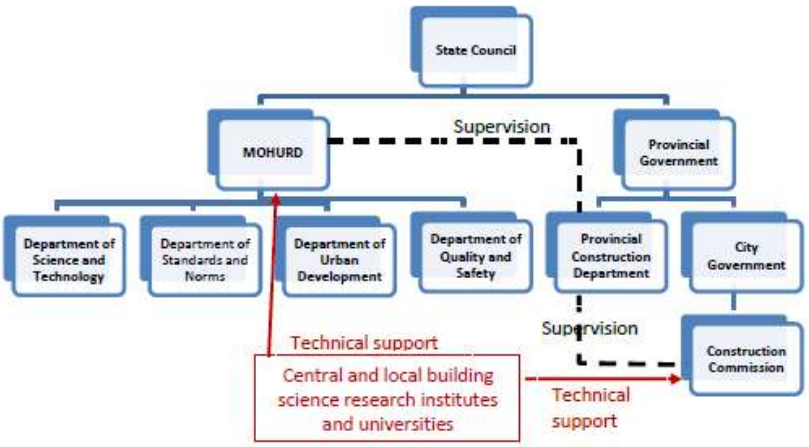


Figure 4-4. Government Organization Chart for Building Energy-Efficiency Policy Development and Implementation

Source: (Levine, et al., 2010)

4.3.1. China's Design Standards for Residential Buildings for Different Climate Zones

China has three residential building energy-efficiency design standards, which cover four out of the five climate zones. The standards reflect the initially iterative process of Chinese building code development, which contrasts with the later centralized national code for commercial buildings. All three design standards apply to new residential construction, residential building expansion or additions, and residential building retrofit projects. The basic metric for thermal integrity in all three design standards is a reduction target for heating energy consumption relative to a baseline. Although the three residential building codes are similar in having heating energy intensity reduction targets, other features of the codes differ as a result of specific climate zone characteristics.

4.3.1.1. Heating Zones

China's first residential building energy-efficiency standard, the Energy Conservation Design Standard for Residential Buildings in Heating Zones (JGJ 26-95), was issued in 1986 with a target of reducing heating energy consumption by 30% for buildings in the heating zones. The 30% reduction target is relative to the heating energy consumption of baseline residential buildings. The baseline is designated as typical inefficient buildings designed from 1980 to 1981 (Lang, 2004). The reduction target was later revised in

December 1995 to 50% of heating energy consumption and, with the newest revision that took effect on August 1, 2010, raised to 65% (Long, 2011). The design standard provides building heat loss and coal consumption indices for heating that designers can use but also allows for the use of a steady-state method for calculating heat loss for buildings that differ from the typical buildings represented in the indices (Lang, 2004). In addition, the standard includes sections on thermally efficient building and heating design. For example, it provides information to assist designers in matching total installation capacity of the heat source with building heating load and gives information on hydraulic balancing devices and piping and heating system insulation (Shui, Evans, Lin, Jiang, Liu, & Somasundaram, 2009).

4.3.1.2. Hot Summer and Cold Winter Zone

China's design standard for residential buildings in the hot summer and cold winter climate zone (JGJ 134-2001) was approved on July 5, 2001 and took effect on October 1, 2001. Like the residential building design standard for heating zones, this standard specifies indoor thermal environment requirements and provides information on energy-efficient building design and HVAC systems. The standard offers two approaches for determining whether a proposed building design will achieve the required 50% reduction in heating and air conditioning energy consumption relative to a reference building with the same indoor thermal conditions. The first approach is prescriptive and allows the design comply with the maximum allowable heat-transfer coefficient for building envelopes and a minimum required energy-efficiency ratio (EER) for heating and air-conditioning equipment (Lang, 2004). The second approach is performance based and gives designers more flexibility by setting a maximum allowable heating and cooling energy consumption per m^2, depending on the heating and cooling degree-days of the project site. Building designers can then use dynamic simulation software (i.e., DOE-2) to calculate the building design's energy consumption under non-steady-state heat transfer conditions (Shui, Evans, Lin, Jiang, Liu, & Somasundaram, 2009). The 2001 design standard was revised in, 2010 to include a more stringent requirement for envelope thermal performance, technology measures, and a new shading coefficient requirement (Long, 2011).

4.3.1.3. Hot Summer and Warm Winter Zone

The newest residential building energy-efficiency design standard for the hot summer and warm winter zone (JGJ 75-2003) was approved in July 2003 and took effect October 1, 2003. As with the residential building design standard for the hot summer and cold winter zone, this standard also requires that annual heating and air-conditioning energy consumption be reduced by 50% through either a prescriptive or performance-based approach (Lang, 2004). The main climate-related adjustments specific to this standard are glazing requirements and shading coefficients to address solar radiation passing through windows, and heat-transfer coefficients for lightweight walls and roofs under the prescriptive approach. Under the performance approach, the maximum allowable heating and cooling energy intensity are based on simulated results for a reference building (Shui, Evans, Lin, Jiang, Liu, & Somasundaram, 2009). This standard is currently under review for a further revision (Yu, 2011).

4.3.1.4. Renovation of Existing Heated Residential Buildings

In addition to the three building energy-efficiency design standards described above, China has a technical standard for energy-efficiency retrofits of existing residential buildings that have central heating systems and are located in cold and severely cold climate zones (JGJ 129-2000). This standard was approved by MOHURD in October 2000 and took effect on January 1, 2001. Because in 2000 many existing buildings did not meet the design standard for residential buildings in the heating zone (JGJ 26-95), this standard was issued to specify the conditions under which existing buildings should be retrofitted and the scope of the retrofit. Specifically, this standard calls for an existing residential building to be retrofitted if 1) the building cannot meet the design standard; 2) the existing boiler system has an efficiency of less than 0.68 or the outdoor pipe network transmission efficiency is lower than 0.90; and 3) the building is a hotel, guest house, childcare facility, or other residential building that is centrally heated cannot meet local insulation requirements for building envelopes (MOHURD, 2000). The standard also addresses retrofits of building envelopes and of heating systems other than central heating in these two climate zones (Long, 2011).

4.3.2. China's Design Standards for Commercial Buildings

China's national design standard for energy-efficient commercial buildings (JGJ 189-2005) took effect on July 1, 2005 and covers new construction, expansion, and retrofits. The standard sets a goal of reducing lighting and HVAC energy use by 50% compared with the energy use in buildings constructed in the early 1980s. DOE-2 software is used to set the benchmark values for lighting and HVAC energy consumption (Hong, 2009). The standard includes two main sections, one on the building envelope and one on HVAC systems. These sections specify the minimum insulation requirements for building envelopes in different climate zones, recommend HVAC system types, and provide design guidelines rather than simply listing efficiency requirements. Only a prescriptive approach is offered for meeting lighting and HVAC requirements (the lighting requirement is in watts per m^2). For building envelope requirements, a performance-based trade-off approach can be used if prescriptive requirements are not met.

4.3.3. Lighting Design Standards

China's national standard for lighting design in residential, commercial, and industrial buildings was issued in 2004. This standard uses lighting power density as the key indicator for lighting energy efficiency, with compulsory maximum and future target values for commercial and industrial buildings and voluntary values for residential buildings (Shui, Evans, Lin, Jiang, Liu, & Somasundaram, 2009).

4.3.4. Implementation, Enforcement and Compliance at the National Level

4.3.4.1. Implementation for New Construction

As mentioned previously, national implementation of China's energy-efficient building design codes is managed by MOHURD and its provincial and local counterparts. Energy-efficiency codes for new buildings are supervised and enforced through regular inspections of new construction during the project approval process and random inspections of completed projects. Regular inspections for new construction follow a "loop system" that includes four separate phases of administrative review and licensing (Levine, et al., 2010). Figure 4-5 illustrates this process.

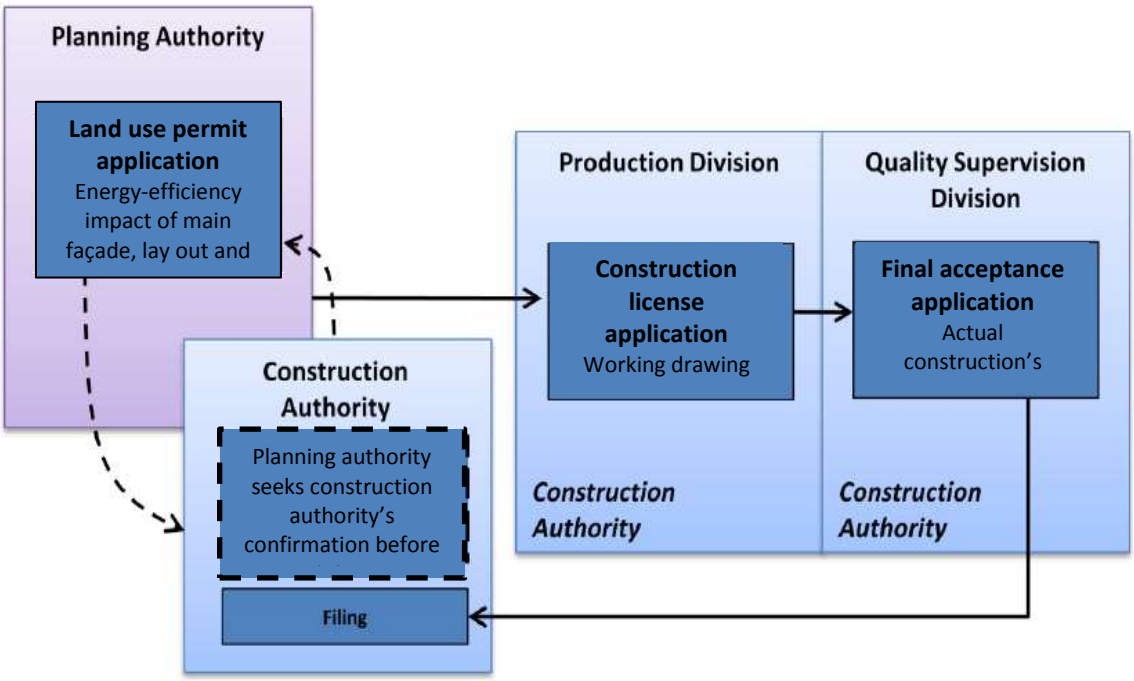


Figure 4-5. Illustration of Loop Inspection System for Compliance with Energy-Efficiency Standards

Source: Levine et al. 2010

In the first phase of review, new construction projects have to apply for land use permits from the local planning authority. Once a land use permit has been approved, the developer has to open a bidding process to form the design and construction team for the project. Certified and registered third parties, including building design companies, construction companies, and construction inspection companies, can participate in the bidding process, which is administered by the local construction department for new construction projects (Shui, 2012). During this phase, the Planning Bureau works together with the Construction Commission to inspect whether the main facade, layout, and shape of the design meet energy-efficiency requirements.

During the second phase of review, the local construction department gives permission for the building project to proceed, based on the initial review of the proposed building design. During the third phase,

the local construction department evaluates and approves the project's blueprints and engineering plans. Once the construction blueprints have been evaluated to ensure compliance with mandatory energy standards, the local construction department will issue the construction permit. If the proposed construction plans or blueprints fail to receive approval, permits are not issued, and construction cannot begin.

Once the construction permit is issued and construction on the new building begins, the building design and construction enterprises and respective supervisory units are responsible for obtaining energy labeling certification, verification of construction completion, and insulation quality assurance. On-site inspections are carried out by construction supervision companies, testing labs, and quality control and testing stations throughout the construction process to assure compliance with energy-efficiency standards. Once construction has been completed, the developer obtains an occupancy permit by submitting to the local construction department a completion report that is based on inspections and testing results of the third parties (Evans M. , Shui, Halverson, & Delgado, 2010). The Code of Acceptance issued by MOHURD in 2007 has helped strengthen this final phase of project approval by providing specific details and a checklist of items that must be inspected as part of the completion report. Making energy-efficiency standards and codes a mandatory element of a project's final acceptance signals that these standards are as important as safety-related building codes (Shui & Li, 2012).

Finished projects that fail to comply with the standards are not accepted by the Construction Commission and are considered illegal construction that cannot be sold or occupied. In addition to withholding the occupancy permit, the government also introduced in 2007 other penalties for noncompliance that include revocation of licenses, imposition of fines, and requirements to correct noncompliant buildings or building components (Evans M. , Shui, Halverson, & Delgado, 2010).

4.3.4.2. Code Compliance Enforcement and Monitoring in China

Since 2008, MOHURD has monitored overall compliance with building energy-efficiency codes by conducting random annual inspections. The most recent annual inspection of 2010 construction projects was completed in April 2011. The annual inspection work is conducted by teams of 10-20 experts organized by MOHURD. Each evaluation team is responsible for inspections in three provinces. A total of 22 provinces were included in the 2010 annual inspection (Levine, et al., 2010). The team evaluates the energy-efficiency work of the provincial Construction Commissions as well as selected construction projects in a city at each of the three different levels of government within a province: the province capital city, one randomly selected prefecture-level city, and one randomly selected county-level city. The inspection process entails evaluation of design and construction drawings and other submitted documents compared to computer simulation results. The actual heat-loss transfer value (U-value) of the walls is also measured, and some adjustments are made based on weather data. Projects that fail the random on-site inspection are issued a document of recommended changes to meet compliance and must report back to MOHURD within 30 days of receiving the recommendations (Wu Y. , 2012). If

after 30 days the building still fails to meet the building codes, the developers will be penalized: high fines are imposed, and the developer's certification is reduced or cancelled.

The nature of ongoing monitoring depends on the type of building. Government and large-scale office buildings are monitored annually for the amount of each type of fuel that is consumed. For residential buildings in certain residential districts, each household on a selected street undergoes a spot inspection each year. The costs of the inspection are covered by the central and local government through designated energy-saving funds. (Wu Y. , 2009). The majority of the inspection work is carried out by the local government; the expert team at the central government level mostly reviews paper documents. At the local level, two to three institutes in each city are accredited to conduct inspections, except in Beijing and Shanghai, each of which has about 10 institutes. On average, 20 to 30 people work in each institute, so the total number of inspectors in each of these city institutes is approximately 40 to 90 (Hao, 2009). The institutes are generally responsible for many other tasks in addition to inspection.

Based on MOHURD's annual inspection surveys of projects in provincial capitals, prefecture-level cities and county-level cities, a national average rate of compliance is reported annually for building code compliance during the design and construction phases.[39] During the past decade, MOHURD's officially reported compliance rates have improved significantly, rising from 5% design compliance and 2% construction compliance in 2001 to 54% design compliance and 20% construction compliance in 2004 (Qiu, 2009; Wu Y. , 2009). In 2010, MOHURD reported 99.5% code compliance in the design phase and 95.4% compliance in the construction phase (MOHURD, 2011). For 2010, the reported compliance rates were based on the inspections of 385 completed construction projects and 391 projects under construction; however, the specific calculation methodologies used and the reliability and representativeness of the samples are not known.

Although there are uncertainties about the accuracy and representativeness of MOHURD's officially reported compliance rates, there is evidence to support that building code compliance rates have improved over time and may be quite high in some cities. Independent city-level inspections have also reported high compliance rates on par with the rates reported by MOHURD. For example, of the 18 million m^2 of new construction in the city of Hefei in 2010, city-level inspections showed a design standard compliance rate of 99.5% and a construction standard compliance rate of 97.5% (Wu X. , 2011). Similarly, local media in the city of Wuxi reported a 100% design compliance rate and more than 98% construction compliance rate in 2011 (Jing, 2011). In general, the officially reported compliance rate is considered to be accurate for prefecture-level cities, but the compliance rate remains uncertain for small county-level cities. In the 12th Five-year Plan, MOHURD has acknowledged the need to strengthen building code compliance in medium and smaller cities below the county-level.

At the same time, there are questions regarding the inspection results and the sampling on which the reported compliance rates are based. First, actual energy consumption and code compliance are difficult to ascertain because the enforcement inspections in both the permitting process and MOHURD's annual

[39] Compliance rates are not often reported or considered for rural areas because codes generally do not apply in those areas.

inspection process focus largely on examination of building designs, with code compliance based on simulation results rather than on measurements conducted after construction has been completed. Second, MOHURD allows multiple software programs, including PKPM-EC, TianZheng and Si Wei Er, to be used for simulations to check building designs for compliance; because simulation results can differ among different software, developers can choose to use the program that produces the most favorable simulation results to ensure compliance during the licensing process. In addition, the lack of protocols for building simulation for code compliance, lack of protocols for testing the software, and the potential for user errors can all lead to inconsistent simulation results (Evans M. , Shui, Halverson, & Delgado, 2010). Finally, some of the allowed tradeoffs in the building codes can compromise a building's actual performance so that the building is only compliant on paper. Thus, while MOHURD's reported compliance rates have demonstrated a real trend of improving code compliance in China, the actual compliance rates are difficult to ascertain given existing limitations in the overall code implementation and enforcement framework.

4.3.5. Challenges and Barriers

Although building energy codes have a relatively long history in China, and compliance has improved thanks to greater government attention and more tools in recent years, some challenges and barriers to implementation remain for China's building energy-efficiency codes.

Weaknesses associated with the technical aspects of existing residential and commercial building energy-efficiency design codes include (Hong, 2009):

- Current building design standards are linked to other national standards, such as the lighting standard, which makes maintenance and revision of the building design codes more difficult.
- Exterior lighting and service water heating are not included in the building code.
- A pre-specified energy intensity reduction target is used in the standards rather than a life-cycle cost analysis to determine minimum envelope and HVAC efficiency requirements. If the life-cycle costs of building code requirements are not considered, the code may not encompass the most cost-effective design criteria for envelope and HVAC systems.

The following barriers and challenges to code implementation and enforcement have been identified:

- Lack of knowledge and training among building designers, design inspectors, construction managers and inspectors, and testing engineers regarding the availability of energy-saving building materials, energy-efficient building technologies, and energy-saving calculation software (Shui, Lin, Song, Halverson, Evans, & Zhu, 2011);
- Lack of training and knowledge about applying the Code of Acceptance to monitor compliance (Shui, Lin, Song, Halverson, Evans, & Zhu, 2011);
- Lack of institutional capacity and infrastructure for enforcement and compliance monitoring in small- and medium-sized cities including, for example, that quality supervision stations lack local construction departments to oversee code implementation (Shui, Evans, Lin, Jiang, Liu, & Somasundaram, 2009); and

- Inadequate consistency or standardization in code compliance software and lack of protocols for using building simulation software, which results in user errors (Evans M. , Shui, Halverson, & Delgado, 2010).

Leadership and supportive policies from both national and local governments can help overcome these barriers. MOHURD's acknowledgment of the need to strengthen code compliance in smaller cities during the 12th Five-year Plan period suggests that code compliance and enforcement will continue to be an area of policy focus in the near future.

4.4. Building Energy Labeling

Although energy labeling (e.g., appliance energy information labels) has been an important policy tool in China's energy-efficiency efforts, whole-building energy labeling is relatively new. China has two domestic building energy labeling programs, the Green Building Evaluation and Labeling (GBEL) Program and the Building Energy Efficiency Evaluation and Labeling (BEEL) program, both of which were established by MOHURD in 2008. Chinese project developers can also apply for the international market-based Leadership in Energy and Environmental Design (LEED) green building program. The voluntary GBEL program consists of a green building design label (GBDL) and the green building label (GBL) for building operations. The GBDL rates buildings on a scale of one to three stars in terms of energy efficiency, land use, water efficiency, construction material resource efficiency, indoor environmental quality, and operational management. Chinese projects have also used the LEED green building rating system, which certifies and rates projects as silver, gold, or platinum based on evaluation criteria that are similar to the categories in the Three-Star GBL.

Additionally, the BEEL evaluates buildings on a scale of one to five stars in terms of energy efficiency, with a focus on HVAC system efficiency, compliance with mandatory standards, and optional building efficiency features. The BEEL also includes two evaluation scores: a theoretical evaluation based on energy simulations of the building design and a measured evaluation based on operational energy consumption.

The GBEL and BEEL programs are also linked in that the BEEL is mandatory for buildings that apply for the GBEL Program (Mo, Burt, Hao, Cheng, Burr, & Kemkar, 2010). Although there are similarities and linkages in the goals and designs of both labeling programs, their scope, specific rating criteria, and methodology differ. The subsections below describe specific elements of each labeling program and the programs' progress and achievements to date, as well as remaining barriers and challenges.

4.4.1. Green Building Program

China's voluntary GBEL program was established in late 2007 following MOHURD's development of the Green Building Evaluation Standards (GB/T 50378-2006) and subsequent management methods and technical guidelines (MOHURD, 2006; 2008a; 2008b). 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 management (Richerzhagen, et al., 2008; Qiu, 2008). The GBEL program is voluntary, and developers are motivated to participate primarily to receive market recognition or as part of a demonstration project.

4.4.1.1. Criteria

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, 2008a; 2008b). Figure 4-6 shows the key components of a GBDL certificate.

Figure 4-6. China Green Building Design Label Certificate

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). 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 evaluation components including the preferred items. Table 4-1and Table 4-2 show the minimum requirements and rating evaluation systems for residential and commercial buildings, respectively.

Table 4-1. Criteria for Green Building Design Label Rating Evaluation for Residential Buildings

Rating Level	Mandatory Items Included	General Items						Preferred Items
		Land Use & Outdoor Environment	Energy Efficiency	Water Efficiency	Resource Efficiency	Indoor Environment	Operational Management	
		Total: 8	*Total: 6*	*Total: 6*	*Total: 7*	*Total: 6*	*Total: 7*	*Total: 9*
★	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, 2008b).

Table 4-2. Criteria for Green Building Design Label Rating Evaluation for Commercial Buildings

Rating Level	Mandatory Items Included	General Items						Preferred Items
		Land Use & Outdoor Environment	Energy Efficiency	Water Efficiency	Resource Efficiency	Indoor Environment	Operational Management	
		Total: 6	*Total:10*	*Total: 6*	*Total: 8*	*Total: 6*	*Total: 7*	*Total: 14*
★	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, 2008b).

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.

4.4.1.2. Program Management

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 Center for Science and Technology of Construction and the Chinese Society for Urban Studies (Figure

4-7). 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 H. , 2011). Figure 4-7 illustrates the Green Labeling Program management structure.

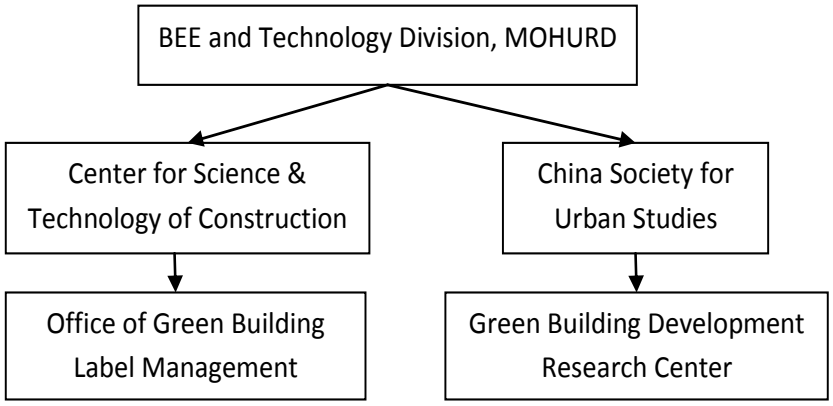


Figure 4-7. Institutional Organization of Green Building Evaluation and Labeling Program Management

Figure 4-8 shows the key steps in the green building labeling application review process. The review process begins with the acceptance of an application and an initial review by the accepting authority to determine whether the application materials and supporting documentation are adequate and complete. After this initial review, the materials are 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 green building label management office will organize a meeting where experts selected from a database of more than 400 individuals review and evaluate the application to determine the star rating (Li H. , 2011). The rating is then reported to MOHURD, and the building is officially certified after a public review process.

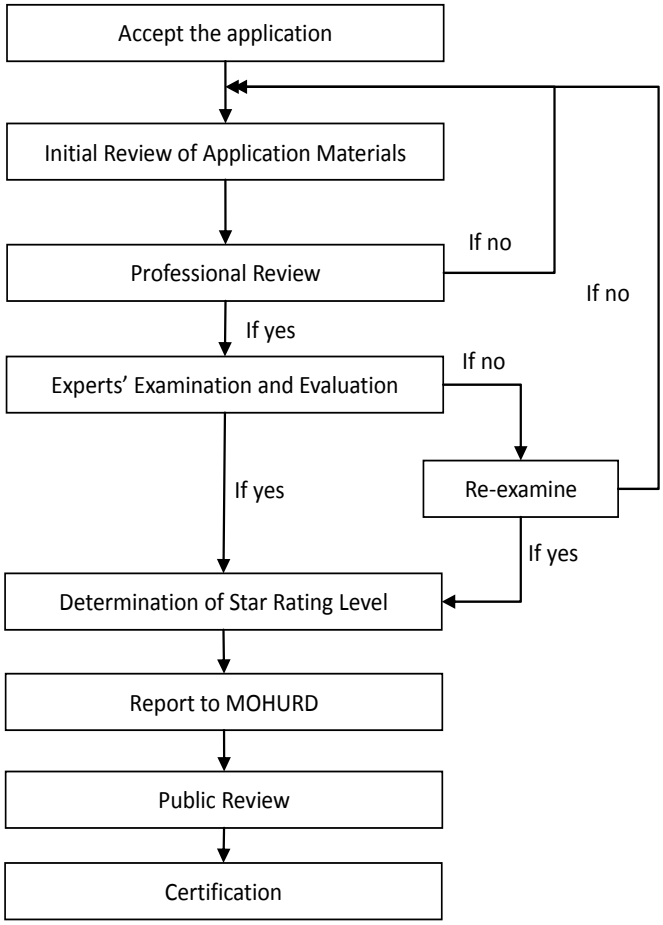


Figure 4-8. Green Building Evaluation and Label Review Process

Source: Personal communication (Li H. , 2011).

4.4.1.3. Current Status

As of August 2011, 217 projects (122 commercial and 95 residential) had been rated and certified as earning one to three stars under the GBEL program. The number of buildings certified and rated annually by the GBEL program has been growing rapidly over time, from only 10 in 2008 to 20 in 2009, 83 in 2010, and 104 by August of 2011. The majority of the projects were awarded the GBDL, and 14 were awarded the operational GBL. Figure 4-9, Figure 4-10, and Figure 4-11 show specific data on trends in building types earning labels, label type, and star rating distribution of labeled buildings.

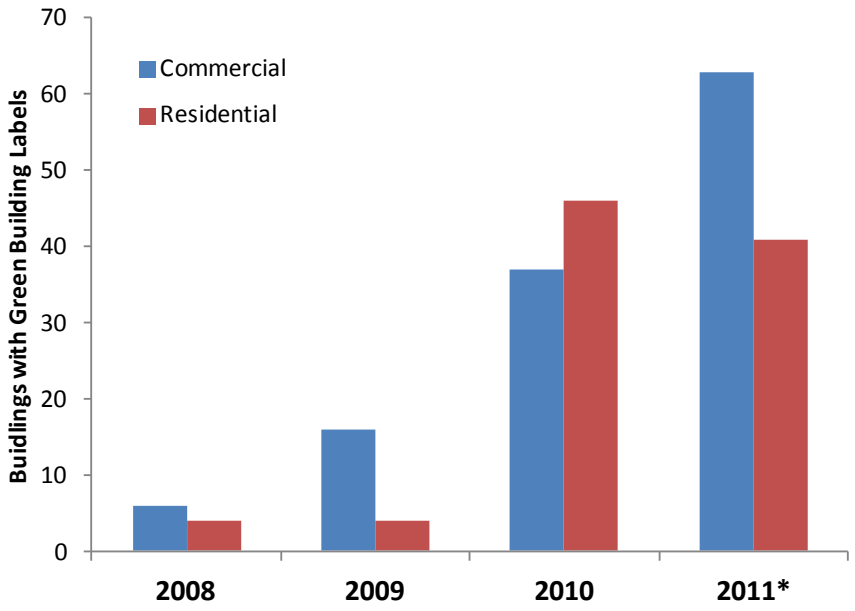


Figure 4-9. Green Building Labels by Building Type

Source: (Cheng, 2011).

**Note: 2011 is as of August 2011*

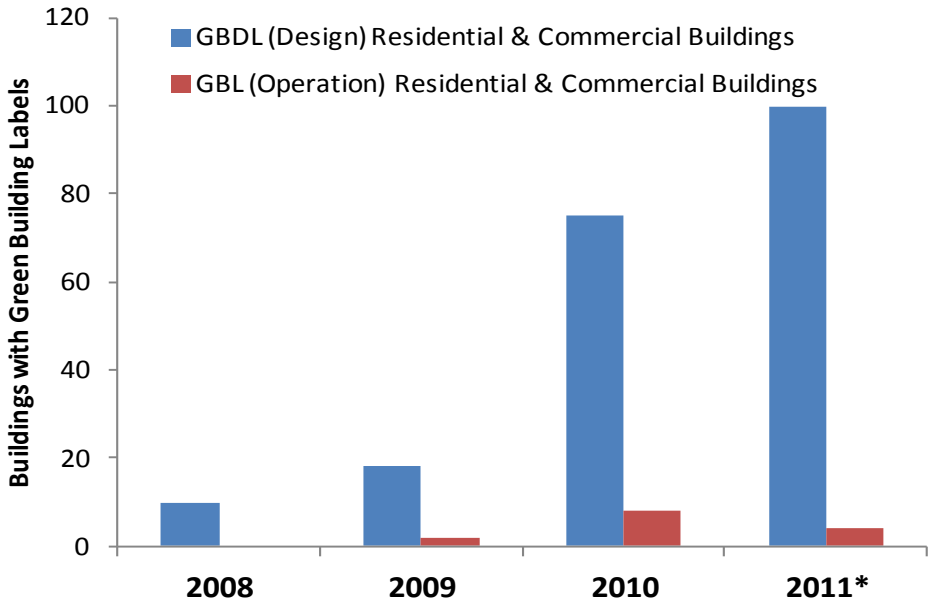


Figure 4-10. Green Building Labels by Label Type

Source: (Cheng, 2011)

**Note: 2011 is as of August 2011*

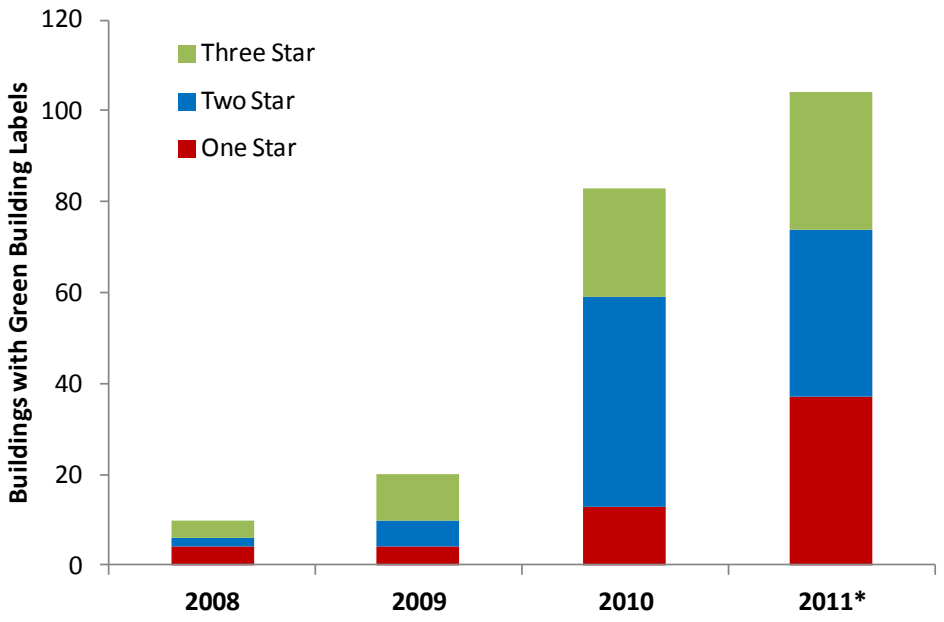


Figure 4-11. Green Building Labels by Star Rating

Source: (Cheng, 2011)
**Note: 2011 is as of August 2011*

In terms of the geographic distribution of buildings certified under the GBEL program, Jiangsu province has the largest share with 54 labeled buildings (25%), followed by Shanghai with 39 (18%), Guangdong with 35 (16%), and Zhejiang with 16 (7%) (Cheng, 2011). Other leading regions include Tianjin, Beijing, Shandong, Hubei, and Hebei, which together account for 20% of labeled buildings in the nation. The concentration of GBEL buildings in certain regions may result in part from Green Building Labels being mandatory in some eco-districts and cities like Suzhou in Jiangsu province. In addition, local governments, including Jiangsu and Hebei provinces and cities like Shenzhen and Beijing, provide incentives and other complementary policies that support the Green Building Label. By the end of 2010, more than 13 million m^2 of buildings had received the green building certification, equal to about 0.5% of new floor space, with a total of 40 million $m^2$of green demonstration buildings, equal to about 1% of total new floor space (MOHURD, 2011).

4.4.1.4. Challenges and Barriers

Despite the rapid growth in the number of building projects certified under the GBEL program, Green Building labels still face a number of barriers and challenges to their success, including:

- No compulsory or incentive policies supporting the label at the national level. Some provinces or cities have supporting policies, but a lack of uniformity in policies limits the reach and market impact of the GBEL program.

- Despite rapid growth in the number of participating buildings, the market share of GBEL buildings is still very small. In 2010, the estimated share of GBEL buildings was about 0.5% of total new construction floor area (MOHURD, 2011).
- The absence of national policies and uniform local policy support as well as the very small market share of GBEL buildings have contributed to relatively low levels of awareness of the concept as well as the benefits of green buildings among developers. Developers also do not face market pressure to participate in the GBEL program (i.e., there is no consumer demand for GBEL).
- GBEL faces competition from international green building labeling programs such as LEED, which have also experienced robust growth in China since 2008 (Li H. , 2011).

Some of these challenges may be addressed in the Green Building Action Plan, which is being developed jointly by MOHURD and National Development Reform Commission (NDRC) and is currently under review. For example, there have been unconfirmed reports that the Green Building Action Plan may include a 75 Yuan (USD $11) subsidy per m^2 for developers able to build a Three-Star rated green building. This subsidy would cover about 30% of the incremental design and construction cost of a building (Connely, 2012). Initial media reports suggest that a total of 1.1 billion m^2 of green buildings and energy retrofits for more than 570 million m^2 from 2011 to 2015 will be included as part of the plan. The Green Building Evaluation Standard is expected to become mandatory by 2017 (Shanghai Securities Daily, 2011). If 1.1 billion m^2 of green buildings are constructed by 2015, green buildings could make up 7% of total projected new construction between 2011 and 2015.[40]

4.4.1.5. Comparison between China's Green Building and Leadership in Energy and Environmental Design (LEED) Ratings

The international LEED Green Building Rating System has increasingly penetrated the building sector in China since Agenda21's Beijing office building became the country's first LEED-certified building in 2005. Building projects in China can apply to the U.S. Green Building Council (USGBC) and be evaluated according to the same criteria that apply to U.S. projects. Chinese building projects fall into one of several different categories in the LEED certification and rating program. A project may be LEED registered if it has been registered with the LEED program and paid the registration fee. A project in the "Core and Shell" category of LEED certification can be considered pre-certified if preliminary design documentation has been submitted to and reviewed by the Green Building Compliance Institute and the institute expects the project to be successfully certified once construction is complete. A project that has successfully completed the LEED certification process will become LEED certified or rated at one of the three LEED levels depending on its LEED evaluation score. A building is LEED certified if it receives a score of 40 to 49 points out of 100. Projects rated silver, gold, and platinum must have scores of 50-59, 60-79, or above 79, respectively.

[40] Projected new commercial and residential construction from LBNL's 2050 China Energy End-Use Model.

LEED is one of the most popular green building certification programs adopted worldwide and has been the subject of growing interest in China, particularly from many of the multinational companies familiar with LEED certification in the United States and other countries. As of October 2011, there were more than 700 LEED-registered projects in China, including 172 LEED-certified projects and 78 pre-certified projects, representing total floor space of 5 million m^2 (USGBC, 2011). Of the certified projects in China, 14 have achieved the LEED platinum rating, 96 the LEED gold rating, and 46 the LEED silver rating (USGBC, 2011).

Because LEED is growing as a green building rating program in China, it is important to compare LEED to China's Three-Star Green Building Program. The key similarities between the two programs include: credit-based systems with some flexibility in which types of credits or measures building developers can choose to pursue; similar rating criteria focusing on land, energy, water, resource/material efficiency, and indoor environmental quality; and the issuance of both green building design and operational ratings (Zhang, 2011). For example, LEED's "energy and atmosphere" category includes measures and activities that help track and improve building energy performance, manage refrigerants to eliminate chlorofluorocarbons, and increase the use of renewable energy on or off site. Figure 4-12 compares the weighting of each evaluation criterion in the LEED and Three-Star programs in. Despite the similarities, China's Three-Star rating is considered to be more rigorous than LEED because the Three-Star program final rating is determined by the minimum rating in each category whereas a LEED rating is determined by the total points summed over all categories (Richerzhagen, von Frieling, Hansen, Minnaert, Netzer, & Rubild, 2008). Thus, a Three Star-rated building will have to meet the minimum requirements in all categories whereas a similarly rated LEED building can receive a rating by excelling in several areas but performing poorly in one or two.

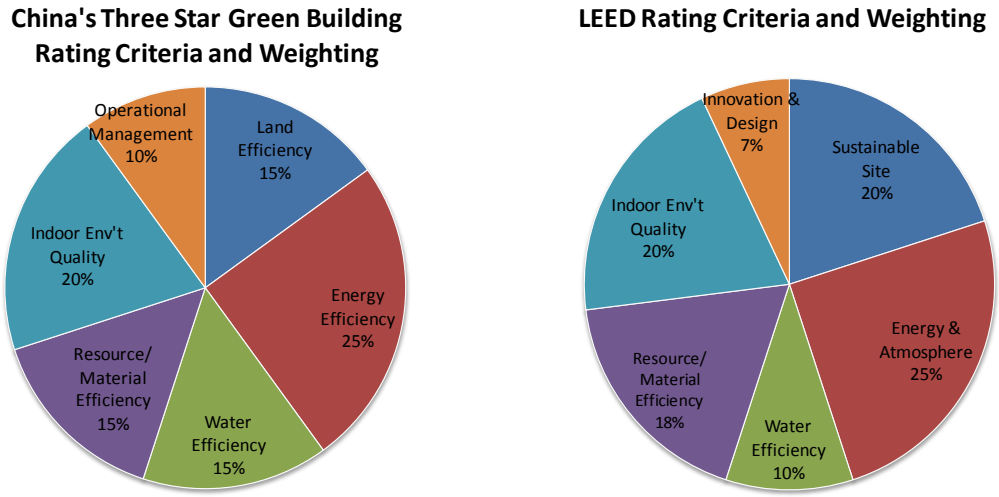


Figure 4-12. Comparison of China's Green Building and LEED Rating Criteria and Weighting Factors

Source: Data from (Zhang, 2011).

4.4.2. Building Energy-Efficiency Label

China's BEEL was established in 2008 after the State Council released the Civil Buildings[41] Energy-Efficiency Regulation, which required government-owned office buildings or commercial buildings of more than 20,000 m^2 to undertake energy performance rating and labeling (State Council of China, 2008) and to publicize the evaluation results (STDDC & CBEE of MOHURD, 2011). MOHURD issued *Interim Management Regulation of Civil Buildings Energy-Efficiency Performance Evaluation and Labeling* as the guiding policy document to manage and support the implementation of the BEEL program, followed by four specific supporting guidelines.[42]

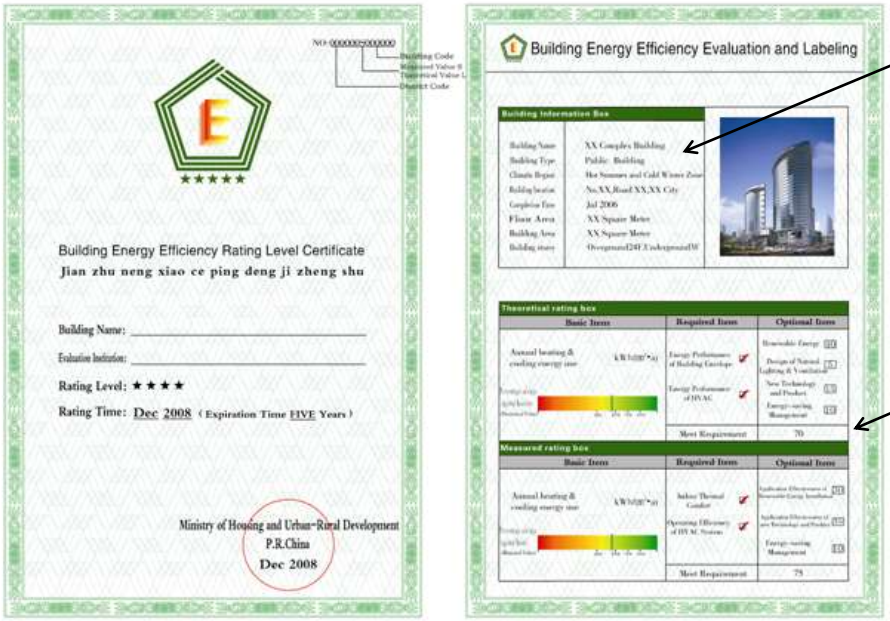
The BEEL program is managed by MOHURD and was piloted in 2008 in 11 cities and 7 provinces. The BEEL covers both residential and commercial buildings. Although the BEEL program is voluntary for residential and most nonresidential buildings, it is mandatory for four specific types of buildings (Mo, Burt, Hao, Cheng, Burr, & Kemkar, 2010):

1. New government-owned office or large commercial buildings larger than 20,000 m^2;
2. Existing government office buildings and large commercial buildings applying for government retrofit subsidies;
3. State or provincial energy-efficiency demonstration buildings; and
4. Buildings applying for the GBEL program.

Similar to the GBEL, the BEEL gives two ratings: a theoretical rating (commonly known as an "asset" rating) that is based on simulated results, and a measured rating (commonly known as an "operational" rating) based on continuously measured operational energy consumption after occupancy. Each rating is a score out of a maximum of 100 points, and both rating scores are shown on the label. Figure 4-13 shows a sample BEEL. The subsections below provide additional details on the specific components, methods, and criteria for the theoretical and measured evaluations and ratings under the BEEL program. In contrast to the GBEL, which evaluates a building's performance in terms of conservation of energy, land, water, and materials; quality of the indoor environment; and management of operations, the BEEL program focuses on energy conservation, with emphasis on HVAC systems, lighting systems, and building envelopes.

[41] In China, the residential and commercial buildings together are referred to as "civil buildings."

[42] The four specific guidelines issued to support the BEEL program include: *Interim Management Regulation for Institutions of Civil Buildings Energy-Efficiency Performance Evaluation*, *Technical Guideline for Civil Buildings Energy-Efficiency Performance Evaluation and Labeling*, *Management Regulation of the Quality of Civil Buildings Energy-Efficiency Performance Evaluation (Recommended)*, and *Certificates and Labels of Civil Buildings Energy-Efficiency Performance Evaluation and Labeling* (STDDC & CBEE of MOHURD, 2011).



Building information, including: name, type, climate zone, location, completion date, floor area, building area, building energy consumption.

Theoretical Rating Box (top) and Measured Rating Box (bottom):
Basic item: annual heating & cooling energy use (kWh/m2/yr) and scale.
Required items: energy performance of building envelope and cooling performance of HVAC.
Optional Items: scores by category and total score.

Figure 4-13. MOHURD Building Energy-Efficiency Label

4.4.2.1. Evaluation Criteria

The theoretical BEEL rating process follows successful inspection of a completed building and is based on simulation assessments, field inspection of design compliance, and performance test results. Based on these evaluations, a theoretical rating score out of 100 and a star rating are determined for the building. Similar to the GBEL, the rating is valid for one year. After the theoretical rating has been completed and the building has been occupied for a period of time, the building owner can apply for a BEEL measured rating by commissioning a building rating agency to conduct continuous energy measurements and audits for at least one year. Specific evaluation methods include a statistical analysis of the building's annual energy consumption data, field performance tests, and on-site inspection and evaluation reports. The building's previous theoretical evaluation score can be revised based on the measured rating evaluation, but the building's star rating will not change unless the required items fail (Mo, Burt, Hao, Cheng, Burr, & Kemkar, 2010). The measured rating score is valid for five years.

According to the *Technical Standard of Building Energy-Efficiency Labeling*, measurement and evaluation commonly target single buildings. To evaluate building blocks, a minimum sample of 10% of the buildings is selected, and the ratings are based on the lowest performances among the sampled buildings (CABR, 2011).

For the two types of BEEL ratings, three key components are considered. Table 4-3 and Table 4-4 show the requirements for each component and the contributions of each to the final score and star rating.

Table 4-3. Scoring System for Optional Items in Building Energy-Efficiency Label Evaluation

Optional Items		Residential Building	Public Building
Percentage of the renewable energy source out of the energy consumption of the HVAC system and the domestic hot water supply of a building (%)	<20	5 scores	5 scores
	20-50	15 scores	15 scores
	50-70	35 scores	35 scores
	>70	55 scores	55 scores
Natural ventilation and natural lighting		20 scores	5 scores
Energy recovery system (equipment)		15 scores	5 scores
Other new energy-saving methods		10 scores	15 scores
Thermal and cooling storage system		/	5 scores
Waste heat utilization		/	10 scores
Regulation of the all fresh air ratio or variable fresh air ratio of the air conditioning system		/	5 scores
Regulation of the variable water volume or variable air volume of the air conditioning system		/	5 scores
Building automation system		/	5 scores
Management system for energy consumption		/	5 scores

Source: (Cao, 2011).

Table 4-4. Evaluation Index for Building Energy-Efficiency Label

Basic items	Stipulated items	Grade	Optional items
Meet the energy-conservation design standard and The energy-saving rate is <65%	All meet the relevant requirements	★	Another star shall be added if the score is above 60(with 100 as the highest score)
65%≤energy-saving rate< 75%	All meet thethe relevant requirements	★★	
75%≤ energy-saving rate<85%	All meet the the relevant requirements	★★★	
energy-saving rate≥85%	All meet thethe relevant requirements	★★★★	
energy-saving rate≥85%	All meet thethe relevant requirements	★★★★★	The score exceeds 60

Source: (Cao, 2011).

Note: "Energy-saving" refers to savings in the energy consumed by heating, air conditioning, and lighting as specified by design standards for a given building type and climate zone. A one-star building must meet the building code but may be more efficient in some regions of the country if its energy-savings rate is greater than 50% (but less than 65%) because the energy-savings rate is only 50% in national standards for most climate zones.

Similar to the GBEL, the three BEEL evaluation indices cover (Cao, 2011):

- Basic Items: energy consumption by heating, air conditioning, and lighting systems per m^2 in accordance with national building energy standards. Each star rating corresponds to a minimum level of energy savings relative to a baseline value. Depending on the climate zone, the baseline can be either a fixed reference value (e.g., 33.7 w/m^2 of heat loss for Harbin) or relative to simulated results of a reference building (Mo, Burt, Hao, Cheng, Burr, & Kemkar, 2010). The measured values of the basic items must be provided on the label (CABR, 2011).
- Required or Stipulated Items: minimum performance requirements for building envelope and HVAC. Specific examples include the air tightness of external windows, EER of air conditioning chillers or heated water systems, regulation of room temperatures, devices for heat metering, monitoring and control systems, and lighting power density for commercial buildings. The required items are based on building design standards and all must meet the required standards for the building to obtain a star rating.
- Optional Items: energy-consuming systems or process technologies such as renewable energy applications, energy-efficient technologies, or energy management systems that exceed current national standards. Specific examples include the share of renewable energy that is used to meet HVAC and water heating demand as well as use of natural ventilation and lighting, energy recovery systems, waste heat, building automation, and energy management systems.
- Table 4-3 illustrates the scoring system used to evaluate the optional items. A score of more than 60 for optional items can increase a building's rating by 1 star (Table 4-4). In the scoring system shown in
- Table 4-3 and Table 4-4, it is interesting to note that a building's star rating can only be upgraded one level with optional items score of 60 if renewable energy is integrated because renewable energy technologies account for more than half of the 100 possible points. Since the sum of scores for all other optional measures does not exceed 60, buildings would not be able to earn the 60 points needed to upgrade its star rating if it does not integrate some form of renewable energy technology.

The first group of approved national-level building performance evaluating institutions are the national and provincial ABRs in each region: North China (China ABR), Northeast China (Liaoning ABR), Southwest China (Sichuan ABR), East China (Shanghai ABR), Central China (Henan ABR), South China (Shenzhen ABR), and Northwest China (Shaanxi ABR) (STDDC & CBEE of MOHURD, 2011). These national institutions are qualified to measure, evaluate, and rate the energy performance of residential and commercial buildings. At the provincial level, more than 30 evaluation institutions are qualified in a number of provinces and cities, such as Beijing, Shanghai, Tianjin, Jiangsu, and Guangdong (STDDC & CBEE of MOHURD, 2011).

Building performance can be evaluated by software simulation, documentation review, on-site inspection, and performance testing. MOHURD recommends three software simulation tools: TRNSYS (TRaNsient SYstem Simulation Program), PKPM, and DeST (Designer's Simulation Toolkit) (STDDC & CBEE of MOHURD, 2011).

4.4.2.2. Status Building Energy-Efficiency Label

The BEEL program is still in its pilot phase and has had only a trial evaluation, so data are limited regarding its application in China thus far. Pilot projects (62 residential and 54 commercial) are being conducted in 20 provinces and cities (STDDC & CBEE of MOHURD, 2011). Of the 116 total projects that applied for the BEEL, only 82 received the label. The projects that received labels were roughly evenly split between residential (44 labels) and commercial (38 labels). The majority of BEEL projects received 1 star (35 projects) or 2 stars (34 projects); only 13 projects received 3 stars (Liu S. , 2011). The results of the remaining projects are expected to be announced in the near future (STDDC & CBEE of MOHURD, 2011).

4.4.2.3. Challenges and Future Directions

The China BEEL program faces challenges that are typical for a new program. These include: insufficient capacity building, unclear program goals, high transaction costs, and low public awareness. Two major barriers that have limited participation in the program are scarcity of expertise in building simulation evaluation and subsequent high costs. The MOHURD-designated models for the theoretical rating process require are complex, so only a small number of highly experienced experts are able to use the software. This has led to high costs, in the range of tens of thousands of Yuan for building rating and labeling services. These costs hamper voluntary participation and result in most pilot projects being demonstration projects funded by national government incentives (Mo, Burt, Hao, Cheng, Burr, & Kemkar, 2010). The BEEL program also faces technical challenges, such as insufficient tests and evaluations for required and optional items on the label and different simulation models producing different results for the same buildings (Cao, 2011).

There is also ambiguity regarding how to integrate the measured BEEL rating into the overall BEEL star rating because the star rating is given on the basis of the theoretical rating only. If the measured rating, which is costly, does not affect the star rating, there is no incentive for developers and building owners to apply for the measured rating (Mo, Burt, Hao, Cheng, Burr, & Kemkar, 2010). Currently, the main motivation for building developers and owners to apply for the BEEL is to be recognized as building or owning energy-efficient buildings and/or to qualify for the GBEL program, but the high costs of obtaining the BEEL measured rating may undermine participation. The low awareness of the BEEL program and possible confusion with the Green Building Label because of similar label features are also obstacles to the BEEL program's success. Greater publicity and a clear identity for BEEL that is distinct from other building labeling programs are both needed to improve the presence and impact of China's BEEL program. Currently, BEEL program research and discussions are focusing on possibly expanding the scope of the BEEL program, i.e., to include more building types, such as existing buildings; using more economic incentives broaden interest in the program; and further promotion of the program at the provincial and city level (CABR, 2011).

4.5. Building Energy Incentives

4.5.1. Commercial Buildings

As part of the 11th Five-year Plan, the Ministry of Finance (MOF) and MOHURD issued the "Interim Administrative Method for Special Fund for Government Office Buildings and Large-Scale [Commercial] Buildings"[43] in 2007. This document was in support of the "Energy Conservation Management in Government Office Buildings and Large-scale [Commercial] Buildings" policy goal of decreasing total energy consumption by 20%. This was followed by an implementation notice,[44] which created a special fund that will subsidize energy-efficiency retrofits and renewable energy integration demonstration projects in government office buildings and large-scale commercial buildings (MOF, 2007b).

The central government has also begun providing financial incentives for building energy end-use data monitoring platforms for large commercial buildings. For example, universities can apply for subsidies in the amount of 5 million Yuan[45] (USD $740,000) to establish an energy end-use monitoring platform that results in a 15% reduction in measured energy consumption. One grantee, the South China Polytechnic University in Guangdong, achieved estimated financial savings of 8 million Yuan (USD $1.2 million) per year as a result of its energy end-use monitoring platform (Wu Y. , 2012). In addition to providing grants to individual universities, the central government has also started to provide subsidies of 15 million Yuan (USD $2.2 million) per city to establish energy end-use monitoring platforms (Wu Y. , 2012).

4.5.2. Residential Buildings

MOF and MOHURD launched financial incentives for retrofitting heating systems in residential buildings in Northern China as part of ongoing heating reform efforts. Established by the "Interim Administrative Method for Incentive Funds for Heating Metering and Energy-Efficiency Retrofit for Existing Residential Buildings" (MOF No. 957) (MOF, 2007c) in late 2007, the incentive policy set a goal of retrofitting 150 million m^2 of existing residential buildings in 15 provinces and municipalities from 2008 to 2010 (Zhong, Gai, Wu, & Ren, 2009). The retrofit area targets are divided by region, as shown in Table 4-5. To qualify for the retrofit incentive program, residential retrofit projects in the targeted regions must fall into one or more of three categories: building insulation, indoor heating system meter and temperature control device installation, and heat source and network pipeline retrofits, with 10%, 30% and 60% of funding distributed to each task, respectively (Levine, et al., 2010).

[43] Interim Administrative Method for Special Fund for Government Office Buildings and Large-Scale Public Buildings (MOF No. 558). For more details, see MOF, 2007a.

[44] Implementation Notice for Strengthening the Implementation of Energy Conservation Management of Office Buildings and Large-scale Public Buildings (MOF No. 245).For more details, see MOF, 2007b.

[45] USD equivalent is based on approximate conversion using 2010 average currency exchange rate of 6.7695 Yuan per USD.

Table 4-5. Northern China Residential Heating Retrofit Target Areas

Province/City	2008 - 2010 Retrofit Target Areas (million m^2)
Beijing	25.0
Tianjin	13.0
Hebei	13.0
Shanxi	4.6
Inner Mongolia	6.0
Liaoning	24.0
Jilin	11.0
Heilongjiang	15.0
Shandong	19.0
Henan	3.6
Shaanxi	2.0
Gansu	3.5
Qinghai	0.3
Ningxia	2.0
Xinjiang	8.0
Total	***150.0***

Source: (Zeng, Yin, & Liu, 2011)

MOHURD designed the northern residential retrofit incentive policy, which includes total incentives of 55 Yuan (USD $8.1) per m^2 for retrofits in the severe cold climate zone and 45 Yuan (USD $6.7) per m^2 for retrofits in the cold climate zone (REEEP, 2009). The incentive is intended to cover approximately 15% to 20% of total retrofit costs, which typically range from 150 to 350 Yuan (USD $22 to $52) per m^2 (Levine, et al., 2010). The incentive is distributed by MOF on behalf of the central government through special transfer incentive payments to provincial governments, which are responsible for allocating the funds on a project-by-project basis. The project funding allocation is determined by several factors including: project type and energy-savings potential, total retrofit area implemented in the region, and progress with retrofit projects conducted earlier in the 2008-2010 period (Li D. , 2009). Initially, 10% of the incentive is allocated to provincial governments, and the remaining 90% is settled at the end of the year after actual energy savings have been measured (Levine, et al., 2010).

By the end of 2008, a total of 1.54 billion Yuan (USD$ 227 million) had been allocated, with the incentive covering about 50 Yuan/m^2 (USD $7.4) out of average total retrofit costs of 200 to 250 Yuan/m^2 (USD $30 to $37) (Wu Y. , 2012). However, primary energy savings of only 270,000 tonnes of coal equivalent (tce) were realized with the retrofit of 39.5 million m^2 of building area in 2008 (Qiu, 2009). The savings per m^2 achieved from energy retrofits reflect only half of the target because many households only installed a heat meter rather than carrying out all of the retrofit projects including envelope and heat supply network retrofits, despite being given comprehensive retrofit incentives (Levine, et al., 2010).

More recently, with a total of 110 million m^2 completed by 2009 and 182 million m^2 completed in 2010, the central government met its retrofit target of 150 million m^2 (Zeng, Yin, & Liu, 2011; MOHURD, 2011). Reported energy-savings estimates resulting from this retrofit project total 2 Mtce with total carbon dioxide (CO_2) emissions reductions of 5.2 million tonnes (Mt) (MOHURD, 2012). Over the entire 11th Five-year Plan period, a total of 24.4 billion Yuan (USD $3.6 billion) was invested in the heating retrofits in Northern China with the central government providing 4.6 billion Yuan (USD $680 million) and local governments providing 9 billion Yuan (USD $1.3 billion) through subsidies (Zhang X. , 2011).

After recent improvements in integrating heat metering with pricing charges, MOHURD reported average heating cost savings of more than 10% (MOHURD, 2011). A recent survey of more than 1,500 stakeholders involved in the retrofit incentive program revealed that 61% believed the incentive policy played an instrumental role in retrofits in Northern China, with reported benefits of improved indoor temperature and thermal comfort, reduced indoor moisture and condensation, and elimination of cold wind infiltration and noise (Zeng, Yin, & Liu, 2011). In the 12th Five-year Plan period, 400 million m^2 of heating retrofits in Northern China are planned with 100 million and 130 million m^2 of heating retrofits planned for 2011 and 2012, respectively (Wu Y. , 2012). By 2020, the government plans to have retrofitted a total of 2 billion m^2, or 25% of the total building floor space in Northern China (Wu Y. , 2012). If China is able to meet the 2 billion m^2 retrofit target by 2020, and the retrofits save the same incremental amount energy as under the 11th Five-year Plan retrofit project, then total energy savings of 22 Mtce and CO_2 emission reductions of 57 Mt CO_2 are possible by 2020.[46]

There have also been several city-level examples of significant energy savings from retrofit projects and development of effective cost-sharing mechanisms for funding retrofits. In Tonghua city of Jilin province, for example, heating supply companies took the lead in heating retrofits by obtaining a bank loan. The investment payback was 10% per year with total savings of 48% (Wu Y. , 2012). In Lanzhou city of Gansu province, pursuing only supply-side heating retrofits reduced energy intensity on average from 31 tce/m^2 to 25 tce/m^2 with 20% of these savings attributed to metering, 70% to pipe work and heat balancing, and 10% to increased efficiency of heating supply equipment through optimized scheduling and distribution (Wu Y. , 2012). Inner Mongolia and Shanxi provinces each adopted an even split cost-sharing structure with the central, provincial, and city governments each paying 55 Yuan/m^2 (USD $8.1/$m^2$) for heating retrofits and the residents paying the remainder of the costs (Wu Y. , 2012). In another case, residents in Jilin province only have to pay 15% of the cost of putting up new windows. In most provinces, low-income families do not have to pay for heating retrofits.

4.5.3. Financial Incentives

In addition to the two financial incentive programs launched during the 11th Five-year Plan period for retrofitting residential and commercial buildings, other incentive programs supported high-efficiency

[46] Estimated based on average energy savings of 0.011 Mtce per million m^2 and 0.286 Mt CO_2 emission reduction per million m^2, calculated from reported energy savings of 2 Mtce and emissions reduction of 5.2 Mt CO_2 for the 182 million m^2 retrofitted during the 11th Five-year Plan.

and renewable energy technology applications for buildings. The NDRC released the regulation "Administrative Methods on the Financial Subsidy Fund for Promoting High-Efficiency Lighting Products" in late 2007. The subsidy fund was intended to support efforts to substitute and replace 50 million incandescent lamps with high-efficiency lighting in 2008 and 2009 (Zhou, McNeil, & Levine, 2010). The subsidy covered 30% of the cost of qualifying high-efficiency lighting products for bulk users such as industrial enterprises, hospitals, schools, hotels, and airports, and 50% of the cost for individual users including urban and rural residents (REEEP, 2009). Qualifying products include self-ballast fluorescent lamps, T8 and T5 fluorescent lamps, metal halide lamps, high-pressure sodium lamps, and light-emitting diode (LED) lighting products. The program was implemented through local energy conservation service centers, and lighting product suppliers were selected by a bid process. Under the subsidy program, 62 million lamps were distributed in 2008, and 120 million lamps were distributed in 2009 (Han, 2009).

After the passage of China's Renewable Energy Law in 2005, MOF and MOHURD began promoting building-integrated renewable energy demonstration projects by issuing management regulations for overseeing these projects in 2006. This was followed by another notice in 2007 to specifically encourage the application of technologies such as solar PV and water heaters, ground-source heat pumps, and water-source heat pumps in buildings. In March of 2009, China launched the first solar subsidy program to support building-integrated solar PV systems (BIPV) and rooftop PV systems with passage of the "Interim Management Methods on Financial Subsidy for Application of Building-Integrated Solar Photovoltaics" (MOF, 2009). This subsidy provides 20 Yuan (USD $3) per watt for BIPV systems and 15 Yuan (USD $2.2) per watt for rooftop solar PV systems, which covers approximately half of the total up-front investment costs (MOF, 2009; Levine, et al., 2010). In 2009, 111 projects with a combined capacity of 91 megawatts (MW) received a total subsidy allocation of 1.2 billion Yuan (USD $180 million). Similarly, 1.195 billion Yuan (USD $176 million) were allocated in 2010 for nearly 100 new demonstration projects with a combined capacity of 90.2 MW (Yin, Liu, & Zeng, 2011).

4.5.4. China's 12th Five-year Plan

As with the 11th Five-year Plan period, new financial incentive programs are also under way for the 12th Five-year Plan period, with at least two incentive programs already announced by MOF and another one likely under development. On May 4, 2011, MOF and MOHURD issued the "Further Notice on [Commercial] Buildings' Energy Efficiency Efforts" (MOF, 2011a) to extend and expand the existing incentives for government and large-scale commercial buildings. This notice set the targets in the 12th Five-year Plan for reducing commercial building energy intensity per m^2, specifically a 10% reduction in energy use per m^2 for commercial buildings and a 15% reduction in energy use per m^2 for large commercial buildings (MOF, 2011a). In addition, 40 cities were chosen to receive a national retrofit subsidy of 20 Yuan (USD $3) per m^2 to meet more stringent 20% and 30% energy-intensity reduction targets for their government and large commercial buildings, respectively (MOF, 2011a). To qualify for the national retrofit subsidy, cities must commit to a total energy-efficiency retrofit area exceeding 4 million m^2 within two years and submit an implementation plan before June 20, 2011.

In addition, MOF and NDRC issued the "Notice of Fiscal Policy for Energy-Efficient and Emission-Reduction Demonstration Provinces and Cities" on June 22, 2011. Under this notice, financial incentives will be provided to eight cities and provinces to support six different initiatives, including green buildings and building energy efficiency as part of the 12th Five-year Plan energy and emissions reduction efforts (MOF, 2011b). The demonstration cities are Beijing, Shenzhen, and Chongqing, and the demonstration provinces are Jilin, Zhejiang, Jiangxi, Hunan, and Guizhou. MOHURD officials have also discussed the possibility of providing limited national subsidies to developers for using more efficient building materials and renewable technologies, such as insulation and rooftop solar water heaters. At the same time, some provincial governments including that of Hunan province have already started to subsidize factories that produce energy-efficient materials, such as triple-layer insulated glass and solar panel components (Bradsher, 2011).

Most recently, 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 45 Yuan (USD $7) per m2 are offered for qualifying Two-Star rated green buildings under the GBEL program and 80 Yuan (USD $13) per m2 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 50 million Yuan (USD $8 million). These new financial incentives are intended to help China meet its targets of constructing 1 billion m^2 of additional green buildings by 2015 and green building share of 30% of total new construction by 2020 (People's Daily, 2012).

4.6. Best Policy Practices

The subsections below summarize indicators of best practices in China's building codes, building energy labeling programs, and building incentives.

4.6.1. Building Energy Codes

National average reported building code compliance rates from MOHURD's annual inspection surveys have increased significantly from 5% design compliance and 2% construction compliance in 2001 to 54% design compliance and 20% construction compliance in 2004 to over 95% compliance for both construction and design in 2010. Although these reported rates cannot necessarily be taken at face value to represent compliance levels in every city because they are calculated based on a sample of projects, the trend of significantly rising compliance rates over time nevertheless highlights overall improvements in code compliance in China. The improved code compliance can be linked to strengthening the loop inspection system for code implementation, instituting a detailed Code of Acceptance checklist for inspections in the final project approval phase, and establishing stricter non-compliance penalties.

4.6.1.1. Best Practices

Regional building codes to account for climate and usage variations: China has adopted regional residential building energy codes that reflect different climate zones and heating/cooling energy usage patterns as well as a national commercial building energy code. In addition to these building codes, there are national technical codes on building retrofits and lighting design.

Significant improvement in code compliance: National average reported building code compliance rates from the Ministry of Housing and Urban-Rural Development (MOHURD) annual inspection surveys have increased significantly from 5% design compliance and 2% construction compliance in 2001 to 54% design compliance and 20% construction compliance in 2004, to over 90% compliance for both construction and design in 2010, based on government surveys in selected urban areas. Although these reported rates do not represent compliance levels in every city, the trend of significantly rising compliance rates over time nevertheless highlights very significant improvements in code compliance in China. The improved compliance can be linked to strengthening the loop inspection system for code implementation, instituting a detailed Code of Acceptance checklist for inspections in final approval phase for projects, and establishing strict non-compliance penalties.

4.6.1.2. Issues

Outdated baselines: An important question about China's building codes is whether the codes' baseline values, which are "typical" conditions of inefficient 1980s buildings, are accurate and appropriate to use as a baseline against which to measure energy reductions. These inefficient 1980s buildings were constructed before one could even purchase insulation in China. Using these conditions as a baseline

results in large overestimates of the energy-savings impact of efficiency standards. The claimed 35% energy savings (from the late 1990s and early years of this century) and more recent 50% savings (65% for several big cities) give the impression that very large savings have resulted from China's efficiency standards. This is misleading for two reasons: (1) today's energy use is compared to the energy use of buildings with very inefficient heating equipment and no insulation other than that provided by the material with which the building was built and (2) the energy savings are based solely on design. The second factor – the design standard – is commonly used throughout the world. However, for China the design standard is set using typical operating and comfort conditions in the United States. This dramatically overestimates energy savings.

Monitoring as a basis for updating baselines: The government is now funding a large number of building energy monitoring projects. The results of these projects can be used to establish an improved baseline for revised building codes and for more accurate calculations of energy saved as a result of standards. In addition, more consistent review and revision of building codes – some of which have not been updated for more than 10 years – are needed to improve code stringency and impacts.

Rural codes: A major issue in China is the design and implementation of codes in rural areas and improved implementation and enforcement in second- and third-tier cities. To achieve these objectives, the government needs to decide whether codes for urban buildings should apply to rural buildings considering their different architectural, design, building materials, lifetimes, and occupant behavior. For standards to be implemented and enforced in rural areas and second- and third-tier cities, there is a need to strengthen (or create) regulatory capacity relating to buildings.

4.6.2. Building Energy Labeling

4.6.2.1. Best Practices

Well-designed national green building labeling program: China's recently created national Green Building Evaluation and Labeling program embodies important successful elements of labeling programs. The label accounts for both design and actual operational energy consumption with the use of both theoretical and operational energy ratings. Rated green buildings must meet all criteria for labeling by meeting minimum scores for each category, in contrast to the LEED requirement of a combined score that enables good performance in one category to offset poor performance in another.

Dedicated government support driving growth of green building labeling program: Starting from the green building labeling program's inception in 2008 and continuing through 2011, the Chinese government exhorted builders to participate in the labeling program. During this phase of the program, hundreds of professionals in design institutes and in the private sector as well as an even higher number of construction professionals learned the techniques for meeting label levels of three stars or higher (up to five stars). The second phase of the program, initiated in 2012, provides government incentives for qualifying buildings (at the two-star level or above) to support the government's target of 1 billion m^2 of new green buildings by 2015.

4.6.2.2. Issues

Distinguishing among similar label programs: Building energy labeling programs are a new area of building energy policy in China, and a number of "bugs" need to be worked out. Differentiation of the two programs is needed to prevent consumer confusion that is already evident For example, users often do not know the advantages and disadvantage of the domestic (five-star) and the international (LEED) rating system for green buildings. These differences are important because the cost of qualifying a building for a rating is thousands of dollars. Along the same lines, the similar use of stars as a rating in both the green building labeling and building energy-efficiency labeling programs need to be identified and distinguished, and the costs of both have to be lowered to make the programs more relevant to building stakeholders. Understanding the relationship between existing local green building energy labeling programs and the national evaluation standard and program will be particularly important after the launch of the Green Building Action Plan, in which the scope of the green building labeling programs will be defined.

4.6.3. Financing and Incentive Programs

4.6.3.1. Best Practices

Key incentive programs driven by specific quantifiable targets: China's major building energy-efficiency incentive programs have all been created to support and meet very specific targets, such as the 150 million m^2 retrofit target and the 50 million incandescent lamp replacement target. These targets not only help drive the incentive programs, but also serve as indicators against which the success and impact of a specific incentive or subsidy policy can be measured. Both the heating retrofit and efficient lighting subsidies have exceeded their targets, resulting in significant overall energy savings and emission reductions as well as reports of improved living conditions. Newly introduced incentive programs for the 12th Five-year Plan include specific targets for heating retrofits, commercial building energy intensity reduction, and new green building construction.

Subsidies designed to increase uptake of efficiency measures by significantly reducing up-front costs: China's building efficiency incentives cover a meaningful portion of the up-front costs of efficiency measures, (e.g., 15 to 20% of total energy retrofit costs). These incentive amounts are made possible by large investments from the central government as well as some innovative local cost-sharing mechanisms.

4.6.3.2. Issues

Leveraging private investment: A key to successful government energy-efficiency incentives, particularly in developing countries where private investment in energy efficiency is limited, is their ability to leverage private investment. China has been successful in leveraging for energy-efficiency

investments in industry, but, until now, it has been difficult or impossible to leverage such investments for buildings.

Using energy management companies: In an effort to overcome this problem, China is just beginning to use energy service companies (ESCOs) – or as they are known in China, Energy Management Companies – as a means of providing incentives for building energy efficiency. ESCOs have proven effective in leveraging private capital for energy efficiency (in the United States, Japan, and Europe) as have electric and gas utilities (United States). It is too early to know whether the attempt to use energy management companies as the delivery vehicle for building energy efficiency will prove to be successful in eliciting private (generally customer) investment in China.

4.7. Conclusions

China's rapidly expanding building sector is an increasingly important energy consumer of energy and has in recent years become the focus of government efforts to improve building codes, introduce labeling programs, and increase energy-efficiency incentives.

In the area of building energy codes, China has continued to expand and update its regional residential building codes and commercial building code while establishing a "loop system" of implementing building codes for new construction. This loop system of implementation directly involves provincial and local authorities, whose participation and commitment are crucial to effective code implementation. The Chinese central government's growing emphasis on code enforcement and compliance has driven improvements in reported national average compliance rates during the past 10 years, but detailed compliance information and data are still limited. Challenges stem from the lack of specialized knowledge and training among building experts and implementation officials and weak institutional capacity and infrastructure for enforcement and compliance monitoring in smaller cities. Going forward, additional capacity building (institutional, technical, staff) is thus needed to further improve code implementation and enforcement, particularly in smaller cities and rural areas.

In addition to mandatory building codes, China has recently developed green building and building energy-efficiency labeling programs tailored to its national context. These labeling programs represent the central (and in some cases local) governments' recognition of the need for market-based as well as regulatory measures to promote building energy efficiency. China's MOHURD has taken the lead in establishing a domestic green building label and a building energy-efficiency label, both of which are voluntary but beginning to emerge in the building market. The green building labeling program in particular is and will likely continue growing rapidly in coverage, with concerted government efforts to establish demonstration projects and financial incentives. Both labeling programs evaluate theoretical and operational energy consumption, but limited availability of building experts and high transaction costs hinder greater adoption of these labels. In addition, both labeling programs are new and face typical challenges of a new program, including lack of public awareness as well as ambiguity and unclear distinction between the two programs and resulting consumer confusion between the two labels.

The central government has also provided leadership in establishing financial incentives to support heating reform in existing construction as well as adoption of energy-efficient technologies and building-integrated renewable energy technologies. Setting clear provincial targets and allocating funding by specific task and region have enabled China to track and measure the achievements of its residential retrofit incentive programs, and adopting cost-sharing structures between different levels of government has resulted in effective city-level heating retrofit incentive programs. Going forward, new incentive programs will likely need to begin tapping into new sources of funding by better leveraging private investment in energy efficiency. In terms of scope, China has expanded its building incentive programs beyond heating retrofits to promote efficient lighting, building-integrated renewable technologies, and energy-efficient materials. However, the scope could be further expanded to spur greater market-based energy-efficiency activity. Specifically, incentives can play an important role in

attracting the market entry of energy service companies and contract companies, which have had relatively limited role in promoting building energy efficiency in China.

Developments across China's building codes, labels, and incentive programs highlight that China's central and local governments have recognized the need to adopt both regulatory policies (i.e., building codes) and market-based and financial policies (i.e., building energy labels and incentives) to improve building energy efficiency. Adherence to strict program targets (e.g., retrofit targets) and development of innovative mechanisms (e.g., cost sharing) have produced effective building energy-efficiency programs in China.

At the same time, given the unprecedented rate of growth in new construction and the relatively new policy focus on building energy efficiency, China's building energy-efficiency codes and labeling and incentive programs still face major challenges. Insufficient institutional and technical capacity pose challenges for developing more stringent and up-to-date building codes, and uneven enforcement and monitoring undermine the implementation of the codes. Existing disparities between urban and rural building energy-efficiency levels and in the levels of policy support between central and local governments have also limited the effectiveness of all three types of building energy-efficiency policies in China. Moreover, the connections among the three types of building policies in China have been limited thus far; their effectiveness could be improved significantly with greater cross-cutting policy linkages and adoption of complementary policies (e.g., linking incentives with building energy labels). As China's building sector continues to expand in tandem with growing urbanization and rising income levels, these barriers and challenges will need to be addressed to maximize the overall level of efficiency in all Chinese buildings.

Chapter 5 - Review of Building Energy-Efficiency Policies: India

5.1. Introduction

India's building energy efficiency programs are the newest of those reviewed in this report. These programs are generally in their early stages and the strength and effectiveness of both current and future implementation are still uncertain.

India's first building energy code, applicable to new and large retrofits of commercial buildings across India,[47] aims to take the construction sector from a near-complete lack of building energy regulations to standards near the level of those of much more mature code jurisdictions like the United States and Europe. The code itself was originally promulgated just five years ago and has yet to become mandatory for the majority of India's commercial buildings. Considerable resources have been expended to ensure that stakeholders are familiar with the regulation and its upcoming implementation, but little evaluation of these efforts has been conducted.

Along with this effort, India has also made considerable, albeit incremental, advances in developing the infrastructure necessary to implement building energy codes. The central government has gradually increased the priority given to building energy efficiency improvements in central planning documents. The new commercial building energy code was expanded to cover more buildings in 2010, and initial pilot projects and government mandates have started to realize code compliance in a small number of government buildings. Building on these initial successes, the national government has recently called for the mandatory implementation of the code in eight states this year. Digitally-available training guides, high-quality online software applications, and live training sessions all are helping to increase local administrative and private capacity to understand and enforce or comply with the code. As the testing of these materials is just beginning, it is expected that considerable further efforts will be needed to develop and apply this infrastructure in India's diverse building sector.

The early development and embrace of locally-relevant building label systems is also encouraging, however market penetration of building labels is exceedingly low and therefore it is still too early to forecast potential future energy savings. LEED made an early inroad in India and the market demand for green buildings appears to be increasing, especially in fast-growing urban centers attractive to high-visibility projects and companies. In addition, due to perceived inapplicability of the LEED systems to the India context, the national government has strongly supported a domestically-developed green building rating system, the Green Rating for Integrated Habitat Assessment (GRIHA), and now offers some financial incentives for GRIHA certification. A government-operated energy-specific rating scheme has

[47] In India, "commercial buildings" include residential buildings over three stories.

also been developed but is rarer than green building labeling programs. India is now home to at least four completely different building rating schemes, and consumer confusion regarding label meaning and quality may become a barrier to further market penetration.

The largest obstacle for the increased penetration of building energy efficiency in India is the need to promulgate local level regulations before implementing codes and to train local enforcers. The national government has no direct power to enforce building codes at the local level, and the effort to develop local level implementing regulations is ongoing but has stalled in some places. Principle barriers appear to be a lack of market support for the development of these codes and lack of funding for and organization of local inspector training. Efforts in Gujarat and Andhra Pradesh states are working with local stakeholders to develop support for code development and these areas will likely develop best practices that can be used by other jurisdictions across India in the future. In the meantime, a large scale effort in India's universities to train future developers, architects, and code enforcers on the requirements of the code will work to work to prepare new professionals.

Apart from GRIHA-related building certification grants and isolated incentives for some building-integrated renewable energy technologies, government incentives and private bank financing schemes for building energy efficiency are quite rare. Without stronger government-supported incentives, it is questionable whether market demand will be sufficient to compel a large-scale embrace of better building energy efficiency.

India is still in the early stages of developing a building energy efficiency regime. The massive growth expected to occur in commercial building floor space between now and 2030 will require strong efforts to develop enforcement and compliance capacity and considerable government investments in incentives that link code compliance and beyond-code performance to social and monetary benefits. If successful in these regards, India is primed to become a leader in developing the strategies necessary to spread building energy efficiency technologies and skills to other fast-growing economies.

5.2. Energy Use in India's Buildings Sector

In 2008 India was the world's fourth-largest energy consumer, using 621 million tonnes of oil equivalent (Mtoe) total primary energy (IEA, 2010b). Coal accounts for 42% of India's total primary energy production, with oil and gas accounting for 23% and 6% respectively (IEA, 2010b). Coal combustion generates almost 70% of India's electricity (IEA, 2010b).

Estimates of India's energy demand growth vary. By one estimate, total national primary energy demand could grow 2.2 times over the next 15 years, in large part because of sustained economic growth (de la Rue du Can, McNeil, & Sathaye, 2009). Another estimate predicts that the country's primary energy demand will expand much more quickly: assuming 8% economic growth, Kumar (2010b) predicts that primary energy supply will grow by 3 or 4 times, and electricity generation capacity by 5 or 6 times (to ~800 gigawatts [GW], from the current 160 GW), compared to 2003–2004 levels. Under either scenario, India could soon become the world's third-largest energy consumer, after the United States and China (Sathaye, et al., 2009).

A few priority energy issues have driven the Indian government to develop energy-efficiency policies in recent years. India has long suffered from insufficient electricity generation capacity, resulting in an annual nationwide electricity shortage of 9.9% and a peak demand shortage of 16.6% in 2007–2008, with an electricity shortage of 10.3% and a peak demand shortage of 12.9% predicted for 2011–2012 (Kumar, Kapoor, Rawal, Seth, & Walia, 2010; India Central Electricity Authority, 2011). Energy equity is also an issue; only 60% of India's population has access to electricity or clean cooking fuels, and future urbanization and rural electrification are expected to result in increased electricity demand (Letschert & McNeil, 2007). Furthermore, domestic petroleum and coal supplies are limited, and India's generation fleet is dominated by fossil-fuel-powered plants, so fuel supply risks are growing (Mathur, 2010).

5.2.1. Energy Use in India's Buildings

Growth in building energy demand will to a large extent determine India's future energy demand. Energy intensity in new construction should be India's building energy policy priority because approximately 70% of India's commercial building stock in 2030 will be built between now and then (Kumar, Kapoor, Rawal, Seth, & Walia, 2010).

India's current commercial building stock is estimated at 660 million square meters (m^2). Residential floor space is estimated at approximately 8 billion m^2 (Kumar, Kapoor, Rawal, Seth, & Walia, 2010; McKinsey Global Institute, 2009). Buildings consume approximately 45% of national primary energy. However, much of this energy is in the form of biomass used in residential houses for cooking and water heating; excluding biomass, buildings consume only about 15% of primary energy. Of this non-biomass primary energy, about 75% is used in the residential sector and 25% in the commercial sector (de la Rue du Can, McNeil, & Sathaye, 2009).

Residential and commercial buildings together represent about 33% of total electricity consumption in India. Despite low electrification rates in rural residential units, the residential sector represents about 25% of India's final electricity consumption and commercial buildings account for about 8% of final electricity consumption (India Bureau of Energy Efficiency, 2009). Electricity use in commercial buildings has been growing at an average of 11%–12% annually in recent years, faster than the 5%–6% average growth rate of electricity use in the economy (Kumar, et al., 2010). Annual residential electricity use is expected to grow at 7% during the same time period, while residential total energy consumption is expected to grow by only 1-2% per year between now and 2030 (IEA, 2007).

Energy prices vary greatly among India's social sectors. Residential electricity use is highly subsidized whereas commercial energy subsidies are lower (Planning Commission, Government of India, 2007). In 2009, average domestic electricity prices were 80% of those paid by industry (OECD, 2011). Other residential fuels, such as kerosene and liquid petroleum gas, are also highly subsidized by the government (Bhattacharya & Cropper, 2010). Subsidized energy prices are maintained to avoid inflation and its political consequences (Ahluwalia, 2011).

5.3. Building Energy Codes

Building energy-efficiency policies and programs in India are in an active design stage with limited implementation to date. Decision making is centralized, but program design and implementation responsibilities are spread across a large number of state and municipal agencies, resulting in a diversity of implementation regimes. With the assistance of international and domestic professionals and academics, the Indian Bureau of Energy Efficiency (BEE) released a national commercial building energy-efficiency code, the Energy Conservation Building Code (ECBC) in 2007 and amended it in 2010 to cover a greaternumber of buildings. The code remains voluntary throughout most of India while local agencies work to develop the capacity to implement the code. Government-associated think tanks have been established to monitor and analyze building energy use, and government and academic institutions are co-developing training modules for building energy auditors and engineers.

5.3.1. National Building Code

India's National Building Code (NBC) was first implemented in 1970 and has been updated five times since by the Bureau of Indian Standards, most recently in 2005 (Bureau of India Standards, 2005). This code mandates structural, safety, and design measures. Energy efficiency is addressed but only with non-mandatory guidances (Evans, Shui, & Somasundaram, 2009a; Huang & Deringer, 2007).

5.3.2. Energy Conservation Code

The lack of mandatory energy standards in NBC 2005 was not consistent with contemporary national level calls for energy efficiency in buildings (IEA, 2008a). However, the Energy Conservation Act of 2001 (Law No. 52 of 2001) delegates responsibility for regulating energy use in buildings to the Ministry of Power (MOP) rather than the developer of general building codes, the Bureau of Indian Standards. The Energy Conservation Act also mandated the creation of BEE and BEE was installed in MOP in 2002 and given the authority to develop the ECBC.

The ECBC now applies to buildings with connected loads greater than 100 kilowatts (kW) or 120 kilovolt-amperes (kVA); originally it applied to buildings with connected loads of 500 kW or 600 kVA. The code only applies only to commercial buildings and large rented apartment buildings, as well as large-scale commercial building retrofits in which the final air-conditioned space of the building is greater than 1,000 m^2.

The Energy Conservation Act states that the ECBC is mandatory nationwide but requires that it be integrated into local regulations before it can be enforced. Although BEE had held back from requiring full implementation while it conducts trainings and builds public support, in March 2011, BEE notified some local areas that the code should become mandatory. Starting in fiscal year 2012, the ECBC will be mandatory for new commercial buildings and large commercial building retrofits in eight states: Delhi, Maharashtra, Uttar Pradesh, Haryana, Tamil Nadu, Andhra Pradesh, Karnataka, and West Bengal (PTI, 2011). Two other states, Orissa and Rajastan, announced plans to implement ECBC by 2012 (Khosla,

2012), and Gujarat is also working on implementation plans (see Section 5.3.4. below). A few of these states have reportedly developed draft codes, but implementation may be delayed while capacity is strengthened and stakeholders agree on best implementation strategies.

ECBC is modeled on ASHRAE 90.1-2004 and therefore resembles the ASHRAE standard in several technical specifications (Kumar, Kapoor, Rawal, Seth, & Walia, 2010). ECBC provisions apply to building envelopes (except non-air-conditioned storage space of warehouses); mechanical systems and equipment, including heating, ventilating, and air conditioning (HVAC) systems; hot water heating and pumping; interior and exterior lighting; and electrical power and motors.

The code evaluates buildings based on expected energy intensity (kWh/m^2/year) as determined by the building design and by design compliance in final construction. Compliance can be achieved by one of two methods: meeting prescriptive standards for material inputs to the building, or demonstrating with computer modeling that the building will use less energy than a standard design in the same climate zone. Under the prescriptive approach, construction inputs and designs have to meet minimum energy-related performance characteristics (U-values, R-values, etc.) although there are some options to trade-off performance of envelope features with better performance elsewhere. The performance-based compliance option applies to all building types covered by the ECBC and closely mimics Appendix G of the ASHRAE 90.1-2004 standard in setting an energy budget for the building type, size, and other features and requiring documentation that approved computer models predict that annual energy use is equal to or less than that of the standard design. Under either the prescriptive or performance approach, the building must first meet mandatory measures.

5.3.2.1. Climate Zones

ECBC code provisions differ by climate zone. India has five climate zones for the purposes of building energy codes: hot and dry, composite, warm and humid, moderate, and cold (Table 5-1). Figure 5-1 shows the location of these climate zones.

Table 5-1. Classification of India's climates

Climate	Mean Monthly Maximum Temperatures (°C)	Relative Humidity (%)
Hot and Dry	>30	<55
Warm and Humid	>30 >25	>55 >75
Temperate	25-30	<75
Cold	<25	All values
Composite	This designation applies when a zone does not fall into the above classifications for six months or more.	

Source: (Bureau of India Standards, 2005)

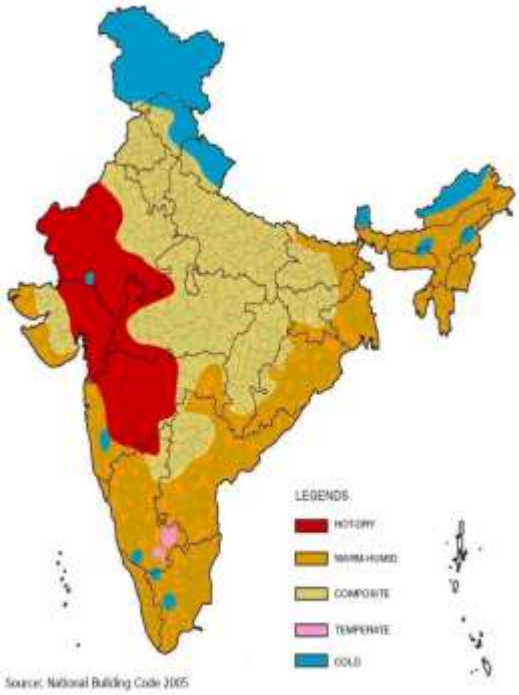


Figure 5-1. The Five Climate Zones Established for India's ECBC

Source: (Bureau of India Standards, 2005)

5.3.2.2. Energy Impacts

At the individual building level, mandatory enforcement of the ECBC is expected to reduce energy use by 27%–40%, to 110–160 kWh/m^2/year in a typical Class A office building depending on operation schedule, compared with a typical commercial building with an annual energy consumption of 200

kWh/m^2 (ECO-III, 2011; Mathur, 2010).[48] Trial implementation has demonstrated similar savings in practice, with some buildings saving as much as 50% compared to the baseline (High Performance Commercial Buildings in India, n.d.). First-year savings after mandatory nationwide implementation of ECBC are projected to be 1.975 billion kWh compared with a business-as-usual scenario (ECO-III, 2011). In 2010, an estimated 300 buildings were being constructed to ECBC standards in India (Chakarvarti, 2010). The payback period for initial project cost increased in several case studies by 10%–15% with energy savings-based payback expected between 5 and 7 years (Seth, 2009).

5.3.2.3. International Comparisons

The physical performance requirements of India's code are quite ambitious when compared to codes in developed countries. Compared to requirements for similarly hot climate types in China, the United States, and Australia, the Indian roof U-factor requirement rates second only to Australia's. Comparing window U-factor ratings in cold climates to those in China, the United States, and Japan, India's ratings are second only to Japan's (Evans, Shui, & Delgado, 2009b). Figure 5-2 and Figure 5-3 below display these code comparisons.

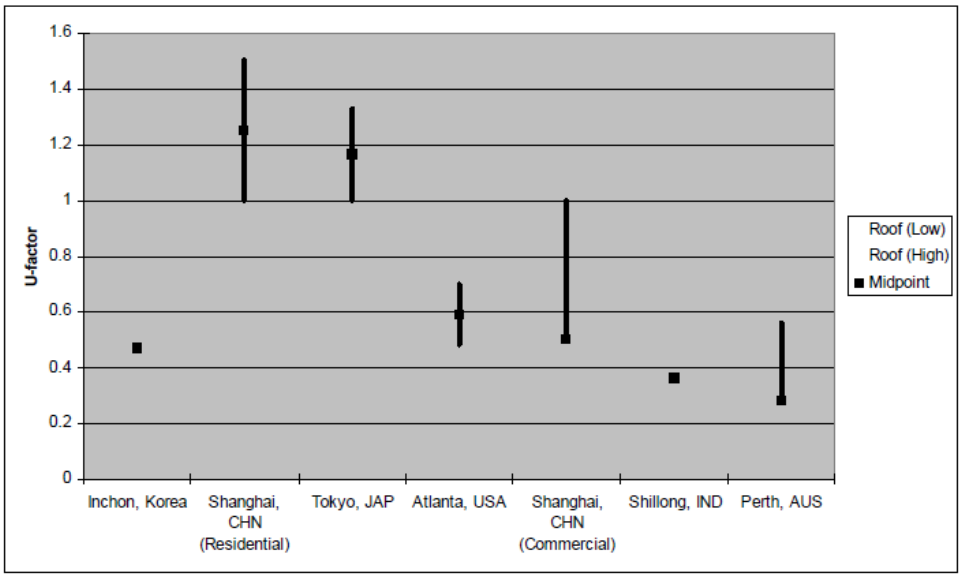


Figure 5-2. Comparison of U-factor Requirements for External Walls in Climate-Equivalent Warm Zones in Seven Countries

Source: (Evans, Shui, & Delgado, 2009b)

[48] Three categories of office space have been defined by the Building Owners and Managers Association (BOMA): Class A, Class B, and Class C, and this is how many professionals in India's construction and real estate sector refer to buildings. According to BOMA, Class A office buildings are the "most prestigious buildings competing for premier office users with rents above average for the area" and have "high quality standard finishes, state of the art systems, exceptional accessibility and a definite market presence (Building Owners and Managers Association International, 2011).

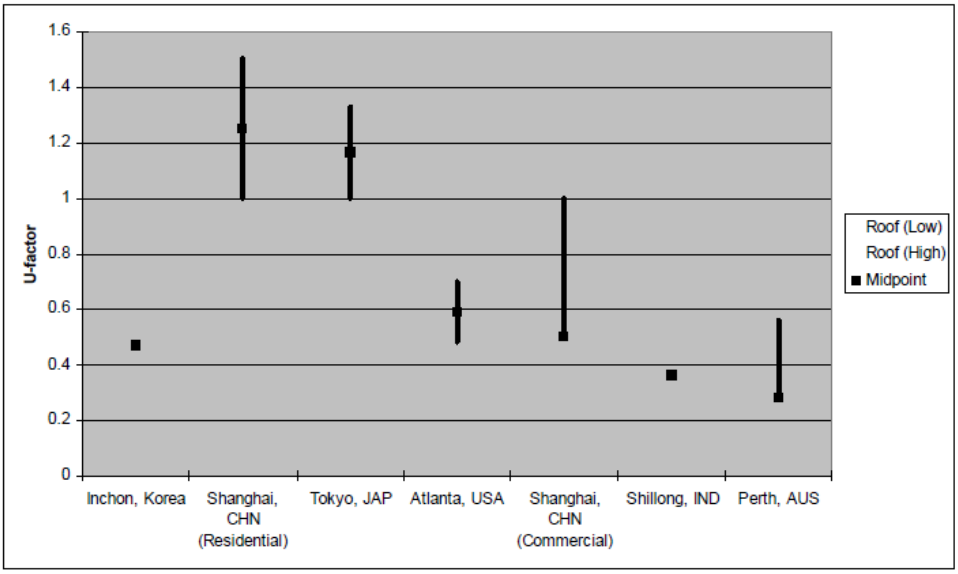


Figure 5-3. Comparison of Window U-Factor Requirements in Climate-Equivalent Cool Zones in Six Countries

Source: (Evans, Shui, & Delgado, 2009b)

5.3.3. Implementation, Enforcement, and Compliance.

Local implementation of the ECBC has two phases: writing local ECBC-compliant building codes and enforcing these codes. States have jurisdiction over local building code development and enforcement under India's Constitution, so the role of central government bodies will be limited to coordinating and monitoring state activities and supporting development through central government-funded schemes (Kumar, Kapoor, Rawal, Seth, & Walia, 2010). Indeed, local governments have some flexibility in how they implement the code, as ECBC guidance documents explicitly state that the "compliance and enforcement process may vary somewhat with each adopting jurisdiction" (India Bureau of Energy Efficiency, 2009). What follows is a general description of how local ECBC implementation will likely work in most jurisdictions.

5.3.3.1. Local Code Development

The ECBC must first be integrated into local building codes, called by-laws.[49] This process begins with BEE issuing a directive to the Ministry of Urban Development (MoUD) calling for ECBC code implementation at the state level. MoUD in turn issues a directive to lower-level bodies to begin integrating the code at the state level. Municipal bodies will be required to amend local building codes consistent with state regulations.

[49] These regulations are commonly referred to as "bye-laws" and "bye laws" in India. To reduce confusion for the international audience, they are referred to as "by-laws" in this report.

Two bodies are primarily responsible for the local-level ECBC integration effort: state-level Urban Development Departments (UDDs) and the municipal-level Urban Local Bodies (ULBs). UDDs oversee and coordinate the activities of the many ULBs within each state. ULBs are responsible for regulating buildings at the town and city level through the writing and enforcement of by-laws. ULBs will respond to the UDD-promulgated General Development Control Regulations (GDCRs). GDCRs broadly cover all aspects of building construction and must be passed by the State Legislative Assembly. Once a GDCR has been passed by the State Legislative Assembly, the ULBs direct their sub-department Town Development Offices (TDOs) to incorporate code provisions into the existing building by-laws. Local by-laws and the GDCR can require more from building owners than national regulations, but BEE must be informed and accept any such changes (Evans, Shui, & Somasundaram, 2009a). Figure 5-4 shows the process by which state-level GDCRs will be formulated.

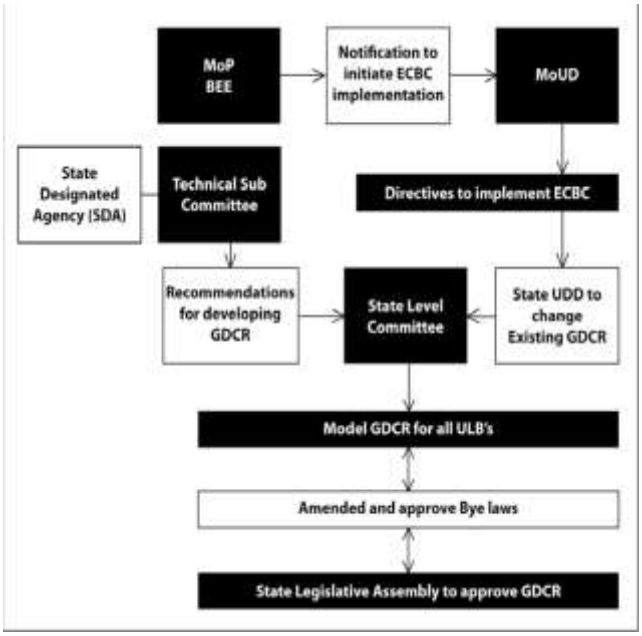


Figure 5-4. ECBC Implementation Process at the Local Level in India

Source: (Kumar, Kapoor, Rawal, Seth, & Walia, 2010)

5.3.3.2. Code Enforcement

The MoUD's Central Public Works Department and other concerned national agencies with jurisdiction over national government buildings can enforce the code in those approximately 8,000 government buildings. For the rest of the public and private sector, code enforcement responsibility falls on the TDOs (Kumar, Kapoor, Rawal, Seth, & Walia, 2010). TDOs will be responsible for "specifying permit requirements, code interpretations, approved calculation methods, worksheets, compliance forms, manufacturing literature, rights of appeal and other data to demonstrate compliance" (India Bureau of Energy Efficiency, 2009). The TDOs will also have the final word on interpretation, claims of exemption, and rights to appeal.

The design team for a building project is responsible for submitting all construction permit application documents (India Bureau of Energy Efficiency, 2009). The code inspector is responsible for verifying that the work satisfies code requirements. Field inspectors are required to visit all building sites during construction to ensure compliance with approved designs (India Bureau of Energy Efficiency, 2009). For non-compliance or omissions discovered during project plan review, the official may issue a correction list and require that plans and applications be revised to come into compliance before a building permit is issued, or work on the project can be stopped altogether (India Bureau of Energy Efficiency, 2009).

5.3.3.3. Role of Other Government Bodies

India's Ministry of Environment and Forest Environmental Impact Assessment (EIA) Procedures also imply but do not explicitly require compliance with the ECBC for projects with a built area between 20,000 and 150,000 m^2 (Ministry of Environment and Forests, 2007). However, EIA procedures do not explicitly mandate full ECBC compliance, and EIA documents only include some ECBC measures. A 2011 review of EIA compliance documents indicates that compliance checks with even the simplifications of ECBC requirements in EIAs may be lacking (Center for Science and Environment, 2011).

On the whole, the development of local by-laws and implementation capacity will be guided by the National Action Plan on Climate Change that was developed in 2008 and outlines existing and future policies regarding climate adaptation and mitigation. Eight core national missions were identified to meet climate change-related goals by 2018. One mission, the National Mission on Sustainable Habitat (NMSH), directly supports the extension of the ECBC nationwide. The NMSH designates MoUD as the central implementing agency for the ECBC; BEE currently serves as an advisor and is monitoring voluntary implementation through local-level State Designated Agencies (SDAs) (Kumar, Kapoor, Rawal, Seth, & Walia, 2010). SDAs administer the information collection and dissemination efforts for the BEE's Energy Star building rating program (see Section 5.4.1 below) and help coordinate local-level policy and capacity development efforts, run pilot projects, and enforce the implementation of energy-efficiency regulations for specifically designated industrial firms, but they are as yet still relatively underpowered in most places (Vedala, Bilolikar, Nalam, & Foster, 2011).

Another national mission under the National Action Plan for Climate Change, the National Mission on Enhanced Energy Efficiency (NMEEE), is the locus for development of standards and labeling goals as well as promotion of energy service companies, demand-side management activities, financing mechanisms, and other directives. There is an ongoing effort under the NMEEE to increase the power of the BEE's SDAs over these activities, with the specific goal of improving regulatory and facilitative functions.

5.3.3.4. Compliance

For the prescriptive standard approach, a combination of project receipts and on-site verification will be used to ensure that materials at the site match those in permit application documents. Computer-aided energy simulation using acceptable computer models is required for performance-based compliance.

5.3.3.5. Compliance Tools

A quick web-based prescriptive methodology compliance check tool, called ECO-III's ECOnirman Tool, has been developed to assist builders (U.S. AID India, 2011). Users input data about the construction plans for their buildings and receive an evaluation of the design in terms of the ECBC's mandatory and prescriptive requirements. ECOnirman also completes optional checks of the "trade-off method" for the building envelope.

A web-based whole-building performance method compliance simulation tool was released in 2011 (Kumar, 2011). The tool compares the energy performance intensity of a user's proposed design to baseline parameters from the ECBC's prescriptive requirements. The tool generates a report of the building's energy intensity that can be used to document compliance with the whole-building method.

5.3.3.6. Training in Energy-Efficient Design

Research has documented significant inadequacies in the topics of energy-efficiency and environmental issues in India's architectural education curricula (ECO-lll, 2010b). National efforts are under way to train faculty in these issues and develop high-quality academic reference materials (Kumar, Kapoor, Rawal, Seth, & Walia, 2010). A focus of these efforts has been on packaging building physics curricula and developing energy simulation proficiency (Kumar S. , 2010a). This work ambitiously aims for world-class building physics and energy simulation capacity in India by 2015 (ECO-lll, 2010a). BEE has also trained mid-career professionals and industry representatives in over 25 workshops in major cities (Kumar, Kapoor, Rawal, Seth, & Walia, 2010; Bureau of Energy Efficiency, 2012).

To aid training and increase marketplace information, a web-based building energy performance benchmarking tool called EcoBench has been developed. EcoBench uses an on-line interface to benchmark a user-defined building's performance (allowing for variance in operations schedule, occupancy, area, percentage air conditioning, etc.) against a database of hundreds of different buildings in three categories (office, hospital, and hotel) throughout India's five climate zones (U.S. AID India, 2011). This tool gives the user insight into how a building would be rated by the BEE's Energy Star building rating program (see Section 5.4.1. below).

BEE, together with assistance from U.S.AID, released an ECBC *Users Guide* in 2009 to assist building designers, architects, and other professionals with ECBC compliance on a project basis, as well as issue and measure specific guidance documents (India Bureau of Energy Efficiency, 2009) (Kumar, Kapoor, Rawal, Seth, & Walia, 2010). These are other documents are made publicly available online at BEE's training website.

5.3.4. Leadings Examples of Sub-National Building Code Development

In 2009, Hyderabad in Andhra Pradesh state adopted a good example of a sub-national building code, the Environmental Building Regulation and Guidelines, although this code remains voluntary. The guidelines were co-developed with the Administrative Staff College of India, and TERI, and cover energy use, water use, waste management, and other ecological issues in new buildings (Vedala S. C., Bilolikar, Nalam, & Foster, 2011) The development of local expertise and stakeholder participation forums during the drafting and adoption of the Environmental Building Regulation and Guidelines appears to have prepared city leaders and stakeholders for upcoming ECBC implementation. Andhra Pradesh state has issued a notification that ULBs will have to incorporate the ECBC into local by-laws. In response, Hyderabad has formed a steering committee to construct draft by-laws, develop software that incorporates other local codes, and undertake administrative capacity development.

Hyderabad is India's fourth-largest city by population and a center of the domestic information technology (IT) and pharmaceuticals industries, with several research and development hubs located within the city. The construction sector in the city, especially in new business districts, is relatively concentrated. The participation of the local chapter of the Confederation of Real Estate Developers' Associations of India appears to have been a critical factor in developing support for local by-laws (Khosla, 2012). Several other stakeholders are involved in the process including universities, think tanks, and non-governmental organizations (NGOs). The Hyderabad steering committee is aiming at integrating the entire mandate of the ECBC into the city's by-laws.

Domestic and international consultants and academics are assisting the city governments of Ahmedabad and Surat in developing ECBC-compliant local by-laws for approval by Gujarat state (Rawal, 2012). Ahmedabad is India's fifth-largest and fastest-growing city. The city is also the home of the Center for Environmental Planning and Technology (CEPT), the location of the Centre for Sustainable Environment and Energy (CSEE), a BEE-sponsored Regional Energy-Efficiency Center (REEC) for buildings (USAID, 2010). Academics at the CEPT and domestic and international consultants are working on designing a net-zero-energy building to house the CSEE-REEC. Several research activities have already taken place and will expand, including energy simulation training, building energy performance studies, and thermal comfort studies. Efforts to develop partnerships with local industry have not progressed as far in Gujarat as they have in Hyderabad (Rawal, 2012). Advocates feel that attempting to integrate the ECBC fully into local by-laws from the beginning will elicit resistance from local developers and in any case may be overly ambitious considering the city's regulatory capacity (Vaidya P. , 2012). Because ECBC gives states power to adapt the ECBC requirements to fit the code to local circumstances, CEPT researchers are pursuing partial implementation of ECBC in local by-laws (in contrast to Hyderabad's efforts to fully integrate the ECBC) (Rawal, 2012). The draft Gujarat policy, currently under review at the state level, targets the immediate mandatory integration of only the efficiency measures that can be evaluated by visual inspection, such as shell and fenestration measures. If passed, these by-laws will allow experimentation with this partial implementation scheme while capacity for whole-building compliance testing can be perfected and local building administrators can be further trained.

Neither Andhra Pradesh's nor Gujarat's ECBC implementation efforts can yet be labeled successes, but the development of these two ECBC compliance strategies is likely to be instructive regarding the needs and limitations of local governments in India, even among large cities. Lessons from both will be important for the national ECBC effort. Questions that may be answered by future studies include:

- Are local developer partnerships essential to attaining ECBC compliance, given the capacity limitations of local governments for building inspections?
- Should local administrators pursue partial compliance or incremental regulatory developments rather than full, all-at-once ECBC implementation?

5.3.5. Challenges and Barriers to Implementation of India's National Code

The subsections below discuss challenges and barriers to implementing the national energy-efficiency code at the local level, including the need for capacity building for enforcement and compliance.

5.3.5.1. Integration of National Code into Local By-laws

As mentioned above, the current major implementation challenge for the ECBC is the integration of its mandates into local building codes. To date, no state has promulgated ECBC-compliant by-laws for private commercial buildings. However, some states have moved ahead of others toward adopting local by-laws: efforts to draft ECBC compliant by-laws are reportedly under way in the states of Rajasthan and Orissa as well as the cities of Hyderabad, Andhra Predesh state; Ahmedabad and Surat, Gujarat state; Bangalore, Karnataka state; and Chennai, Tamil Nadu state (Das, 2010); (Vedala S. C., Bilolikar, Nalam, & Foster, 2011). Haryana state and the capital region of New Delhi have made ECBC compliance mandatory for all government buildings (Das, 2010). The greatest need in these efforts is to dedicate considerable resources to ensuring that new by-laws match the local workforce, administrative capacity, and market contexts (Rawal, 2012; Khosla, 2012) Steering Committees including academic and international experts have been formed by local governments in leading states to help with the code development process. However, there are no apparent best-practice models for ECBC integration in India, so these efforts remain experimental.

5.3.5.2. Code Enforcement Capacity

A World Bank study found that considerable staffing development work needs to be done as India begins to make the ECBC mandatory (Liu, Meyer, & Hogan, 2010). Notably, the report finds that the financing necessary for this effort is still unidentified. Implementing the ECBC through ULBs will likely require developing the skills of high-level administrators, program officers and evaluators, informational personnel, and building inspectors. Under the MoUD's Jawaharlal Nehru National Urban Renewal Mission launched in 2005, the national government has dedicated substantial resources to improving the economic and social infrastructure of India's top cities (Ministry of Urban Employment and Poverty Allevation and Ministry of Urban Development, 2011). These efforts are expected to continue and strengthen under the upcoming 12th Five-year Plan (2012-2017), especially regarding training ULB staff in urban management, project development implementation and management, and regulatory

operations (Working Group on Capacity Building, 2011). Whether ECBC training will be incorporated into these efforts is still uncertain.

A specific concern is ensuring that there are sufficient building inspectors within ULBs and TDOs. The Pacific Northwest National Laboratory reports that building code enforcement is difficult, in part because of a low skill level among inspectors (Evans, Shui, & Somasundaram, 2009a). The BEE's industrial energy auditor and inspector training program may become a template for developing the capacity of TDOs to enforce the ECBC, however no plans for such could be found in this review. Another route to building enforcement capacity, increasingly used in the United States and Europe and under research in India, is to outsource code compliance verification work to third parties (Vaidya P. , 2012). To a certain extent, the third-party inspection model is already in operation in India, as both the LEED and GRIHA building labeling schemes essentially require compliance with the ECBC, and both programs have established protocols for certifying inspection parties.

5.3.5.3. Enhancing Construction Materials Certification Capacity

Neither government nor third-party testing laboratories are currently capable of certifying all the products and equipment necessary to comply with the ECBC's prescriptive compliance methodology (Kumar, et al., 2010). BEE's energy-efficient appliances program certification system is likely to be used as a template for moving forward in certifying construction products (Kumar, Kapoor, Rawal, Seth, & Walia, 2010). In partnership with the Glazing Society of India and with funding from the national and state government, the CEPT REEC for Buildings has recently acquired capabilities to characterize the energy performance of almost all building materials (Rawal, 2012). This center is currently working toward accreditation with the National Accreditation Board of Laboratories (Rawal, 2012).

5.3.5.4. Training Building Professionals

India lacks a sufficiently large cohort of building professionals trained in energy-use issues, building physics, building energy simulation, and building systems engineering (Manu, et al., 2010). Moving forward, mid-career professional training programs and specialized academic courses will need to be expanded. The development of these programs is already under way; the National Institute for Advanced Studies in Architecture was created to strategize the development of a new advanced curriculum for India's 140 architectural schools. Educational curriculum enhancement began in 2007 within 18 institutions and is currently being expanded to include 40 architectural and engineering colleges.

5.3.5.5. Strengthened Incentives for Enforcement

Full enforcement of building codes in India is "almost non-existent" and "in practice, many builders end up not obtaining the occupancy permit" (Vaidya, Bharvirkar, Ward, Vasudevan, & Cherail, 2010; Liu, Meyer, & Hogan, 2010). Instead, local officials often check construction plans for compliance with only a

few local by-laws, such as setbacks and permissible heights (Vaidya, Bharvirkar, Ward, Vasudevan, & Cherail, 2010).

One reason for low code compliance rates might be the long wait times and multiple permitting processes for construction projects. These can differ substantially among jurisdictions and can be as long as 224 days (World Bank & International Finance Corporation, 2009). The lack of code enforcement also appears to be at least partially a result of the multiple public and private opportunities for corruption (KPMG, 2011). This problem of aligning enforcement incentives may be partially addressed by efforts to increase transparency and reduce the complexity of permit application and review. Several jurisdictions have implemented electronic filing systems for building permit applications, and many allow online tracking of permits as they move through the approval process (D'Souza, 2011). Single-window (one-stop) permitting has also been instituted in several major cities to reduce permit wait times. However, these programs are not guaranteed to increase transparency, and a critical element in solving this problem may be increasing the penalties for non-compliant officials and permit applicants. Efforts at the national level to develop such penalties are ongoing but might not result in a complete alignment of incentives and compliance (Raja & Datta, 2011).

5.4. Building Energy Labeling

Although some building consumers are paying increasing attention to buildings that have been certified as green or energy efficient, building labeling in India is still quite rare. There are currently three ways for commercial buildings to be rated and certified as energy efficient or "green" in India. The BEE's Star Rating System evaluates buildings based on operational energy use and is the only energy-use-specific building label used in India. Two green building certification programs, LEED India and GRIHA, are the most popular in the marketplace and address many issues aside from building energy use, such as materials, water consumption, and environmental and human health. GRIHA is both design- and operations-based whereas LEED is a design-based label. A much smaller green building certification scheme, called Eco-Housing, applies only to residential buildings.

5.4.1. Bureau of Energy Efficiency (BEE) Star Rating System

BEE developed the Star Rating scheme, an official system for labeling buildings based on energy use, in February 2009. Like the ECBC, the Star Rating program applies only to commercial buildings with a connected load of 100kW or 120 kVA or greater. Although BEE's Star Rating system ratings are currently only available for shopping malls, office buildings, and buildings designed for business process outsourcing, ratings will eventually be created for four additional commercial building types: hotels, hospitals, schools, and IT parks (Vaidya, Bharvirkar, Ward, Vasudevan, & Cherail, 2010). Star Ratings have been developed for air-conditioned and non-air-conditioned buildings in the warm and humid, composite, and hot and dry climates. The label, like ECBC compliance, is voluntary. The label compares the building to similar buildings and gives the consumer specific energy use information about the labeled building.

5.4.1.1. Star Rating System Label Information

The Star Rating scheme is based on the appliance star rating scheme previously developed by BEE and uses the same label format. Figure 5-5 shows this logo. The stars in the red field in the figure indicate the ranking of the building (0 stars is the worst, 5 stars is the best). The red field below the stars gives the building's energy intensity in kWh/m^2/year. The energy intensity score excludes electricity generated from on-site renewable sources (Liu, Meyer, & Hogan, 2010). The label is both easy to understand and is already familiar to Indian consumers of home electronics.

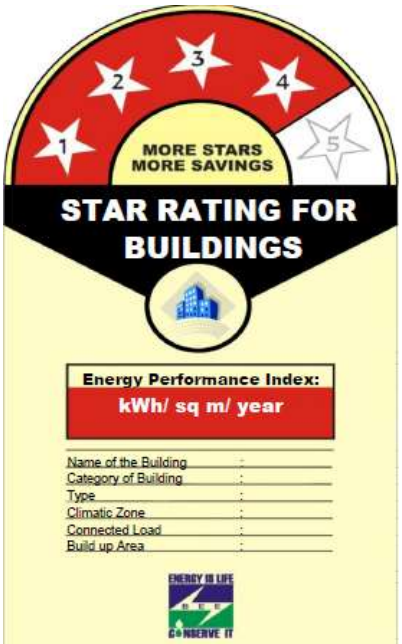


Figure 5-5. Star Rating for Buildings Label

Source: (Bureau of Energy Efficiency, n.d.)

5.4.1.2. Requirements

Applicant buildings are assigned an energy performance index after a thorough (investment-grade) audit of their energy use after one year of operation with full occupancy. SDA and/or BEE inspectors audit the building, and there are means to challenge the inspectors' findings.

5.4.1.3. Stages of Development

By the middle of 2010, BEE had certified 110 buildings (Times of India, 2010). It is unknown how much energy has been saved as a result of the Star Rating Program, but future expansion is expected as benchmarks are created for more climate zones and building types.

5.4.2. Leadership in Energy and Environmental Design–India (LEED-India)

LEED India is the local adaptation of the U.S.-based LEED and is administered by the India Green Building Council (Kumar, 2010b).These voluntary standards address sustainable site development, water conservation, energy efficiency, materials selection, and indoor environmental quality. There are two LEED India commercial building programs: New Construction, and Core and Shell. LEED India for New Construction (LEED-NC) is available to commercial buildings such as offices, retail and service establishments, institutional buildings, hotels, and multi-family buildings of four or more stories. LEED India for Core and Shell (LEED-CS) applies to rented commercial spaces in which the building occupants

do not control aspects of the building's design and construction. Examples of buildings of this type are IT parks, malls, retail centers, and warehouses.

5.4.2.1. Requirements

Certification with LEED requires meeting or exceeding LEED-determined building requirements, with the level of compliance determined by a system of interchangeable points associated with energy and water conservation measures; several prerequisites essentially require ECBC compliance. Different LEED grades (Certified, Silver, Gold, and Platinum) are given for achieving certain point thresholds.

LEED certification is attained through a complicated documentation and third-party certification process. Compliance can only be certified by LEED-certified auditors, and certain persons on the construction team are required to have LEED certification. LEED compliance can increase design-stage costs by 20% and construction costs by 5%–10% (Vaidya P. , 2011). However, total cost premiums have dropped to under 10% of total project costs during the past five years (Venugopal, Krechowicz, Shinde, Singh, & Padamadan, 2010).

5.4.2.2. Stage of Development

LEED received strong initial popular support and in 2010 India ranked second in certified floor space only to the United States (Earth Policy Institute, 2010). As of this writing, 241 buildings had been certified by LEED India, with over 1,600 building projects awaiting certification (IGBC, 2012a). As of 2012, IGBC's website lists 160 LEED Accredited Professionals (IGBC, 2012).

Because LEED points can accumulate for a number of measures related to both energy and non-energy categories, a LEED label might not indicate that the building is more energy efficient than one built to ECBC standards. In addition, unlike the BEE Star Rating scheme, LEED certification is based on building design rather than building operation, so it does not result in a determination of whether the design strategies actually result in better energy performance. Furthermore, because placards do not display points awarded for each category, the LEED scheme can be quite opaque to consumers interested in understanding building energy use.

5.4.3. Green Rating for Integrated Habitat Assessment

GRIHA ,a domestic rating system for green buildings, was developed in 2005 and adopted by the Ministry of New and Renewable Energy (MNRE) in 2007 as their preferred standard for rating green buildings in the country. GRIHA's day-to-day operations have now been transferred to the Association for Development and Research of Sustainable Habitats (ADaRSH), an independent certification body.

The purpose of GRIHA was to integrate a variety of India-specific building code compliance requirements within one system and develop a green building standard better suited to India's patterns of building energy use. GRIHA certification requires compliance with the ECBC; Bureau of Indian Standards codes

like the NBC and codes for concrete, steel, water quality, and functional requirements; guidelines of the Central Ground Water Board; and solid-waste handling and local building regulations (MNRE & TERI, 2010; Evans, Shui, & Somasundaram, 2009a). GRIHA certification is currently limited to commercial and institutional buildings with a minimum built area of 2500 m^2. A simplified rating system called the Small Versatile Affordable GRIHA (SVAGRIHA) has been developed and applies to smaller buildings. There are also plans to implement a large-scale development rating system that would cover educational campuses and mixed-use township developments. A draft of this larger project certification system was released at the beginning of 2012 (TERI, 2012a).

The GRIHA system includes standards for India's different climate zones and establishes rating levels, in part using the same survey-based building energy consumption benchmarks as the Star Rating scheme and the ECBC (Figure 5-6). GRIHA can be used to rate air-conditioned, naturally ventilated, or mixed-mode-conditioned buildings. Naturally ventilated buildings may not need full ECBC certification, but a fully air-conditioned building will need to be ECBC compliant to obtain a GRIHA rating. In addition, GRIHA makes mandatory some of the non-mandatory prescriptive provisions of the ECBC. GRIHA differs from LEED in that it evaluates the expected environmental performance of a building over its lifetime.

Figure 5-6. GRIHA Logo and Star Rating Scheme

Source: (S. Kumar 2010b)

ADaRSH appears to estimate (with general language regarding green buildings) that GRIHA certification can result in savings of 40%–60% of electricity use and 40%–80% of water use compared to conventional buildings (MNRE & TERI, 2010). These average savings may change in the future as GRIHA standards are revised every three years (Vedala, Bilolikar, Nalam, & Foster, 2011).

5.4.3.1. India's Green Rating for Integrated Habitat Assessment Requirements

Compliance with GRIHA is attained by meeting policy, construction, and operational requirements in 34 different categories. As in LEED, some measures are mandatory to achieve a GRIHA rating. GRIHA has an

independent, simple, web-based evaluation tool that designers and project managers can use to understand qualitative and quantitative point options. The system also establishes requirements for professionals who are mandated to review each category of measures. Points are awarded provisionally until on-site validation takes place (GRIHAIndia.org, n.d.). GRIHA ratings are valid for five years after the final score has been awarded, and ADaRSH reserves the right to undertake random audits to verify that points have been awarded accurately (GRIHA, n.d.). GRIHA compliance has been estimated to increase project costs by about 1% with no further incremental costs beyond ECBC compliance (World Business Council for Sustainable Development, 2011; Prasad, 2011).

5.4.3.2. Stage of Development

As of the writing of this report, GRIHA has rated eight buildings, and over 200 projects were undergoing the rating process (Green Rating for Integrated Habitat Assessmen, 2012). Some local jurisdictions have responded very positively to GRIHA. It appears that the states of Himachal Pradesh, Punjab, Haryana, and Nagaland have already required that all new government and public-sector buildings be constructed according to GRIHA standards (MNRE, 2011). The Cabinet of the Delhi Capital Region and the city of Pimpri-Chinchwad, Maharashtra, have recently announced that all new buildings in those cities must be GRIHA-compliant. In addition, the Central Public Works Department of India, the construction arm of the central government, has adopted GRIHA as its official Green Building Standard (Kumar, 2010b). Under this program, all new central government buildings will be constructed to meet the GRIHA Three-Star rating (Kumar S. , 2010b). The current 11th Five-year Plan (2007-2012) aims to achieve GRIHA compliance in five million m^2 of built area (Kochar & Convenor, 2010). As of the end of 2010, GRIHA had trained 400 professionals in 12 evaluator and trainer workshops. Of those individuals, 115 went on to conduct trainings for others, and 92 went on to become GRIHA-certified evaluators (Tripathi, 2010).

Like LEED ratings, GRIHA ratings are based on points awarded for a variety of different building strategies, not all directly related to energy use. Therefore, a higher GRIHA rating doesn't necessarily indicate superior energy performance than a building built to ECBC requirements.

5.4.4. Eco-Housing India

Considerably smaller than the three building labeling schemes described above is Eco-Housing India, developed by the Eco-Housing Partnership. Eco-Housing India is a star-based rating scheme exclusively for multi-story apartments (Liu, Meyer, & Hogan, 2010). This program is still being developed and appears to have been launched only in the Maharashtra state cities of Mumbai and Pune. Phase II of the Eco-Housing Project focused on creating certification measures for all climate zones, a goal that had been accomplished by 2010, but there are no implementation evaluations for these new standards (Pandit, Patankar, & Prem, 2010).

5.4.4.1. Requirements

The Eco-Housing assessment criteria incorporate 77 measures spread over seven focus areas: site planning, environmental architecture, energy conservation and management, efficient building materials, water conservation, solid waste management, and other measures. Points are awarded out of a possible total of 1,000, based upon performance in each focus area, and buildings are given one to five stars depending on the points earned. Forty of the 77 measures are mandatory. It is expected that compliance in new construction will result in 10%–15% higher project costs (Pandit, Patankar, & Prem, 2010).

A national certification mechanism has been established for the Eco-Housing Program, and an Eco-Housing Auditor's Training Manual is being developed concurrently with an inspector examination to be administered by the Sustainable Building Technology Center. Certification is also through the Science and Technology Park, Pune, a third-party certification body (Pandit, Patankar, & Prem, 2010). Certification is similar to that of GRIHA and LEED India. Preliminary registration of a project is followed by document submittal and site visits. A provisional Eco-Housing rating is given, which is confirmed and awarded through post-construction inspections. Certification lasts for five years, at which time it must be renewed.

5.4.4.2. Stage of Development

The Pune local government appears very supportive of the development of Eco-Housing, and Eco-Housing rated projects can apparently apply for mortgage financing rebates of between 50 and 150 basis points from Indian Banks (see Section 5.5 below) (Liu, Meyer, & Hogan, 2010). Both Mumbai and Pune governments are also offering rebates on developers' fees and on residents' property taxes for projects that have been rated under the standard (Liu, Meyer, & Hogan, 2010).

Table 5-2 shows the Eco-Housing rating scheme, and Figure 5-7 shows the Eco-Housing logo.

Table 5-2. Eco-Housing Rating Scale

Points	Rating
500	*
501-600	**
601-700	***
701-800	****
>801	*****

Figure 5-7. Eco-Housing India Star Rating Scheme and Logo

Source: (International Institute for Energy Conservation, n.d.)

5.4.5. Challenges and Future Directions

The market for building labeling schemes is still small in India. The majority of labeled buildings are owned by governments, large multi-national corporations, or domestic corporations like hotels whose clientele come at least in part from other countries. This indicates a relative lack of market demand for labeled buildings among domestic, non-public building owners. Furthermore, with the exception of the operational-energy-based BEE Energy Star label, buildings are labeled based upon a variety of characteristics and thisobscures the energy-use implications of labels.

Building labeling efforts are starting with highly visible targets, which might result in increased consumer awareness of the labels and allow labeling systems to experiment and evolve before a larger-scale rollout. However, the co-existence of four labeling schemes in a low-demand market is likely to confuse consumers. Competition among labels increases the need for proponents to expend significant resources before the real estate market is able to capitalize on the informational value that labels offer. Efforts should be made to better understand the motivations of actors who seek building labels and to increase the general domestic market attractiveness of building labels through stronger information campaigns.

5.5. Incentives for Energy-Efficient Buildings

As is the case with building labels, government financial incentives and public financing options are rare and still being developed in India. The majority of such measures are for appliances, renewable energy (especially rooftop solar), and energy-efficient light bulbs, rather than for energy-efficient space-conditioning measures. Most incentives are in the form of rebates for building labeling program costs, application of renewable technologies such as photovoltaics (PV) and solar water heaters, and direct installation of lighting measures. However, some incentive programs are experimenting with tax concessions for buildings that incorporate energy efficiency and renewable energy. In addition there are a few limited experiments with instituting procedural concessions such as expedited permitting for buildings incorporating energy-efficiency or renewable energy measures.

Funds appear to mostly be sourced from government general tax coffers; however, Haryana state and a few others are starting to use state energy conservation funds as required by the Energy Conservation Act of 2001 (Government of Haryana Department of Economic and Statistical Analysis, 2011; Limaye, Nataraian, Kumar, Lalnad, & Tharakan, 2008). Utility-managed and -funded work in the buildings sector is minimal and has traditionally been limited to lighting upgrades. Despite the relatively small size of these efforts, the diversity of incentives will help to build programs that can expand over time.

5.5.1. National-Level Incentives

India has promulgated a variety of national incentives and financing schemes for energy-efficiency measures in industry, but only one large-scale national-level incentive scheme exists for buildings: the MNRE incentive program for GRIHA-rated buildings. Under the MNRE "Energy-Efficient Solar/Green Buildings" program, developers can be reimbursed for 90% of the registration and rating fee for projects up to 5,000 m^2 with a minimum three-star rating and for projects larger than 5,000 m^2 with a minimum four-star rating (MNRE, 2009). Architects and consultants will be awarded 250,000 Rs. (2011 USD $5,100) for projects up to 5,000 m^2 of built area with a minimum three-star rating and 500,000 Rs (2011 USD $10,200) for four-star projects that are larger than 5,000 m^2. Training and workshop support is also available, as are awards for municipalities that increase GRIHA certification the most over the year.

Inter-government assistance is also available: 5,000,000 Rs (2011 USD $102,000) is available to municipal corporations and 2,500,000 Rs (2011 USD $51,000) to other local bodies that announce property tax rebates for green buildings, require GRIHA rating for new buildings in the government and public sectors, and sign a memorandum of understanding with GRIHA for large-scale promotion of green buildings in a local area. To encourage rating of government buildings, the first 200 government/public-sector buildings to be certified will be exempted from paying registration fees, through a combination of up-front payments and completion-based rebates (MNRE, 2011).

Similarly, to kick-start its Energy Star rating program, BEE is also offering full subsidies for the first 100 applicants for the BEE Star Rating program.

The National Mission on Enhanced Energy Efficiency (NMEEE) calls for the real estate financing sector to begin packaging financing for efficient lighting and space-conditioning systems within building financing transactions. The NMEEE also calls for the development of appliance financing schemes and utility-based efficiency programs funded through on-bill financing (Government of India, 2008).

5.5.2. State-Level Incentives

India's state-level incentives for building energy-efficiency code and label compliance are scattered and piecemeal. The most distinctive and well-documented of these are tax concessions offered by the Pune Municipal Corporation, Maharashtra State, which decrease property taxes by 10%–50% on the total premium paid by builders for Eco-Housing-rated projects, depending on the rating achieved (Pandit, Patankar, & Prem, 2010). The bank will also provide up to 20 Rs/m^2 of proposed built area, capped at 350,000 Rs (2011 USD$6,000) per project. It has been reported that Hyderabad and some other state governments are looking into enacting procedural subsidies, such as expedited building permit approval for ECBC compliant buildings, once ECBC is integrated into local by-laws (Vedala, Bilolikar, Nalam, & Foster, 2011).

5.5.3. Building-Integrated Renewable Energy Incentives

The subsections below describe India's national and state incentives for integrated renewable energy in buildings.

5.5.3.1. National-level

The MNRE and many state governments offer incentives for the adoption of building-integrated renewable energy technologies. These incentives include partial assistance with preparation of detailed project reports for building projects with energy-conscious designs, which can include both energy-efficiency and renewable energy measures. In 2005, these incentives were 50% of design preparation costs up to 200,000 Rs (2011 USD $4,080) (Nayak & Prajapati, 2006). Additional government support could be obtained for construction of public and government buildings and other pilot projects under the administration of state agencies. In 2005, this additional support covered 10% of construction costs for such projects, up to a total of 5,000,000 Rs (2011 USD$110,000) (Nayak & Prajapati, 2006). This program will support two building-integrated-renewable projects in each province.

MNRE has also been offering reduced-interest loans for small-scale renewable technologies to customers of the India Regional Economic Development Agency and seven designated banks (Nayak & Prajapati, 2006).To take advantage of this subsidy scheme, many states have requirements that buildings incorporate technologies, including solar water heating, air heating, cooking, biomass gasification, biogas, etc. One example of these subsidies is a 2% interest rate on purchases of solar water heaters (Pandit, Patankar, & Prem, 2010).

5.5.3.2. State-Level

Quite a few state and municipal bodies have instituted by-laws requiring solar hot water heating systems in new buildings (Nayak & Prajapati, 2006). Many of these state and city governments offer property tax rebates and other incentives for properties that install and use solar heating and lighting systems. For example, the Hyderabad government offers a 10% rebate to builders who choose solar heating and solar-powered lighting systems when upgrading buildings (Jaiswal, Vedala, & Bilolikar, 2010).

In addition to government incentives, certain local utilities offer building-integrated renewable energy incentives. For example, the Bangalore Electricity Supply Company Limited in 2006 was offering 0.40 Rs rebate on every unit of electricity generated by the building itself, up to a maximum of 40 Rs per month (Nayak & Prajapati, 2006).

5.5.4. Public and Private Bank Financing Incentives for Green Buildings and Technologies

Several Indian banks are offering financing incentives for both green buildings and technologies (Table 5-3).

Table 5-3. Financing Incentives for Green Buildings and Technologies in India

Bank Name	Incentive Scheme Description
State Bank of India (SBI)	Green Home Loan: supports environmentally friendly projects and offers various concessions. Loans available for projects rated by the IGBC. Financial benefits include: a 5% concession fee in margins, 0.25% concession in interest rates, and processing fee waivers.
State Bank of Mysore	Energy-efficient, green housing, renewable energy, and waste management projects are eligible for small interest concessions at this bank. Subject to limitations, the entire cost of a rainwater harvesting system for a newly purchased house will be incorporated into a loan with no additional interest.
Industrial Credit and Investment Corporation of India Bank	Reduced mortgage processing fees for customers who purchase LEED-certified buildings.
Bank of Maharashtra and ING Vysya Bank	Eco-Housing Mortgage products offered under the Eco-Housing Pune Program (see Section 5.4.4. above): These products offer a 0.5% rebate on prevalent interest rates, 1% interest rate subsidy on certain efficiency equipment and appliances (solar water heaters, efficiency lighting, refrigerators, and air conditioners); and either a longer repayment tenure or a 3-month moratorium on repayments. The program also appears to offer larger loan amounts for Eco-Housing projects (10% more than normal loans).

Source: (Vedala, Bilolikar, Nalam, & Foster, 2011; Pandit, Patankar, & Prem, 2010)

5.5.5. Energy Efficient Lighting

Nationally developed incentives support a large incandescent bulb replacement scheme in India. The current penetration of compact fluorescent lamps (CFLs) in the Indian residential sector is estimated to be 10% whereas 95% of the commercial sector already uses CFLs (Chakarvarti, 2010). The off-the-shelf cost of CFLs is about 10 times the cost of incandescent bulbs (Chakarvarti, 2010). The Bachat Lamp

Yojana project seeks to replace 400 million incandescent bulbs with CFLs by 2012, for an estimated power savings of 600 MW (Chakarvarti, 2010). This program appears to be a no-cost, unit-for-unit replacement of residential bulbs only (Chakarvarti, 2010). Part of the funding for the scheme is due to the program being the largest carbon credit project under the Clean Development Mechanism (Suki, 2010).

5.6. Best Policy Practices in India

5.6.1. Building Energy Codes

5.6.1.1. Indicators of Best Practice

Development of advanced building energy codes for commercial buildings: The Indian Bureau of Energy Efficiency (BEE) with the assistance of international consultants developed a national model energy code for commercial buildings, the Energy Conservation Building Code (ECBC). This code and associated surveys represent an initial and early effort by India to address the issue of rapidly increasing energy use in commercial buildings.

Initial plans to implement ECBC at the state level: Implementation is planned to start in some of India's fastest-growing, economically-strongest areas. Several state and central agencies are in the process of incorporating the code into guidelines and requirements for public buildings; eight states are required as of 2012 to make the code mandatory for all new and major retrofits of commercial buildings.

Concentration on both mid-career and pre-professional capacity building using state-of-the-art tools: To improve code compliance, and ensure that building owners understand their building's energy use intensity and designers understand whether their projects comply with the ECBC, three web-based software tools have been developed for use by code officials and building professionals. A partnership among 18 universities is developing a building sciences curriculum that is intended to provide training directly applicable to the ECBC and for related purposes.

5.6.1.2. Issues

Need to watch efforts of leading local jurisdictions: The effort to develop ECBC-compliant local by-laws is the most important obstacle facing building energy efficiency efforts in India. Although several states are purported to already have such by-laws, there is little public documentation of these accomplishments. The by-law development trajectories of two cities, Hyderabad, Andhra Pradesh state, and Ahmedabad, Gujarat state, will be instructive as to the needs of even advanced, well supported, wealthy cities in developing local by-laws. The efforts of these cities should be tracked by future research because both are experiencing construction booms but face their own particular development circumstances that are impacting the development of local level ECBC-compliant by-laws. Neither of these efforts can yet be labeled as successes, but the development of these two different ECBC compliance strategies is likely to be instructive regarding the varying needs and limitations of local governments in India, even amongst large cities. Undoubtedly, lessons from both will be important for the national ECBC effort. The most important questions to be targeted by future studies are:

- Should local level administrators pursue partial compliance or incremental regulatory developments rather than full, all-at-once ECBC implementation?
- Are local developer partnerships absolutely essential to attaining ECBC compliance, given the capacity limitations of local governments for building inspections?

- Are local-level inspectors an appropriate means of enforcing codes, or should third-party code enforcer programs be pursued?
- Where are the greatest weaknesses in the supply chain for building energy-efficiency measures?

Working toward a low-rise residential building code: India has yet to develop an energy code for low-rise residential buildings. This may be a rational choice considering the growing importance of commercial and high-rise residential buildings covered by the ECBC and the need to work within administrative and technical capacity constraints. However, it appears that middle-income and wealthy residential households, especially in urban areas, are quickly increasing their energy consumption as incomes rise, and this will continue into the medium-term future. Regulating energy use in residential buildings will require amendments to India's Energy Conservation Act, which does not currently allow BEE to establish residential building codes. Before this occurs, basic research needs to be conducted to better characterize this sector and strategies for the integration of residential buildings into the ECBC.

Evaluating code stringency according to local benefits: Similar to building energy codes in China, the ECBC may not accurately reflect common building usage patterns, especially in regard to the whole building performance compliance methodology. A survey being conducted in India (ECO-III) that includes ongoing building monitoring efforts is expected to provide information that will permit the localization of the ECBC.

5.6.2. Building Energy Labeling

5.6.2.1. Indicators of Best Practice

Locally relevant labeling systems: India's GRIHA and the LEED green building rating systems are the most popular building labeling systems in the country.[50] Between the two, the GRIHA system is more closely linked with typical India building operational characteristics such as significantly reduced demand for cooling. The national government and several state governments support GRIHA, with four states requiring GRIHA rating for government buildings and the national government requiring GRIHA compliance in all new national government buildings.

Labels gaining initial market footholds by appealing to high-premium market sectors: LEED buildings are still more costly than regular buildings.[51] However, despite high costs, LEED received strong initial support and, in 2010, India ranked second in LEED-registered building floor space only to the United States. As of the writing of this report, LEED has registered more than 1.1 billion m^2 of LEED building projects. Part of LEED's appeal is its international character and recognition as a high-quality standard by international and domestic corporations. The Indian Green Building Council has used this recognition well to increase market reach, especially in new business districts attracting multinational corporations.

[50] LEED uptake has been dramatically higher in the private sector, and GRIHA uptake has dominated the government sector, so they are not equivalently popular in all sectors.

[51] Recently some LEED projects have reported marginal costs between 2 and 5%.

Gaining a foothold in these high-visibility projects will undoubtedly work to expand LEED's market appeal.

Label programs as a source of capacity development: The ability of labeling programs to deliver targeted training on energy-efficient design and operations should not be ignored. GRIHA and LEED have been significant sources of training on green building and building energy issues, with GRIHA training 400 professionals as of the end of 2010, and the Indian Green Building Council listing 160 LEED accredited professionals.

5.6.2.2. Issues

Effects of multiple labeling programs on consumers: The existence of three labeling systems (the two described above plus a small Energy Star program put forward by BEE) will undoubtedly lead to consumer confusion at a time when most consumers are unaware of building energy use issues. The experiences of EU countries, especially countries with little history in building energy-efficiency regulations, suggest that the approach of developing a standardized building energy performance labeling program should be investigated for lessons that may apply to India's efforts.

Electronic information management for greater label utility: The recent advent of electronic systems that store and make available all local building and land permits in some states should be investigated to see whether database-integrated label programs can be used to collect and distribute building energy intensity information.

Research on leading sectors: Another potential avenue for research is to understand the motivations for the relatively stronger uptake of building labels such as LEED and GRIHA by companies that finance and build their own buildings, such as the ITC Hotels Chain that has achieved LEED-platinum certification for their entire line of luxury hotels in India.

5.6.3. Financing and Incentive Programs

5.6.3.1. Indicators of Best Practice

Incentives for all actors: Incentives and financing mechanisms for building energy efficiency are few and uncoordinated in India and require further development and testing. An early leader in this effort is the Indian Ministry of New and Renewable Energy's GRIHA-based incentives. This program stands out as a means of increasing building energy-efficiency awareness through simultaneously targeting multiple actors in the building supply chain. The package combines incentives for developers, owners, and local-level administrators, all of whose support is necessary at this stage in dramatically increasing the market for efficient buildings.

5.6.3.2. Issues

Data on the effectiveness of incentive programs: Incentives and financial mechanisms for building energy-efficiency are few and haphazard in India. Government incentive programs are strongest, and the finance industry appears to be a long way from widespread efficiency financing because of concerns about a lack of demand. No program reviews for any incentive scheme could be found, so there are no means of evaluating the cost effectiveness of these policies. Most importantly, little is known about the effect of existing building energy-efficiency incentives on actual building energy use.

Data on the benefits and costs of energy-efficient buildings: Anecdotal evidence suggests that project developers are unsure of the costs of efficiency measures, and the real estate market generally does not appreciate the value of higher-efficiency buildings. Basic research is needed to understand the economic benefits of energy-efficient buildings in India, including energy cost savings, rental and sale premiums, and occupant comfort benefits, so that investment payback times can be better understood by developers. In particular, market research should be undertaken to isolate owner and building types and geographic areas that might be more willing to take on efficiency projects and then to prioritize incentives targeting this subsector.

Industrial incentive programs: Both banks and utilities in India are working with the government in delivering energy-efficiency programs for industrial firms where these programs offer social benefits, such as providing better grid stability through demand-side management (DSM). These experiences should be researched to understand the extent to which the commercial building and residential sectors hold potential to offer the same kind of DSM services.

5.7. Conclusions

During the past 10 years, professionals within India's national government; consultants from India's academies, think tanks, and corporations; and international experts have worked together to quickly build a commercial building energy-efficiency improvement strategy for the country. These efforts have resulted in a comprehensive model building code and several tools and strategies to tune the code to India's local circumstances. Although implementation is just now moving beyond initial pilot projects, these code infrastructure development successes are noteworthy and deserve acclaim.

The next step is implementation on a large scale. Developing implementation capacity will be a significant challenge and will require further concerted efforts by all stakeholders, especially governments at all levels, to align incentives and drive initial market demand for inputs such as skilled labor and certified materials. To provide a secure foundation for further policy development and ensure successful implementation, national government resources should be deployed to characterize building energy use in greater detail and to keep codes and tools current according to new building energy use data. Concurrently, capacity development efforts need to be ramped up to use tools to train current university students as well as mid-career building inspectors and other political stakeholders at the local level. These efforts should absolutely be supported by careful, systematic, well-documented research into the results of such expenditures, both for the benefit of India as well as the rest of the world. In addition, the perspectives and needs of stakeholders such as developers, manufacturers, and banks should inform capacity development efforts to maximize knowledge sharing among all parties.

Labeling programs may benefit from consolidation; however, this will be difficult because LEED and GRIHA appear to be direct competitors, and the BEE Energy Star program has yet to realize significant market demand. If label consolidation is not possible, the national government could instead push label programs to prioritize operational energy use intensity measurements and to transparently incorporate specific energy use information into labels. Financing mechanisms that base incentives on the level of certification achieved, such as the approach used by MNRE, should be expanded.

In general, much stronger financial incentives and bank financing support for whole-building efficiency efforts will likely be needed to drive market demand to levels necessary for widespread building energy-efficiency measure uptake. The expansion of incentive programs should follow the MNRE's lead in targeting multiple actors in the building supply chain, including the suppliers of building efficiency inputs.

The current urban building construction boom in India is likely to continue into the long-term future; this presents both opportunities and challenges. On the one hand, it means that India still has some time to improve current policies and work toward creating integrated policy packages. On the other hand, urbanization is a difficult and expensive process, and urban leaders will likely have to balance many different priorities with limited financial resources. Building energy policies from other regions may only offer limited lessons as India faces dramatically different physical, economic, and political contexts than historical code leaders such as Europe and the United States. However, successful implementation of

codes in India is of global interest. Well-documented experiences over the coming years will undoubtedly provide vital lessons to the global community regarding the high-speed development, deployment, and iterative refinement of building energy-efficiency policies relevant to industrializing countries.

Chapter 6 - Case Studies of Best Practices

6.1. U.S. Best Practice Case Studies

6.1.1. ENERGY STAR Buildings: A Platform for Driving Energy Efficiency in Existing Commercial Buildings in the United States

The primary barriers to improving the energy efficiency of commercial buildings in the United States include lack of information and awareness of building energy consumption relative to other similar buildings (e.g., building of similar size and use); lack of knowledge of the most effective measures to increase building energy efficiency; split incentives between building owners and tenants; and misperceptions about the cost, convenience and savings associated with energy-efficiency upgrades. The U.S. Environmental Protection Agency's (U.S. EPA) ENERGY STAR Buildings Program provides a framework and a series of tools to address these barriers and drive greater investments in energy efficiency in existing commercial buildings. The reach and impact of the program has increased as program elements have become a platform for ratepayer-funded efficiency programs and, increasingly, a crucial element in the mandatory building energy use rating and disclosure policies.

The ENERGY STAR Buildings Program leverages the widely-recognized ENERGY STAR brand which is used to label energy-efficient consumer products (e.g., appliances, electronics, lighting, etc.) in the United States and many other countries around the world. In the United States, the scope of the ENERGY STAR program extends beyond product labeling and includes programs for new homes, home retrofits, commercial equipment (e.g., food service equipment, commercial HVAC systems, etc.), and commercial building energy management.

6.1.1.1. Description of U.S. ENERGY STAR Buildings Program

U.S. EPA launched the ENERGY STAR Buildings Program in the late 1990s as a voluntary public-private partnership designed to take the success of the Green Lights Program to whole building efficiency improvements. The program brings together a suite of tools designed to address the barriers to greater investment in energy-efficiency improvements in existing commercial buildings and to build demand for better building energy performance. The program consists of four core elements, each targeting a particular barrier or market need.

ENERGY STAR Portfolio Manager and Performance Score

Early in the program, U.S. EPA and its initial program partners realized that they needed a tool for benchmarking building energy consumption. Without a benchmarking tool, the program could not readily identify the best-performing buildings in terms of energy intensity or compare the performance

of buildings of different physical characteristics and usage patterns. Working with data collected by the U.S. Department of Energy, U.S. EPA developed and introduced the ENERGY STAR Portfolio Manager (described above in Chapter 2, Section 2.3.2.).

Building owners and managers use Portfolio Manager to better understand the energy performance of individual buildings or an entire portfolio of buildings, identify underperforming buildings in need of attention, and verify efficiency improvements including savings from changes made to operations and maintenance practices. Initially developed to benchmark commercial office buildings, Portfolio Manager has been expanded and can now be used to benchmark fifteen non-residential building types including hotels, hospitals, K-12 schools, retailers, and data centers, among others. In addition, the tool is widely used for a number of building types for which performance scores are not currently available.[52] In those cases, Portfolio Manager is used to assess and track the building's energy performance rather than to compare the energy performance of the building to that of others. Automated benchmarking tools allow companies to continuously monitor their building's energy performance and track their energy performance score without ongoing manual data entry.

ENERGY STAR Buildings Label

Commercial buildings with an ENERGY STAR Performance Score of 75 or higher (i.e., the building outperforms 75% of similar buildings) are eligible for the ENERGY STAR Buildings Label. To earn the label, building energy performance must be certified to U.S. EPA and the building must meet certain standards for indoor air quality. The ENERGY STAR Buildings label offers building owners and managers recognition for their energy management efforts and incentives to improve the energy efficiency of underperforming facilities. For investors and tenants, the label has become a widely-recognized and easily-understood symbol of energy efficiency. Qualified buildings receive an ENERGY STAR Buildings plaque for display in the building, providing additional recognition for the building owner and further expanding visibility and awareness of the program. Information on the label includes the year when the building was qualified for the ENERGY STAR recognition. To hold onto the ENERGY STAR designation, the building must demonstrate continued top performance through ongoing annual certification.

Financial Evaluation Tools

One critical barrier to greater investment in energy-efficiency upgrades and improved energy management is a lack of awareness or misconceptions about the potential financial benefits. Building owners and managers may believe that the benefits from efficiency improvements accrue mainly to building tenants or that the savings are not interconnected to their bottom line. To address this barrier,

[52] Performance scores require sufficient data to establish a valid comparison of an individual building to similar buildings across the United States. For some building types, obtained data are insufficient to generate a statistically rigorous analysis. U.S. EPA is adding additional building types as more data become available.

U.S. EPA developed a set of free financial evaluation tools[53] to help make the business case for better building energy performance:

- The **Financial Value Calculator** presents energy investment opportunities through key financial metrics, which are customized for specific commercial market sectors. For example, commercial real estate users can calculate changes to net operating income, earnings per share, and market valuation. The calculator generates reports that can convey the value accumulated as a result of improved energy performance to senior financial decision makers, investors and other stakeholders.
- The **Cash Flow Opportunity Calculator** helps decision-makers determine the impact of energy-efficiency investments on the company's cash flow by considering projected savings, comparing current financing options to future cash payments, and addressing other cash flow issues.
- The **Building Upgrade Value Calculator** is designed especially for office properties and it estimates the financial impact of the proposed efficiency investments. U.S. EPA developed this tool together with the U.S. Building Owners and Managers Association, which has actively promoted this tool to their members.

Technical Assistance Resources

Through the ENERGY STAR Buildings Program, building owners and managers have access to the tools to help them establish improved energy management practices. U.S. EPA has published *Guidelines for Energy Management* and an *Energy Management Assessment Matrix* (U.S. EPA, 2012) as well as "how-to" guides on forming effective energy teams and other topics. These resources introduce and support a strategic energy management framework to help building owners and managers set goals, prioritize opportunities, and establish management practices. The *Building Upgrade Manual* (U.S. EPA, 2008) guides users through a recommended sequence of building performance assessment, retro-commissioning (largely operations and maintenance improvements), load reduction, and equipment upgrade.

6.1.1.2. ENERGY STAR Buildings Program's Role in Ratepayer-Funded Energy-Efficiency Programs

As of January 2012, a growing number of energy-efficiency programs across the United States have incorporated ENERGY STAR Buildings Program into their commercial sector programs, as shown in Table 6-1. In most cases, program managers work with participants to benchmark buildings, identify facilities with the greatest opportunities for energy-savings and the facilities qualified for the ENERGY STAR Buildings label, establish priorities, and drive participation in relevant incentive and/or technical assistance programs offered by the program administrator. A number of programs have also used ENERGY STAR benchmarking to drive competition for improved energy performance among building

[53] The financial analysis tools discussed here can be downloaded from the ENERGY STAR website: http://www.energystar.gov/index.cfm?c=assess_value.financial_tools

owners. Some programs offer automated benchmarking services that allow customers to submit electronically their monthly energy consumption data to U.S. EPA; in return, the customers receive their ENERGY STAR performance scores, weather-normalized energy use intensity benchmarks, and carbon emissions estimates for ongoing tracking and continuous energy management.

In 2010, U.S. EPA launched the Building Performance with ENERGY STAR (BPwES) as a pilot program with eight program partners. Modeled on the Home Performance with ENERGY STAR program, BPwES is intended to serve as a framework to encourage more programs to adopt comprehensive whole buildings performance programs using the ENERGY STAR Buildings Program platform. Results of the initial pilot effort will be released soon.

Table 6-1. Number of Programs and List of States with Programs Utilizing the ENERGY STAR Buildings Platform

Type of Program	Program Sponsors	States with Programs
Benchmarking with Portfolio Manager	36	AR, AZ, CO, CT, DC, IA, ID, IL, MA, MD, ME, MI, MN, MT, NC, NE, NH, NJ,NM, NV, NY, OH, OR, PA, RI, SC, TX, WA, WI
Automated Benchmarking Service	10	CA, ID, IL, NY, WA
Building Performance w/ENERGY STAR	7	IL, MA, NJ, WI

6.1.1.3. Building Energy Use Rating and Disclosure Policies

Since 2007, two states and five large cities in the United States have passed legislations that require benchmarking and disclosure of building energy ratings. The legislations cover an estimated 60,600 buildings and more than four billion square feet (more than 371 million square meters of space) (Institute for Market Transformation, 2011b). Each jurisdiction requires the use of ENERGY STAR Portfolio Manager as the standard for benchmarking (see further discussion of these policies in Chapter 2, Section 2.3.2.1.). Through these policies, state and local governments in the United States can leverage the federal resources to collect data on building energy consumption and to develop and disseminate Portfolio Manager to help meet their energy-efficiency objectives. For states and municipalities, rating and disclosure requirements are low-cost policies, making this an important tool in reducing energy consumption and in addressing climate change at a time that state and local governments across the United States are facing budget constraints.

State and local governments are pursuing benchmarking policies as a way to verify the energy-savings from publicly-funded retrofit programs, to develop an energy performance database for their building stock in order to guide informed decision-making concerning programs and investments, and to promote awareness of building energy performance in building purchase and lease, as well as financing transactions.

6.1.1.4. Program Impacts and Lessons Learned

Since the first ENERGY STAR building was labeled in 1999, the energy performance of more than 200,000 buildings has been assessed using Portfolio Manager. These buildings represent more than 1.86 billion square meters of space—over 25% of total U.S. commercial sector floor space. Of the buildings assessed, more than 12,600 (1.94 million square meters) have a certified Energy Performance Score of 75 or higher and have earned the ENERGY STAR label. Program participation continues to ramp up—in 2010, more than 6,200 buildings earned the ENERGY STAR, an increase of almost 60% over 2009. Buildings with the ENERGY STAR label can signify large energy savings compared with typical buildings: 10% of all ENERGY STAR certified buildings use 50% less energy than typical buildings (U.S. EPA, 2011a). Figure 6-1 shows the growth in ENERGY STAR benchmarking and certification since program launch.

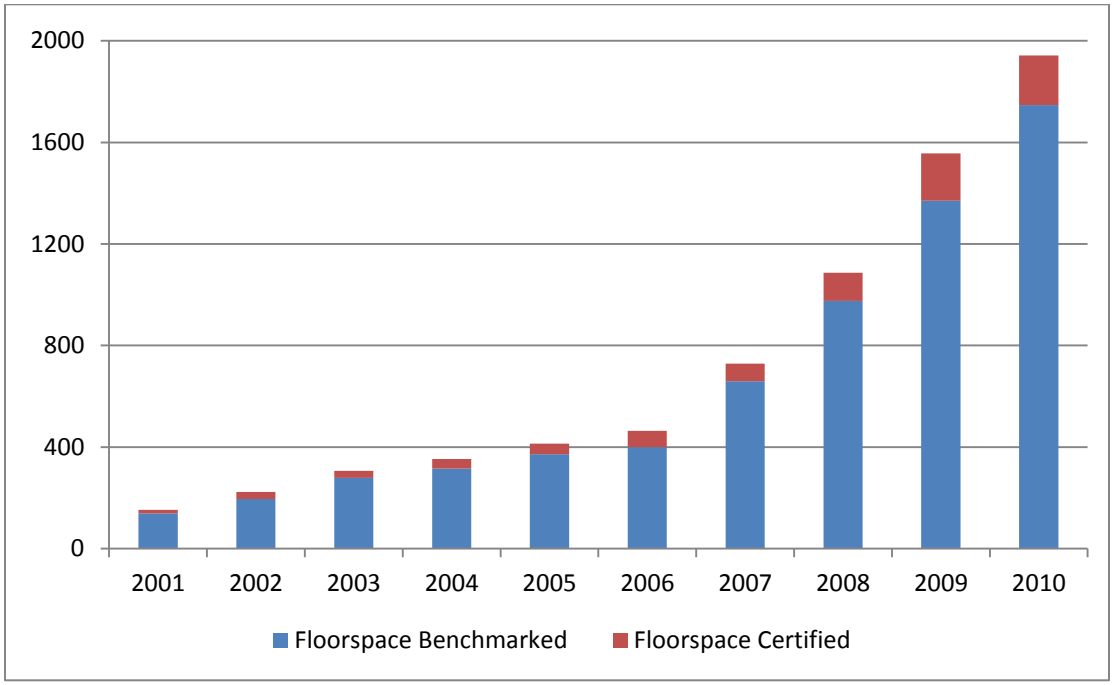


Figure 6-1. Building Space Benchmarked and Certified (million square meters)

Source: (U.S. EPA, 2011a)

Of the buildings benchmarked to date, more than 8300 have improved their energy performance score by 10 points or more, and as a growing number of building owners work to benchmark their entire portfolio of properties, at least one firm has achieved a 50% portfolio-wide improvement in energy performance (U.S. EPA, 2011a). As of 2009, U.S. EPA estimates the program prevented emissions of nearly 120 million metric tons of carbon dioxide equivalent, equal to the emissions from the electricity used by more than 60 million American homes per year. As mandatory benchmarking and disclosure policies ramp up, the program's impact will increase substantially.

In the absence of an in-depth national evaluation of the program, it is difficult gauge the overall impact of the program and its effectiveness. However, it is possible to draw conclusions on the program strengths and weaknesses based on its market penetration.

Further evaluation of the program is needed to understand the extent to which participation (e.g., benchmarking with Portfolio Manager, use of financial calculators and other tools, engaging in utility-sponsored programs using the ENERGY STAR Buildings Platform, etc.) drives investments in energy efficiency through changes to building O&M, energy management practices, and/or equipment upgrades. Evaluations of several ratepayer-funded efficiency programs using the platform suggest that the program can increase customer engagement and drive increased participation in incentive programs, despite the fact that these evaluations are on relatively small sample sizes or on short cycles of program.

There is evidence that the label is having a real impact in the marketplace. Recent studies prove the perceived value of the ENERGY STAR rating in the commercial buildings market. Six studies that compared the ENERGY STAR buildings with similar non-labeled buildings have found that ENERGY STAR buildings carry a rental rate premium, sale price premium, and/or occupancy premium. Figure 6-2 summarizes the findings of six studies.

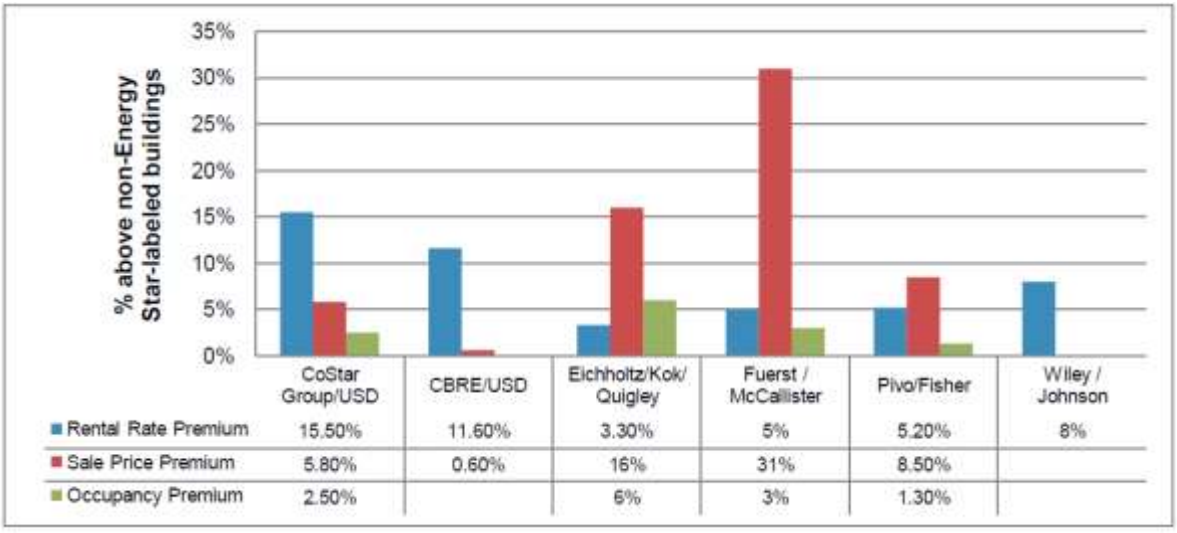


Figure 6-2. Summary Findings from Studies on Market Premiums for ENERGY STAR Buildings

Source: (Institute for Market Transformation, 2011b)

6.1.2. California: Leading the Way on Buildings Energy Efficiency

Since 1970, energy use trends in California and in the rest of the United States have diverged. While California's overall energy consumption has followed a similar growth trend shared by the United States as a whole, its per capita energy consumption has declined. In the buildings sector, California's growth in per capita electricity use since 1970 has been only one-third of that of the United States as a whole. Its

electricity consumption has increased by 42% between 1970 and 2009, compared with 127% for the United States as a whole (U.S. EIA, 2011).

Figure 6-3 shows the trends in per capita electricity consumption for the residential and commercial buildings in California and the United States.

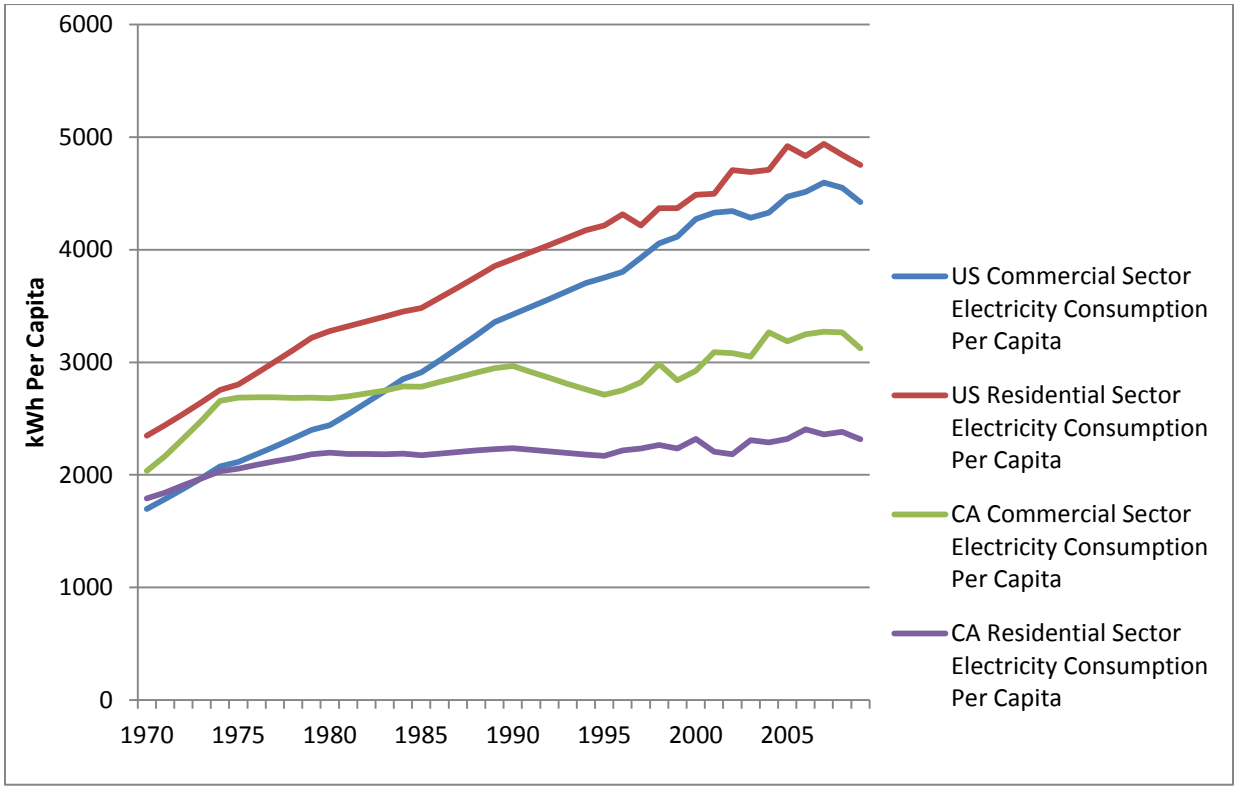


Figure 6-3. Comparison of Per Capita Electricity Consumption for the United States and California

Source: (U.S. EIA, 2011)

California's success stems from a long-term commitment to energy efficiency and its efforts in developing and implementing statewide policies and programs to address energy efficiency with a particular emphasis on the buildings sector. Over the decades, the state has revised and expanded these approaches to keep up with the evolving economic and social trends driving energy use in the state. Early policies enacted in the 1970s had established state-wide building codes and appliance standards; utilities in California also offered their first ratepayer-funded efficiency programs. In the 1980s, a revenue decoupling mechanism[54] was designed to remove financial barriers to utility investment in energy efficiency. In the 1990s, a public benefits fund (the Public Goods Charge) was established to

[54] Revenue decoupling refers to the separation of a utility's profits from its sales of electricity as a commodity. Instead, a utility's revenue requirement is met by setting a revenue target, then electricity rates are regularly fine-tuned to meet that target. There are a number of regulatory mechanisms that achieve this result. A commonly used approach is to establish a "revenue per customer" formula and use periodic true-ups based on actual energy sales (ACEEE, 2012).

provide additional funding to efficiency programs. Since 2000, a series of energy-efficiency and climate policies have been enacted that introduce performance incentives to utilities, establishing a "loading order" that requires utilities to pursue all cost-effective efficiency resources available before putting investment in boosting energy supply (with renewables as a favorable source of supply, and setting aggressive targets for statewide carbon emissions reductions and utility-sector carbon emissions. Table 6-2 shows the timeline of the most important policy developments.

Table 6-2. Key California Policies Driving Energy Efficiency

Year Enacted	Policy
1977	Appliance efficiency standards (Title 20).
1978	Building efficiency standards (Title 24).
1982	Utility decoupling (mechanism suspended 1996-2003).
1996	AB 1890 Electricity public goods charge; AB 995 extended charge in 2000.
1999	AB 1002 Natural gas public goods charge.
2000	AB 995 Loading order makes energy efficiency a priority resource.
2004	Utility decoupling resumes; utility performance incentives begin.
2006	AB32 Greenhouse gas emissions targets.
2006	AB 2021 Mandate for all cost-effective energy efficiency; energy efficiency savings targets.

California's major efforts in improving building energy efficiency include: statewide building energy codes, appliance standards as well as long-term, sustainable ratepayer-funded electricity and natural gas efficiency programs. The California Energy Commission (CEC) estimates that from 1975 through 2003, these efforts resulted in energy savings of nearly 40,000 GWh of electricity, equivalent to 15% of statewide electricity use in 2003 (CEC, 2005). Building codes and appliance standards accounted for just over half of the savings and the remainder came from utility-administered efficiency programs. In recent years, savings from efficiency measures have accelerated from 582 GWh in 1998 to more than 5,000 GWh in 2010 as the level of investment continued to increase, bringing the overall electricity savings to more than 60,000 GWh (Martinez, Wang, & Chou, 2010; CEC, 2012). Natural gas savings over this period yield additional economic and environmental benefits.

6.1.2.1. California's Building Energy Codes

In 1978, California became the first state in the United States to enact a statewide building energy code (California Title 24, Part 6). Title 24 establishes prescriptive and mandatory guidelines for construction methods, materials, equipment, and controls that are used in new construction and major retrofits. Unlike most other states, Title 24 is not based on the national model codes. The CEC institutes a stakeholder-driven public rulemaking process to update and revise the code on an approximately three year cycle.

This standard applies to new residential and commercial buildings, renovations and/or additions to existing buildings, and is based on building design. Permits are contingent on if the building's design has met prescribed criteria. However, inspectors have to visit the building to ensure it was built as designed before the final certificates of occupancy can be issued.

Stringency

California's building energy codes are considered to be among the most aggressive and better enforced building energy codes in the United States, and they have been a powerful vehicle for advancing energy-efficiency standards for building equipment. The most recent code (the 2008 Standards), effective January 1, 2010, is mandatory statewide and exceeds 2009 IECC standards for residential buildings and meets or exceeds ASHRAE/IESNA 90.1-2007 for commercial buildings. Although Title 24 is considered the most stringent t energy code in the country, California allows for local adoption of more stringent codes contingent upon approval by the CEC. As of May 2010, eleven cities and five counties had adopted—and the CEC approved—more stringent requirements than those in the 2008 Standards. Many Title 24 specifications are performance-based, offering flexibility in building design. Although California allows builders to use either a prescriptive or a performance approach to comply with Title 24, the performance approach is used much more widely. As of 2003, more than 90% of the new homes were built to comply with performance standards (Benningfield & Hogan, 2003).

In January 2011, California became the first state to require new buildings—residential and non-residential—to comply with mandatory green building standards. The 2010 California Green Building Standards Code (CALGREEN)[55] requires a 20% reduction in indoor water use, a separation of water meters for indoor and outdoor water use (for commercial buildings), diversion of 50 percent of construction waste from landfills, mandatory inspections of energy systems in commercial buildings larger than 9290 square meters, and the use of low-emissions interior finishes (e.g., paints, carpets, vinyl flooring, and particle board), among other provisions. The California Air Resources Board estimates that the mandatory provisions of CALGREEN will reduce greenhouse gas emissions by 3 million metric tons in 2020, helping California meet its state goal of 33% reduction in GHG emissions from 2010 to 2020.

In addition to the state's formal code requirements, California has established goals for zero net energy new construction. Announced by the California Public Utility Commission (CPUC) in 2008 as part of the state's Big Bold Energy Efficiency Strategies, the goals call for all new residential construction in California to be zero net energy by 2020, and for all commercial new construction to meet the same goal by 2030. The CPUC defined a zero net energy building as one that "employs a combination of energy-efficiency design features, efficient appliances, clean distributed generation, and advanced energy management systems to result in no net purchases of energy from the grid." The zero net energy goals serve as aspirational targets to inspire residents and engage market actors to work toward a clear and aggressive, yet achievable goal. At this point, the goal remains an aspirational target; the zero net energy levels are not yet codified in building codes or other mandatory requirements, despite the fact that the state is developing interim codes that constitute a pathway to make zero net energy codes feasible by 2020 and 2030.

[55] The full text of the 2010 CALGREEN Code is available for download: http://www.documents.dgs.ca.gov/bsc/CALGreen/2010_CA_Green_Bldg.pdf

Given California's size and its long history of enacting leading energy-efficiency policies and programs, the state is well-positioned to develop and implement their own codes. State agencies can build on their own resources and experience as well as those of a sophisticated community of utilities, energy efficiency advocates, consultants, and others. Other states with fewer resources and less experience may find it more difficult to pursue their own standards development process. Recent advances in national model codes make it easier for other states to adopt codes, allowing states to focus more on compliance and enforcement activities.

Compliance and Enforcement in California

Code enforcement in California is conducted at the local level: there are building departments in each of the state's 536 city and counties. Online training is available at www.energyvideos.com.

A concerted education and training effort was undertaken in response to a 2005 survey that estimated overall compliance at 70% and showed that compliance varied widely for different aspects of the code, ranging from 28% non-compliance for hardwired lighting in residential buildings to 100% non-compliance for ducts in commercial buildings (Quantec, 2007). Utilities, CEC staff, and local organizations and trade groups now provide training to building departments as well as to contractors and homeowners. Education and training resources include: an energy hotline run by CEC staff; design manuals; utility-sponsored training programs; and training programs for builders offered by the Building Industry Association and funded by U.S. DOE.

Unlike many states, California allows utilities to claim credit for savings associated with codes and code-related activities. Since 2000, utility involvement has increased in the development and implementation of codes and standards. Over the 2006–2008 program cycle, the investor-owned utilities (IOUs) spent more than $8 million on codes and standards activities; and for the first time they were able to claim savings attributable to these activities. Total savings from the IOU codes and standards activities account for 8% to 9% of electricity savings goals, 11% to 12% of demand reduction goals, and 9% to 17% of gas savings goals (York, Kushler, & Witte, 2008). Projected IOU expenditures for the 2010–2012 program cycle are substantially higher at$30.4 million (CPUC, 2010). Utility activities include research on potential new design practices and technologies for new codes, campaigning to influence the code development process, and developing training and tools for building departments and the building industry/trades.

6.1.2.2. California's Ratepayer-Funded Energy Efficiency Programs

California serves as a robust example of how purposeful policy drivers combined with a few particularly relevant economic conditions can effectively engage large utility sector to put more investments in buildings energy efficiency.

Program Budgets and Expenditures

As a result of the energy efficiency and climate policies outlined above, investor-owned and public utilities in California are investing more than ever in programs targeting the buildings sector. From 1998 to 2008, IOU investment alone increased from about $210 million to more than $1 billion. Publicly-owned utilities (POUs) are also ramping up their efficiency budgets: expenditures grew from less than $60 million in 2006 to $166 million in 2010 (Martinez, Wang, & Chou, 2010).
Error! Reference source not found. summarizes recent utility expenditures on residential and ommercial sector energy efficiency.

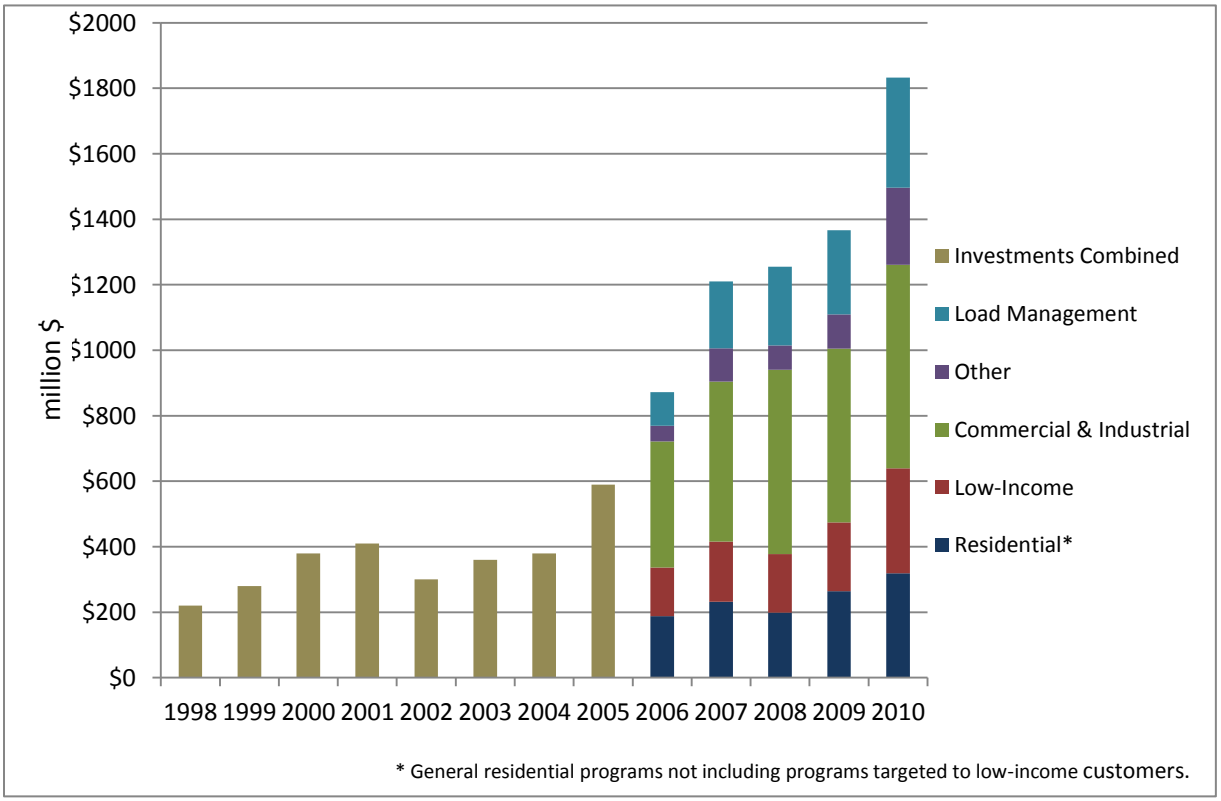


Figure 6-4. California's Utility Efficiency Program Expenditures

Source: (Martinez, Wang, & Chou, 2010) and (CEE, 2010)

Program Portfolio

The utilities have developed robust program portfolios to meet their efficiency goals. In addition to support for state building codes and appliance standards, discussed above, a wide array of programs target end-use consumers as well as trade allies (e.g., architects, builders, engineers, contractors, distributors, manufacturers, installers, retailers, etc.) to advance the adoption of energy-efficient technologies, practices, and behaviors.

During the early years of demand-side management (DSM) in the 1980s and 1990s, rebate programs providing incentives for the purchase of high efficiency products were the major emphasis of utility

programs. Since that time, program portfolios have broadened their reach to work with consumers and other market actors to expand the market for energy efficiency using both resource acquisition and market transformation approaches.[56] The evolution in program design has allowed for more sophisticated offerings that address more complex building systems, comprehensive retrofits, a much wider range of efficiency products and services (e.g., programs targeting operations and maintenance improvements in commercial buildings, including the ENERGY STAR Buildings platform, as well as high efficiency equipment upgrades), and a broader range of customers including hard-to-reach or underserved market segments. Program offerings for the 2010–2012 program cycle are summarized in Table 6-3.

Table 6-3. Sample California Utility Program Portfolio, 2010–2012

Program Type	Sample Offerings
Residential Retrofit	Appliance and consumer electronics rebates HVAC rebates and quality control/maintenance Home energy audits and information Direct installation of energy efficiency measures Comprehensive whole-house retrofits Upstream programs
Residential New Construction	Single-family, multi-family and manufactured housing Green building practices
Non-Residential Retrofit	Rebates and other financial incentives Technical assistance and energy audits Direct installation of energy efficiency measures Continuous energy savings Benchmarking On-bill financing Upstream programs
Non-Residential New Construction	Design assistance Owner and designer team incentives Green building practices
Emerging Technologies	Increase adoption and supply of new energy-saving technologies
Codes and Standards	Code/standards proposal development and advocacy Code compliance assistance
Local Government and Higher Education Partnerships	Retrofits Benchmarking Financing
Workforce, Education and Training	Training Needs assessments
Marketing, Education and Outreach	Statewide/local/multi-lingual marketing and rural education Integrated program outreach and central web portal School education programs
Competitive Solicitations	Innovative technologies and programs Harder-to-reach markets and specialized programs
Pilot Programs	Exploration of new programs and technologies to expand portfolio scope and comprehensiveness

[56] A *resource acquisition* approach focuses on the "generation of energy savings which are sufficiently reliable, predictable, and measurable to replace supply-side options in the planning process" (Eto, Prahl, & Schlegel, 1996). The most common resource acquisition activity is customer rebates. A *market transformation* approach focuses on strategic interventions in a market to create lasting change in market behavior by removing identified barriers or exploiting opportunities to accelerate the adoption of all cost-effective energy efficiency as a matter of standard practice.

Savings and Cost-Effectiveness

Investments in more aggressive efficiency programs have resulted in significant energy-savings for the state of California. Savings from efficiency programs have tracked the policy climate in California:

- **1976 to 1995:** Savings from energy efficiency ramped up as the first codes and standards took effect and utilities increased their investments in DSM programs in response to decoupling rules. Savings increased steadily to a peak of around 1,900 GWh in 1984. In the late 1980s, annual savings declined to less than 1,000 GWh, but rebounded in 1991 and again peaked at close to 1,900 GWh in 1994.
- **1995 to 1999:** With the advent of utility deregulation in the mid-1990s, energy-efficiency programs were put on hold and savings dropped precipitously, falling below 500 GWh in 1999.
- **2000 to present:** In response to the electricity crises in 2000 and 2001, California introduced a series of policies to re-establish energy efficiency as a high priority for the state. The restoration of decoupling, introduction of utility performance incentives, adoption of a loading order favoring efficiency and other policies highlighted above resulted in renewed utility investments in energy efficiency. For the 2002–2006 period, annual electricity savings from IOU programs exceeded 0.5% of annual electricity sales (in 2005 savings approached 1% of sales). Since 2007, IOU program savings have exceeded 1% of annual electricity sales. Savings from POU programs also ramped up each year, exceeding 0.5% of sales for the first time in 2008. These savings translated into more than 2,600 GWh in 2008 and another 3,400 GWh in 2009, far exceeding earlier savings peaks.

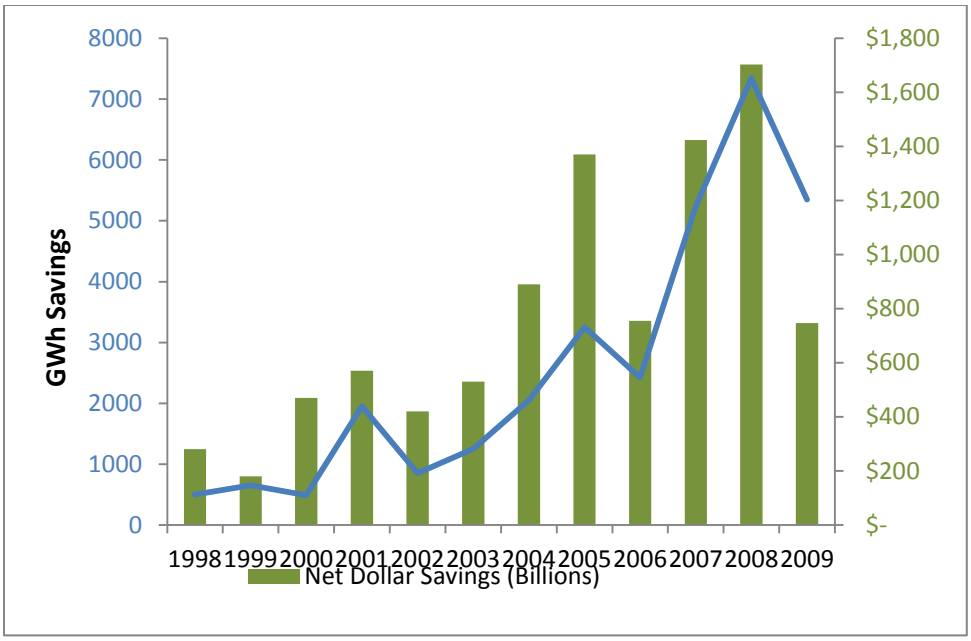


Figure 6-5. Energy and Dollar Savings from Ratepayer Funded Efficiency Programs in California[57]

[57] Data compiled from annual energy efficiency reports submitted to CPUC by California investor-owned utilities available at: http://eega2006.cpuc.ca.gov/DisplayAnnualReport.aspx

6.1.3. PlaNYC: Buildings Energy Efficiency as a Core Component of Comprehensive Climate and Community Revitalization Policy

In 2007, the municipal government of New York City (NYC) released PlaNYC,[58] a comprehensive approach to meeting aggressive greenhouse gas reduction targets while improving the sustainability and vitality of neighborhoods and communities throughout the largest city in the United States. PlaNYC laid out the city's goals for greenhouse gas reductions:

- 30% citywide greenhouse gas reductions by 2030 relative to 2005 emissions levels; and
- 30% city government greenhouse gas reductions by 2017 relative to 2005 levels.

To meet these goals, the city government has engaged 25 city agencies in more than 125 individuals initiatives, most of which had been launched as of early 2011.

Given its density and heavy use of mass transit, NYC's per capita carbon emissions are only one-third the United States' average; it also ranks among the lowest in per capita greenhouse gas emissions of major global cities. Despite its performance relative to the rest of the country, the city government has recognized the potential for further reductions and the important role of buildings in its efforts to meet its emissions reduction goals. The buildings sector is responsible for 75% of NYC carbon emissions; any effort to reduce emissions would focus heavily on the buildings sector.

To that end, the city enacted the Greener, Greater Buildings Plan (GGBP), a set of four key policies to increase the energy efficiency of larger buildings, and launched the Green Codes Task Force, an effort to update and strengthen building codes covering new construction and renovations. In addition, PlaNYC includes initiatives to improve energy code compliance, improve energy efficiency in smaller buildings and in historic properties, provide energy-efficiency financing and information, train workers in energy efficiency, develop and share a knowledge base on energy-efficiency strategies, and exhibit leadership through advanced energy management in NYC government buildings and operations.

6.1.3.1. PlaNYC's Greener, Greater Buildings Plan

A central focus of PlaNYC from its inception has been increasing the efficiency of existing buildings. An estimated 85% of the city's overall real estate in 2030 is already in operation. To improve building energy efficiency, the city passed the GGBP in December 2009 establishing requirements for energy-efficiency upgrades and energy use disclosure for public and private sector buildings.

Energy Use Benchmarking and Disclosure

This section of the GGBP, Local Law 84, requires owners of public buildings over 929 square meters and private buildings over 4645 square meters to benchmark their energy use each year using the ENERGY STAR Portfolio Manager. The law required initial benchmarking data to be submitted to the city by May

[58] The original 2007 PlaNYC document as well as the 2011 PlaNYC update and other reports and materials can be found at: http://www.nyc.gov/html/planyc2030/html/home/home.shtml

1, 2011, and will require ongoing submissions every May 1st thereafter. The law also requires public disclosure of annual benchmarking results on a city-run website. Results for NYC-owned buildings were posted in September 2011; public reporting for all other non-residential buildings and residential buildings is required as of September 2012 and September 2013, respectively.

To gauge the new policy's effectiveness, the law requires the city to conduct studies assessing compliance with the requirements and the accuracy of the benchmarking tool each of the first three years that the law is in effect. A team from the University of Pennsylvania is conducting the first year accuracy study, while New York University is studying compliance (Burr, 2011).

Energy Audits and Retro-commissioning

The next major section of the GGBP, enacted as Local Law 87, requires energy audits and retro-commissioning of all public buildings larger than 929 square meters and all private buildings larger than 4645 square meters. Owners are required to submit an Energy Efficiency Report including both an ASHRAE Level 2 Energy Audit and a Retro-commissioning Report covering all building energy systems: HVAC, electrical and lighting, domestic hot water, building envelope, and conveying systems. The energy audit and retro-commissioning are required every ten years with a staggered compliance schedule (based on tax block number) beginning in 2013, with all buildings submitting Energy Efficiency Reports by 2022. Buildings less than ten years old as of the due date and those with all base systems in compliance with the NYC Energy Conservation Code as certified by a registered design professional as of four years prior to the due date are exempt from the first scheduled compliance deadline.

The law also incorporates some incentives for early compliance and rewards for demonstrated good energy performance. Owners that submit their Energy-Efficiency Report in 2013, prior to the building's scheduled filing date, will not have to file again until ten years after the first scheduled filing (e.g., a building that is scheduled for filing in 2016 but files in 2013, will not have to file again until 2026). Buildings that are qualified for the ENERGY STAR label for at least two of the three years prior to their reporting due date or have earned LEED-EB (LEED for Existing Buildings) certification within four years prior to the due date are exempt from the audit requirements. Buildings that have earned the LEED-EB within the two years prior to the due date and have received both Commissioning Investigation and Commissioning Implementation points are exempt from the retro-commissioning requirement.

Lighting Upgrades and Sub-metering

The final piece of the GGBP legislation, Local Law 88, sets requirements for lighting upgrades and sub-metering of electricity in commercial tenant space in public buildings larger than 929 square meters and all private buildings larger than 4645 square meters. The lighting upgrade component requires lighting systems upgrades in all space types, except residential, by January 2025. For sub-metering, the law requires installation of sub-meters for all floors over 929 square meters and for all non-residential tenants over 929 square meters. It also requires owners to submit monthly electricity statements to all non-residential tenants. Owners must file compliance reports with the NYC Department of Buildings.

In addition to these requirements, the GGBP closed a loophole in the city code that allowed renovations of less than 50% of a building or major system to avoid meeting current energy codes.

6.1.3.2. PlaNYC's Green Codes Task Force

On February 1, 2010, the NYC Green Codes Task Force, led by the Urban Green Council, released a comprehensive analysis of the City's building codes. The Task Force was charged with recommending changes to the laws and regulations affecting buildings in New York, to bring them to the next level of energy and sustainability performance. The report was prepared for the Mayor and City Council by compiling the work of more than 200 leading thinkers in green building. Because the project was conceived by the government New York City, the resulting proposals focus entirely on actions that can be implemented by the city. However, these actions were taken on not only by New York City. Since the report's release, a few of the recommendations have also been acted upon by the federal government and others are under consideration by the state government.

The Task Force's 111 recommendations impact new construction and renovations, and many of them remove current impediments to green practices. The proposals affect building codes as well as other codes, such as zoning, health, consumer affairs, and environmental protection, which aim to create greener, healthier buildings for all New Yorkers. Urban Green Council is now advocating for full adoption of the recommendations. As of February 2012, two years after the release of the report, 29 recommendations had been implemented and an additional eight recommendations are actively under consideration (Urban Green Council, 2012).

The 111 recommendations of the Task Force fall into ten categories based on U.S. Green Building Council (USGBC)'s LEED subject areas and have been modified to include areas of particular interest in New York City. The categories are: Overarching Code Issues (7 recommendations); Health & Toxicity (20); Energy & Carbon Emissions, subdivided into Fundamentals (17), Energy Efficiency (28), and Operations & Maintenance (6); Building Resilience (9); Resource Conservation (5); Water Efficiency (7); Stormwater (7); and Urban Ecology (5). Of the 111 recommendations, 19 are intended to remove existing impediments to green building practices, many of which are specific to the New York City codes. The rest of the recommendations involve enhancing local codes that are often based on national model codes. In these cases, many of the recommendations are applicable to other municipalities. The recommendations from the Energy & Carbon Emissions categories make up nearly half of the recommendations, and Energy Efficiency recommendations alone more than a quarter. Table 6-4 summarizes the energy-related code changes that have been implemented to date.

Table 6-4. Energy-related Code Changes Implemented to Date

Code Change Implemented	Estimated Savings and Payback
Overarching Code Issues	
• Add Environmental Protection as a Fundamental Principle of Construction Codes. • Streamline Approvals for Green Technologies & Projects. • Don't Exempt Existing Buildings from Green Codes.	
Energy & Carbon Emissions: Energy Efficiency	
• Increase Lighting Efficiency in Apartment Buildings. • Use Manual On/Auto Off Lighting. • Reduce Artificial Lighting in Sunlit Lobbies & Hallways. • Increase Lighting Efficiency on Construction Sites. • Provide Ventilation Air Only as Needed in Large Spaces. • Ensure Lighting Systems Function Properly.	• 3 to 10 year payback. • $910/year savings, immediate payback. • N/a. • $41,760 to $1,368,800/year savings, 0.04 to 1.73 year payback.
Energy & Carbon Emissions: Fundamentals	
• Allow Use of Biofuels. • Promote Super-Insulated Exterior Walls. • Allow External Insulation Beyond Zoning Limits. • Increase Allowable Size of Solar Shades. • Minimize Air Leakage through Building Exteriors. • Reduce Summer Heat with Cool Roofs. • Clarify Standards for Attaching Rooftop Solar Panels. • Allow Large Solar Rooftop Installations. • Removing Zoning Impediments to Alternative Energy.	
Energy & Carbon Emissions: Operations & Maintenance	
• Re-tune Large Buildings Every Seven Years. • Measure Electricity Use in Tenant Spaces.	• $188,000/year savings, 3 year payback. • $341,375/year savings, 1.5 year payback.
Water Efficiency	
• Enhance Water Efficiency Standards. • Catch Leaks by Measuring Water Use. • Stop Wasting Drinking Water for Cooling.	• $15 to $7,800/year savings, 3.8 to 28 year payback. • $1,135 to $1,230/year savings, 4.1 to 8.5 year payback. • N/a.

Nearly all of the policies adopted so far have low or no upfront costs with considerable monetary savings potential after the initial payback period. Other than these policies recommendations that have been adopted, there are many more recommendations that will produce greater energy savings and lower energy costs for building residents and owners.

6.1.3.3. Impacts of PlaNYC

It is still too early to evaluate the PlaNYC initiatives' impact on energy efficiency. Laws enacted as part of the Greener, Greater Buildings Plan has yet to take full effect and the code changes will take time to phase in. However, early experience with the new building benchmarking requirements is promising. In November 2011, the city released its initial public report on the 2,730 city-owned buildings benchmarked under the requirements of the GGBP. Owners of private buildings larger than 50,000

square feet were required to submit their initial benchmarking scores to the City in May 2011 (the deadline was extended to August, 2011).The City estimates compliance rates of nearly 70%, exceeding most expectations (Burr, 2011). Aggressive efforts by contractors to market benchmarking services resulted in significant outsourcing of private building benchmarking, which costs at $500 to $1500 per building. Many firms are encouraging building owners to work with them on benchmarking now to help them prepare for the upcoming audit requirement deadlines.

Three out of the four GGBP laws only impact the city's largest 16,000 properties, both public and private. Yet these buildings account for roughly half of citywide building floor space and 45% of citywide greenhouse gas emissions. By 2030, the City estimates these laws will reduce GHG emissions by at least 7.5% citywide (4.5 million metric tons of CO_2e per year by 2030) and save New Yorkers more than $750 million annually. In addition, the City estimates the laws will create almost 18,000 construction-related jobs over ten years.

6.1.4. Indicators of Best Practices from U.S. Case Studies

ENERGY STAR Buildings

The ENERGY STAR buildings program created and implemented by the U.S. Environmental Protection Agency (U.S. EPA) certifies a building as "energy efficient," meaning in the top quartile of existing buildings. To provide a basis for this certification, U.S. EPA developed a tool (Portfolio Manager) that, after being fed large data sets of characteristics and energy use of commercial buildings, provides a basis for comparing the actual energy performance of any one specific building to peer buildings. This process, along with the accompanying ENERGY STAR label, provides important information to inform decisions on the desirability of retrofits for specific buildings. Portfolio Manager represents a shift from theoretical energy savings (i.e., estimates based on calculations) to the real world (i.e., actual savings based on energy bills and metered data). This approach helps owners recognize savings from improved operations and maintenance (O&M) and encourages continuous focus on sound building energy management.

By engaging commercial real estate firms, private companies, institutions, and public agencies that own or operate massive building fleets, U.S. EPA and its partners have increased the reach of the program. The calculators, tools, and customized messages developed to demonstrate the value of energy efficiency and the metrics that resonate with each target audience have been crucial in driving the program's success.

Finally, the ENERGY STAR Buildings Program demonstrates the value of creating a unified platform (or brand) and a set of tools that the larger energy-efficiency community and a broad set of market actors can disseminate and further develop through their own innovations. A few examples that show the program has been widely leveraged include: growth in utility programs using the ENERGY STAR Buildings platform, adoption of state and local government policies mandating benchmarking, and a marked increase in the number of companies providing benchmarking services as a way to engage their customers.

As a result of these efforts by U.S. EPA and its partners, the energy performance of more than 200,000 commercial buildings, representing more than 25% of commercial sector floor space in the United States, has been benchmarked. Participation continues to grow. The introduction of a credible, accepted national benchmarking tool has made it much easier for state and local governments to adopt mandatory benchmarking and disclosure policies.

California's Statewide Leadership on Energy Efficiency

California has a long history of leadership in energy efficiency stemming from its sustained commitment to comprehensive efficiency policies and, more recently, climate change policies. Over the years, the state has revised and expanded its suite of efficiency policies and programs to keep up with the evolving economic and social trends driving energy use. Coordination among the agencies responsible for administering these policies—the California Energy Commission, the California Public Utilities Commission, and the California Air Resources Board—has been important to the success of these policies.

Mandatory building energy codes for new buildings and appliance efficiency standards that are more stringent than the national standards were first enacted during the 1970. Mandatory benchmarking and disclosure requirements for commercial buildings, now taking effect, will begin the process of systematically addressing existing commercial buildings.

Electric and gas utility ratepayer-funded efficiency programs offer incentives and other types of market support to accelerate the adoption of new technologies and practices, continually feeding the pipeline for more stringent codes and standards. The state's commitment to efficiency has created a policy environment that allows for more rapid and stronger advances in codes and standards levels than in most other states or at the federal level.

The state's commitment to energy efficiency also encourages a broader view of the role of ratepayer-funded programs and the benefits of greater coordination between voluntary programs and mandatory requirements. California's utilities actively use ratepayer funds to identify new opportunities for stronger codes and standards and to advocate for their adoption at the state and federal levels as well as by working with builders, code officials, and the construction trades to improve code compliance and enforcement in California.

The California Energy Commission estimates that energy-efficiency investments in California (including Title 24 building codes and Title 20 appliance standards along with utility efficiency programs) have resulted in an estimated $56 billion in electricity and natural gas savings through 2006, with an additional $23 billion in savings anticipated through 2013. These savings have yielded almost $5 billion in net benefits from avoided generation, transmission, and distribution and natural gas usage – more than $900 million in 2008 alone. Between 2006 and 2008, utility programs generated savings at a cost of less than $0.03/kWh compared with $0.08/kWh for base-load power.

The success of innovative policy and program approaches introduced in California has encouraged state energy officials across the United States to pursue similar policies and programs. California's leadership in energy and environmental policy continues as the state works to meet aggressive goals for zero-net-energy new construction and building retrofits.

PlaNYC: Greener, Greater Buildings Plan

PlaNYC is a comprehensive strategy to address climate change and community revitalization in New York City and an example of how government leadership can leverage private-sector support. Nearly 30 major New York City institutions agreed to match the government's PlaNYC goal to reduce its GHG emissions by 30% by 2017. PlaNYC led to the adoption of the city's Greener, Greater Buildings Plan (GGBP). The city estimates that laws enacted to date under the GGBP will reduce GHG emissions in 2030 by 7.5%. In addition, code changes implemented in the wake of PlaNYC will further reduce GHG emissions by an estimated 4% by 2030.

Early results show that compliance with the initial private-sector benchmarking requirements was much greater in New York City (nearly 70%) than in other cities where requirements were not enacted as part of a comprehensive package, thus drawing much less public awareness and media attention. By comparison, initial compliance with benchmarking requirements in Seattle and San Francisco is estimated to be approximately 30%.

The success of New York City's Green Codes Task Force reflects the importance of collaboration among local government, the non-profit advocacy community, and industry leaders. Because the Mayor and City Council Speaker initiated the project, it attained legitimacy, recognition, and industry buy-in from the outset. The city's Urban Green Council also played a critical role as an independent advisor and convener for the project. That organization has strong ties with both the city government and industry and is viewed as having a practical approach to achieving environmental goals.

Architects and engineers have been essential in identifying ways to improve the code. The real estate industry has provided important feedback on the feasibility of implementing changes in construction and ongoing building operations. Adding credibility to the recommendations, Urban Green Council produces a report that explains and provides support for the rationale for each recommendation. The report also provides statutory language and implementation guidance. This last step, of developing easily understandable explanations along with providing code-level language was one of the most resource intensive yet valuable steps in the process.

6.1.5. Conclusions

The U.S. case studies highlighted here demonstrate that state and local commitments to energy efficiency—to meet goals for environmental protection and economic stability as well as to address local challenges—have led policy makers to pursue innovative policies and more comprehensive approaches to energy efficiency in buildings. Many advocates use examples of comprehensive sets of policies and

programs in states[59] and cities[60] to press for stronger programs at the federal level. These case studies also show the important role the federal government has played in providing a national platform for energy efficiency—the ENERGY STAR brand—as well as credible, consistent tools and a foundation for state, local, and utility-level program and policy development.

[59] California is the most widely recognized as having created and implemented highly successful energy efficiency policies and programs. However, many other states are also recognized as leaders, including Vermont, New York, Massachusetts, Texas, Connecticut, Wisconsin and others.

[60] In addition to New York City, Austin Texas, Sacramento California, Seattle Washington, and Ann Arbor Michigan are all examples of cities with innovative and successful energy efficiency programs.

6.2. EU Best Practice Case Studies

6.2.1. Financing Renovation through Government-backed Loans & Grants– the German KfW Scheme

6.2.1.1. Introduction of KfW Program

On the backdrop of the dual needs to improve energy security and reduce greenhouse gas emissions, the German government has committed to reducing energy demand in buildings by 80% by 2050. Achieving this will require deep thermal retrofits across the existing building stock. One of the main vehicles for financing improvements in the energy performance of Germany's building stock is through the government's development bank, KfW[61].

KfW was formed in 1948 as part of the Marshall Plan. Based in Frankfurt and owned by the Federal Republic of Germany (80%) and the States of Germany (20%), KfW funds its activities almost exclusively via international money and capital markets, mainly through bonds that are guaranteed by the federal government. This allows KfW to raise funds at advantageous conditions. Typically, KfW does not lend directly to enterprises or individuals, but it provides commercial banks with liquidity at lower rates and with long maturities. Thus, loans are accessed through normal retail banks.

The bank lends across a wider variety of areas—from student loans and mortgages to business development and sustainability. In 2010, a total of €81 billion was made available in its core programs.[62] Of this, around €5 billion was for investments in improving the energy performance of existing residential and non-residential buildings.

6.2.1.2. KfW's Energy Performance Improvement Landscape

KfW loans and grants sit within a wider landscape of measures to improve the energy performance of the existing building stock, through energy-efficiency measures, increased deployment of building integrated renewables and connection to district heating schemes. A number of these initiatives emanate from the requirement to comply with EU Directives, notably the Energy Performance of Buildings Directive (EPBD), while others are driven by Federal or State-level goals.

Broadly speaking, there are three main streams of activities:

- legislative measures imposed by government;
- promotional programs, including financial support mechanisms such as KfW; and
- support measures such as raising awareness, knowledge transfer, training, energy performance certificates, etc., which are delivered through various market actors including energy agencies such as the Deutsche Energie-Agentur GmbH (dena)— the German Energy Agency.[63]

[61] KfW was originally called "Kreditanstalt für Wiederaufbau" or Reconstruction Credit Institute
[62] The core programs cover lending primarily within Germany
[63] http://www.dena.de/en/about-dena.html

These three strands, as depicted by Figure 6-6, are working together to mutually reinforce and support each other to create a positive environment to stimulate improvement in the energy performance of the building stock in Germany.

Figure 6-6. Three Complementary Mechanisms to Improving Building Energy Performance[64]

6.2.1.3. How KfW Program Works – Scheme Criteria[65]

A number of previous KfW programs offering loans and grants for CO_2 reduction in buildings were combined in 2007 into the current program entitled "Energy-Efficient Renovation". Energy-efficient[66] renovation is supported by KfW through either a grant or a preferential loan. The level of support is dependent on the resulting energy performance: the more efficient the property after renovation, the higher the level of support. The benchmark for determining the energy performance of the renovated property is the building energy code in force. Thus, a "KfW Efficiency House 100" is a renovation that meets the energy performance of an equivalent new building, while a "KfW Efficiency House 55" (the best performance standard within the scheme) is one that requires just 55% of the energy of an equivalent new build property.

The following tables (Table 6-5 and Table 6-6) provide details of the current level of support for renovation of residential properties, with either a grant or a loan, that are available through KfW.

[64] http://www.iea.org/work/2011/sbn/SBN05_Kraus.pdf
[65] See weblink for details http://www.kfw.de/kfw/en/Domestic_Promotion/Our_offers/Housing.jsp
[66] "energy efficiency" includes building integrated renewables and passive measures such as solar gain/shading.

Table 6-5. Grant Levels under KfW Energy Efficient Renovation Program

Grant as % of total investment	Target level of performance	Maximum grant (€)
20.0 %	KfW Efficiency House 55	15,000
17.5 %	KfW Efficiency House 70	13,125
15.0 %	KfW Efficiency House 85	11,250
12.5 %	KfW Efficiency House 100	9,375
10.0 %	KfW Efficiency House 115	7,500

Alternatively, KfW-approved loans of up to €75,000 per property are available from commercial banks at a preferential interest rate in the range 1%-3%. The banks' decisions on granting loans are based on the quality of the investment, amount of collateral provided, and the applicants' financial position.

For investments that meet one of the five "KfW Efficiency House" standards, there is also a repayment bonus calculated on the loan amount, as illustrated in Table 6-6.

Table 6-6. Loan Repayment Bonus Levels under KfW Energy Efficient Renovation Program

Target level of performance	Repayment Bonus (% of loan)
KfW Efficiency House 55	12.5%
KfW Efficiency House 70	10%
KfW Efficiency House 85	7.5%
KfW Efficiency House 100	5%
KfW Efficiency House 115	2.5%

In all cases, the monetary value of the loan (comprising repayment bonus and level of financial subsidy) is greater than the equivalent grant (Climate Policy Initiative, 2011).

Figure 6-7 below compares the average annual energy consumption of typical existing housing in Germany with two of the KfW standards. For the existing stock, the average energy consumption of houses from three different periods—pre-1918, 1958–68, and 1969–78—are presented, illustrating typical unmodernized, partially-modernized and modernized houses. These are compared with the average KfW Efficiency House 100 standard (equivalent to the current new build requirement).The KfW 100 standard achieves energy-savings of up to 74%, when compared with the unmodernized property.

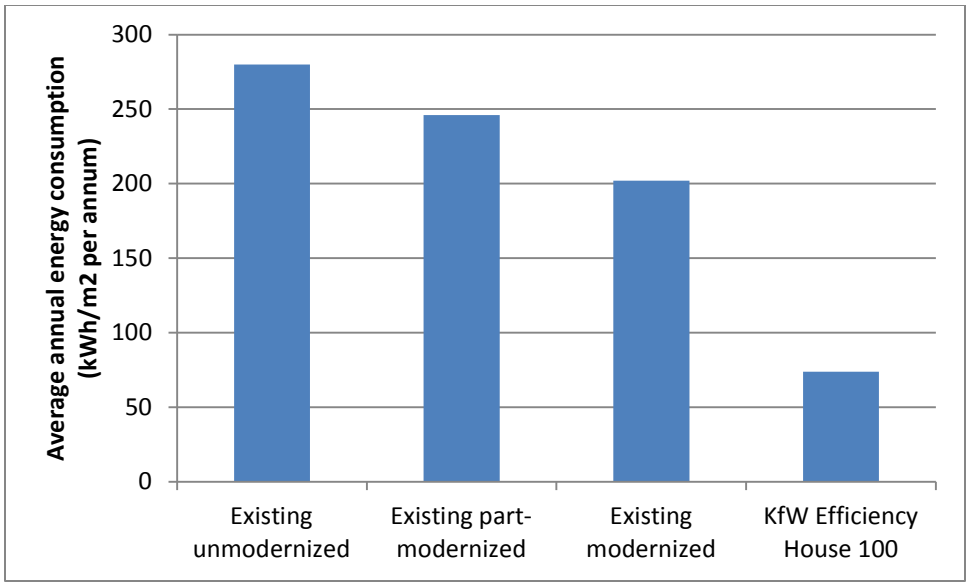


Figure 6-7. Comparison of Energy Consumption of Existing Housing[67]

To ensure loans and grants meet the required standards, a certified energy expert[68] must verify the proposed renovation prior to commencement of works (see Figure 6-8 below). Spot checks after completion of the investment indicate a high level of compliance.[69]

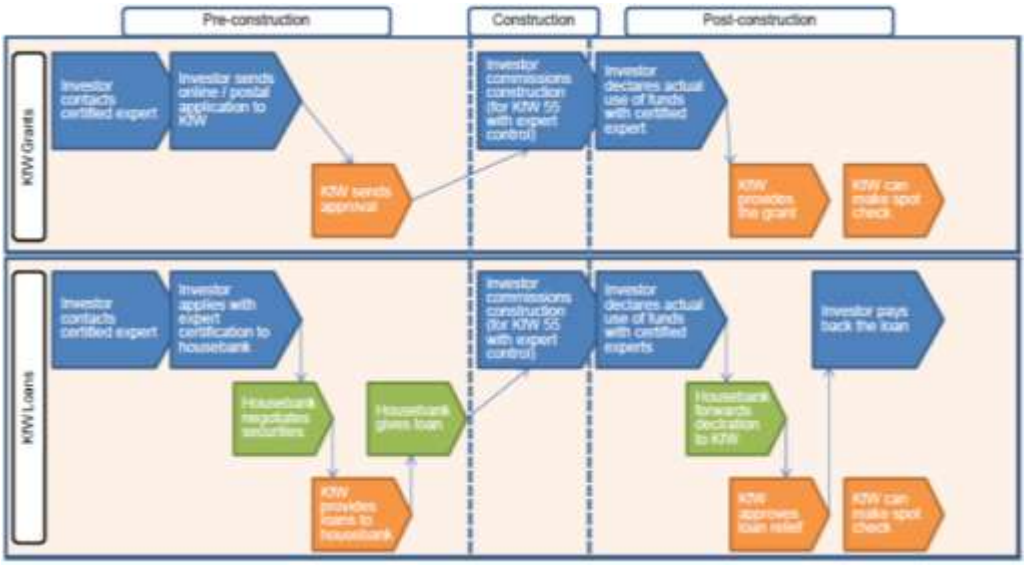


Figure 6-8. KfW Application Procedure for Both Loans and Grants

Source: (Climate Policy Initiative, 2011)

[67] Wohnungsbau in Deutschland – 2011. Modernisierung oder Bestandsersatz. ARGE, 2011

[68] The expert must be approved by a national scheme, or legally qualified to issue an energy performance certificate.

[69] "Using Tax Incentives to Support Thermal Retrofits in Germany", Climate Policy Initiative, 2011

Note that loans and grants are also available for non-residential investments in energy-saving retrofit and construction.

Table 6-7 summarizes the total value of KfW credits for energy-efficient refurbishments and new construction in 2010, together with the amount of private sector funding stimulated. Note that the credits are ultimately returned to KfW in loan repayments, and that the net outgoing from KfW is the figure in the final (costs) column. It can be seen that **approximately €15.50 of investment in energy-saving is generated for every €1 of net cost to KfW.**

Table 6-7. Value of kfW Credits, Costs and Total Investment Stimulated in Energy Efficient Building Sector, 2010

	KfW credits (€M)	Private sector funding (€M)	Total investment in EE measures (€M)	KfW costs* (€M)
Energy Efficient Renovation	5,092	7,042	12,134	785
Energy Efficient Construction and Infrastructure	3,768	5,292**	9,060	581
	8,860	12,334	21,194	1,366

Source: (KfW Bankengruppe, 2011a; KfW Bankengruppe, 2011b)

** KfW costs include management, administration and subsidies (grants & subsidized interest accounting for 13% of total costs in 2010). NB costs have been apportioned* pro rata *across the two programs.*

***This reflects the value of the additional investment cost to achieve the high energy performance rating only, and NOT the total construction cost of the new buildings*

6.2.1.4. Evaluation of KfW Program

During 2011, two studies were undertaken to evaluate different dimensions of the program:

- the Bremen Energy Institute undertook two evaluation studies focusing on energy, carbon and employment impacts of the programs covering public buildings and private homes respectively;[70]
- Forschungszentrum Jülich performed an assessment of the impact on public finances.[71]

The Bremen evaluation of the public sector program identified nearly 1,000 applicants from the period 2007–2010 with a combined investment in energy savings of €625 million, of which €364 million (or 58%) was provided in the form of loans from KfW. Annual delivered energy-savings from these investments are 329,000 MWh (1,184 TJ/yr), reducing greenhouse gas emissions of 116,000t CO_2e per year. For the residential sector, support for the renovation of 340,000 dwellings was granted in 2010, delivering annual energy savings of 2,450,000 MWh/yr and reductions in greenhouse gas emissions of 847,000t CO_2e per year.

[70] Evaluation der KfW-Program „KfW-Kommunalkredit - Energetische Gebäudesanierung“, “Energieeffizient Sanieren – Kommunen“ und „Sozial investieren – Energetische Gebäude-sanierung“ der Jahre 2007 bis 2010. *AND* Monitoring der KfW-Programme „Energieeffizient Sanieren“ 2010 und „Ökologisch / Energieeffizient Bauen“ 2006 – 2010. *BOTH* Bremer Energie Institut (Only available in German)

[71] Impact on public budgets of KfW promotional programss in the field of “energy-efficient building and rehabilitation”, KfW, October 2011 (abridged translation)

Bremen also estimated the total investment of €7.5bn across both programs generated around 100,000 person-years of employment. This equates to approximately 13.5 jobs per €1 million of investment.

The study by Forschungszentrum Jülich GmbH of Jülich Research Centre focused on the impact of the program on public budgets. They calculated the amount of taxes and other revenues accruing to public bodies, together with reduced expenditure on unemployment benefits and the like that were stimulated by the investment in energy-saving measures in buildings. Key figures are summarized in Table 6-8 below.

Table 6-8. Budgetary Implications of KfW Energy Efficiency in Buildings Program

Item	Amount €M	% of Program Costs
KfW Program Costs	1,366	100%
Taxes and levies on materials	2,682	196%
Income tax and insurance contributions from increased labor	2,282	167%
Corporation tax	388	28%
(A) TOTAL (excluding impact of additional employment)	**5,352**	**392%**
Net increase in public funds after deducting program costs	3,986	292%
Reduced unemployment etc. benefits	1,823	133%
(B) TOTAL (including impact of additional employment)	**7,175**	**525%**
Net increase in public funds after deducting program costs	5,809	425%

Note 1 — Total (A) represents the impact assuming all the additional labor is taken up by increased overtime, i.e. with no additional jobs, whereas total (B) assumes all additional labor is down to new employment. The true figure would lie somewhere in between the two.

Note 2 — The table only represents direct investments – if induced investments are taken into account, the public benefit is even greater).

Note 3 — The value of the environmental benefits of reduced CO_2 emissions or increased energy security have not been quantified.

6.2.1.5. Forward Plans of KfW Program

Building on the success of previous years, KfW funds to improve buildings energy efficiency are to be increased to €1.5 billion a year from 2012 to 2014 and additional amortization opportunities are to be introduced in the building sector.

As the building regulations are progressively tightened in anticipation of the requirements to achieve nearly zero energy new buildings in the next decade, efficiency standards will be amended to ensure funding is directed towards savings above and beyond the minimum requirements.

6.2.2. From Passive Houses to Nearly Zero Energy Buildings: How Europe is Slashing New Building Energy Requirements

6.2.2.1. Backdrop of Nearly Zero Energy Buildings (NZEB)

Across the countries in Europe, a mixture of voluntary and mandatory standards is continually driving down the energy requirements of both residential and non-residential new buildings. At the same time, increasing deployment of building-integrated renewable energy systems is further reducing their net energy requirements, leading to progressively lower carbon dioxide emissions. The ultimate goal for an entire new and existing building stock is to achieve zero net emissions. Although such aspiration may not materialize until the second half of 21st century, new buildings with nearly zero net energy requirements will become a reality across Europe within a decade.

The case study in the following subsections examines the role of both voluntary and mandatory measures in driving down the energy requirements of new buildings, discusses how they complement each other on the path toward net zero energy buildings, and introduces the countries that are playing a leadership role on this agenda.

6.2.2.2. The Voluntary Approach of Towards Low Energy Buildings

For over 20 years, voluntary standards for very low energy buildings have been developed in several European countries. One of the earliest initiatives, and now probably the best known globally, is the German *Passivhaus,*[72] or Passive House, standard. Developed in around 1990, it specifies an annual heating requirement of less than 15 kWh/m² (or 4755 Btu/ft²),a level at which conventional heating systems can normally be dispensed with and an annual total primary energy consumption not exceeding 120 kWh/m² (or 38039 Btu/ft²).

Passivhaus has also been adopted as a voluntary standard in other countries throughout Europe, together with more limited uptake in North America and Asia.[73] Figure 6-9 illustrates the growth in the number of *Passivhaus* buildings in ten European countries since 2000, as estimated by the "PASS-NET" project that was funded by the EU's Intelligent Energy Europe program.[74] To date, most Passivhaus buildings have been constructed in Germany (DE) and Austria (AT). Other countries with small but growing numbers include Belgium (BE), Sweden (SE), United Kingdom (UK) and Czech Republic (CZ).

According to PASS-NET, the annual CO_2 savings from the existing approximate 23,500 *Passivhaus* buildings (retrofits as well as new build) is currently 150,000 tonnes of CO_2. That is forecast to grow to 1.4 million tonnes of CO_2 per year by 2015 as the market reaches a quarter million buildings.

[72] http://www.passiv.de/
[73] http://www.passivhausprojekte.de/projekte.php
[74] http://www.pass-net.net/downloads/pdf/report_int-ph_database.pdf

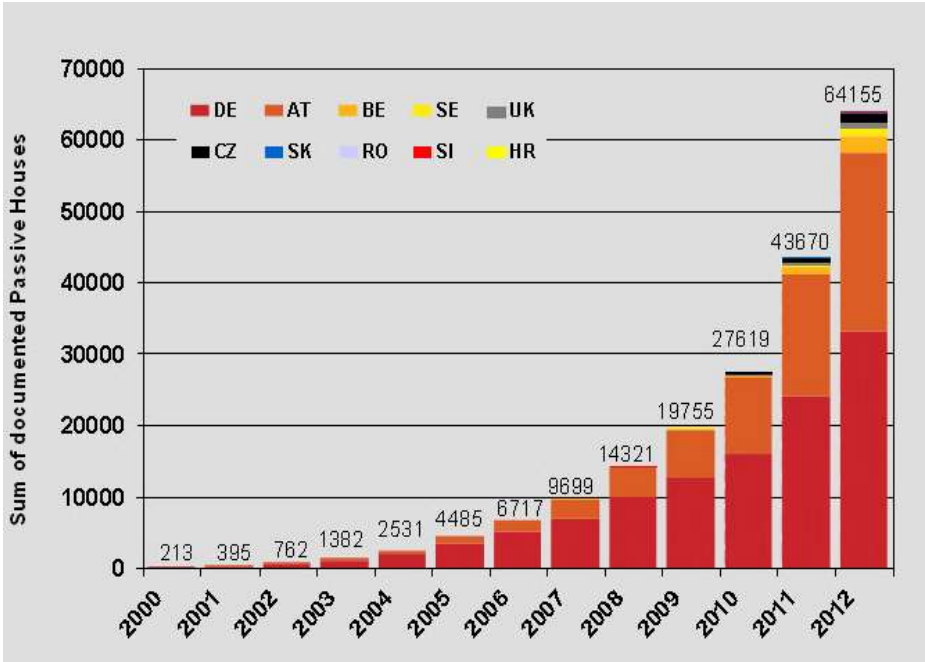


Figure 6-9. Passive House Trend in the 10 PASS-NET Countries

The *Passivhaus* standard is not limited to new buildings. The same design principles have been successfully applied to non-residential buildings, as well as to the renovation of existing buildings. Meanwhile, in Switzerland, Minergie-P is another voluntary example that goes further than the national regulations and incorporates strong branding, labeling and certification.[75] Minergie-P requires a consumption of residential buildings not exceeding 30 kWh/m2 per year.

6.2.2.3. Design Principles of Passivhaus

The *Passivhaus* standard is not determined by a particular style of construction or use of materials. Rather, it sets an energy performance benchmark and leaves the specific technical details to the design team. That said, a number of general design principles still apply (Table 6-9):

[75] http://minergie.ch/

Table 6-9. Passivhaus Design Principles[76]

Compact form and good insulation:	All components of the exterior shell of the house are insulated to achieve a U-factor that does not exceed 0.15 W/(m²K) (0.026 Btu/h/ft²/°F).
Southern orientation and shade considerations:	Passive use of solar energy is a significant factor in *Passivhaus* design.
Energy-efficient window glazing and frames:	Windows (glazing and frames, combined) should have U-factors not exceeding 0.80 W/(m²K) (0.14 Btu/h/ft²/°F), with solar heat-gain coefficients around 50%.
Building envelope air-tightness:	Air leakage through unsealed joints must be less than 0.6 times the house volume per hour.
Passive preheating of fresh air:	Fresh air may be brought into the house through underground ducts that exchange heat with the soil. This preheats fresh air to a temperature above 5°C (41°F), even on cold winter days.
Highly efficient heat recovery from exhaust air:	Most of the perceptible heat in the exhaust air is transferred to the incoming fresh air (heat recovery rate over 80%).
Hot water supply using renewable energy source:	Solar collectors or heat pumps provide energy for hot water.
Energy-saving household appliances:	Low energy refrigerators, stoves, freezers, lamps, washers, dryers, etc. are indispensable in a *Passivhaus*.

6.2.2.4. Where Voluntary Passivhaus has become Mandatory

As the experience of deploying *Passivhaus* in new construction has grown, some authorities have begun to adopt it as a *de facto* standard. This is the case in parts of Austria and Germany, the two countries with the greatest uptake to date. Starting 2010, all social multi-family new construction in Vorarberg, an Austrian province, must meet the *Passivhaus* standard. A number of cities in Germany have also specified similar requirements.[77]

6.2.2.5. Passivhaus Costs

Building a higher energy performance generally comes at a cost, as higher specification materials and designs are required to meet the stipulated standards. There are, however, cost saving opportunities that partially offset these costs, as the very low heating requirement eliminates the need for a conventional heating system. in addition to the higher material costs, two factors that sway the initial cost are, firstly, the fact that the numbers of *Passivhaus* buildings remains low, and hence the economies of scale of large volume production have yet to be realised; and secondly, the limited number of practitioners in the design and construction of *Passivhaus* buildings.

A 2009 paper by the European Commission examined the European evidence of the cost premium of very low energy buildings as opposed that of standard buildings. [78] It concluded that in Germany, Austria, and Sweden, it is now possible to construct *Passivhaus* buildings for costs that are not significantly higher than those of normal standards because of increasing competition in the supply of the specifically designed and standardised *Passivhaus* building products. In these countries, the cost of

[76] http://www.passiv.de/07_eng/index_e.html
[77] Establishment of a Co-operation Network of Passive House Promoters (PASS-NET) – International PassiveHouseDataBase.eu
[78] Low Energy Buildings in Europe: Current State of Play, Definitions and Best Practice

construction is generally 4–6 % more compared with the standard alternative. In Switzerland, additional upfront cost for the Minergie® low energy standard is between 2% and 6%; for the Minergie® P standard, it is up to 10%.

Overall, the additional upfront cost is estimated at €100/m², with a payback of less than 20 years.

6.2.2.6. Mandatory Energy Performance Requirements

It is perhaps no surprise that governments, residents and businesses in the countries stretching into the Arctic Circle have a vital interest in buildings with a high energy performance. This is reflected in the building codes and standards for new buildings, as the IEA found that the five countries/regions with the strictest new build standards were to be found in Scandinavia—Sweden, Denmark, Norway and Finland—and parts of Ontario, Canada (Laustsen, 2008).

Following the 2010 recast of the Energy Performance of Buildings Directive (EPBD), the trend towards very high energy performance new buildings has taken on new momentum, not just in Scandinavia but across the whole of Europe.[79] One of the requirements in the EPBD is that all new construction from the end of 2020 onwards must achieve "nearly zero energy", and that the very low energy requirements should be met, to a significant degree, by energy from renewable sources produced on-site or nearby. For buildings owned and occupied by public authorities, this requirement will come into force two years earlier from 2019 onwards. .

A number of EU countries are playing a leading role in the drive towards the Nearly Zero Energy Building (or nZEB) requirements, in most cases predating the Directive.

Progress towards ever tighter building regulations has been going on in some European countries for over half a century. A case in point are the Danish Building Regulations, as illustrated in Figure 6-10, which shows progressive energy reductions since 1982 and the targets to 2020 that have been agreed by the Danish Parliament. The prevailing standards enforced since 2010 is similar to those of *Passivhaus* in terms of energy performance.

The 2015 and the 2020 codes and standards have already been specified in the existing building codes of2010 as low energy standards. Thus, if a residential building is able to meet the stipulated requirements now, it will then be certified as compliant with even future building codes. Similar standards have been set for non-residential buildings.

[79] Technically, the EPBD only applies to the 27 EU Member States, though in practice, many non-EU countries adopt or follow similar requirements, particularly those seeking to join the EU at a later date.

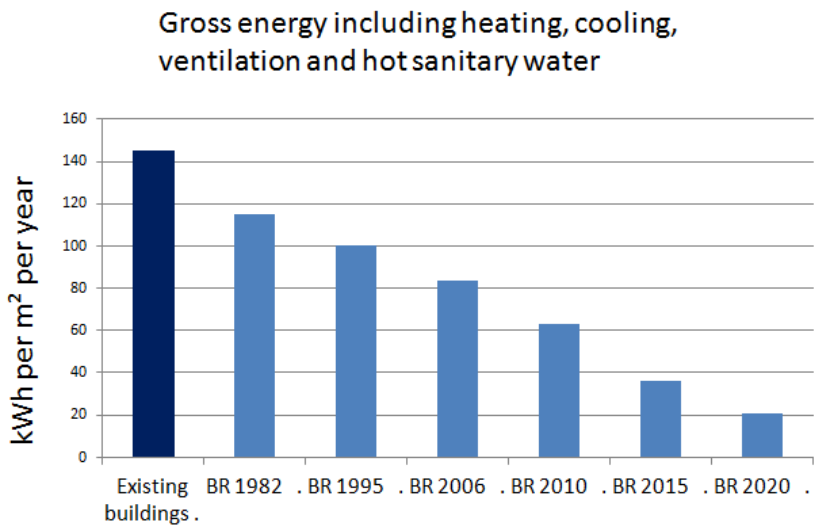


Figure 6-10. Increased Energy Performance in Danish Building Regulations, 1982-2020

Building on this momentum, several countries across Europe are starting to express their ambition in achieving outstanding energy performance in new buildings. Both voluntary and mandatory measures have been adopted. Increasingly, these are now coming together. Successful experience gained in driving adoption of voluntary standards have encouraged policy makers to increase stringency in building codes and standards of all new buildings.

In addition to actual measures to tighten building regulations and increase the uptake of higher voluntary standards, several European governments had made future commitments to achieving yet higher goals before the EPBD made this a mandatory requirement in the 2010 recast (see Table 6-10). Although the timeframe, substance, metrics and level of ambition vary from country to country, it is evident that future lies with buildings with very good energy performance, requiring very little or no energy for heating, cooling, hot water and ventilation, as well as featuring both passive and active renewable energy systems as a standard.

Table 6-10. Selected Targets for New Buildings – National Commitments made as of 2008

Country	Target
Finland	Passivhaus standards by 2015
France	By 2020 new buildings are energy-positive
Germany	By 2020 buildings should be operating without fossil fuel
Ireland	Net zero energy buildings by 2013
Netherlands	Energy-neutral by 2020 (proposed)
Norway	Passivhaus standards by 2017
UK (England &Wales)	“Zero carbon” as of 2016

6.2.2.7. International Comparisons of Low Energy Building Standards

Three UK-based organizations—the Zero Carbon Hub[80], NHBC[81] Foundation and PRP Architects—have established the Zero Carbon Compendium as a global knowledge sharing platform. [82] Its aim is to achieve improved understanding of the issues surrounding achievement and delivery of zero carbon housing as a basis for better international comparisons and collaboration. Among its analysis is a comparison of requirements for fabric insulation across a number of countries. This puts the European standards and aspirations into a global context. Although *Passivhaus* and Minergie-P remain are evidently the most ambitious voluntary standards that aim to achieve U-values of 0.1W/m^{2}K, they have now been matched by Denmark and Sweden, where in 2010 this has been made as the minimum requirement for all new residential buildings.

The European experience has shown how a voluntary standard in one territory can be adopted as the *de facto* mandatory standard in another (Figure 6-11).

[80] http://www.zerocarbonhub.org/
[81] National House-Building Council
[82] http://www.lowcarbonhomesworldwide.com/

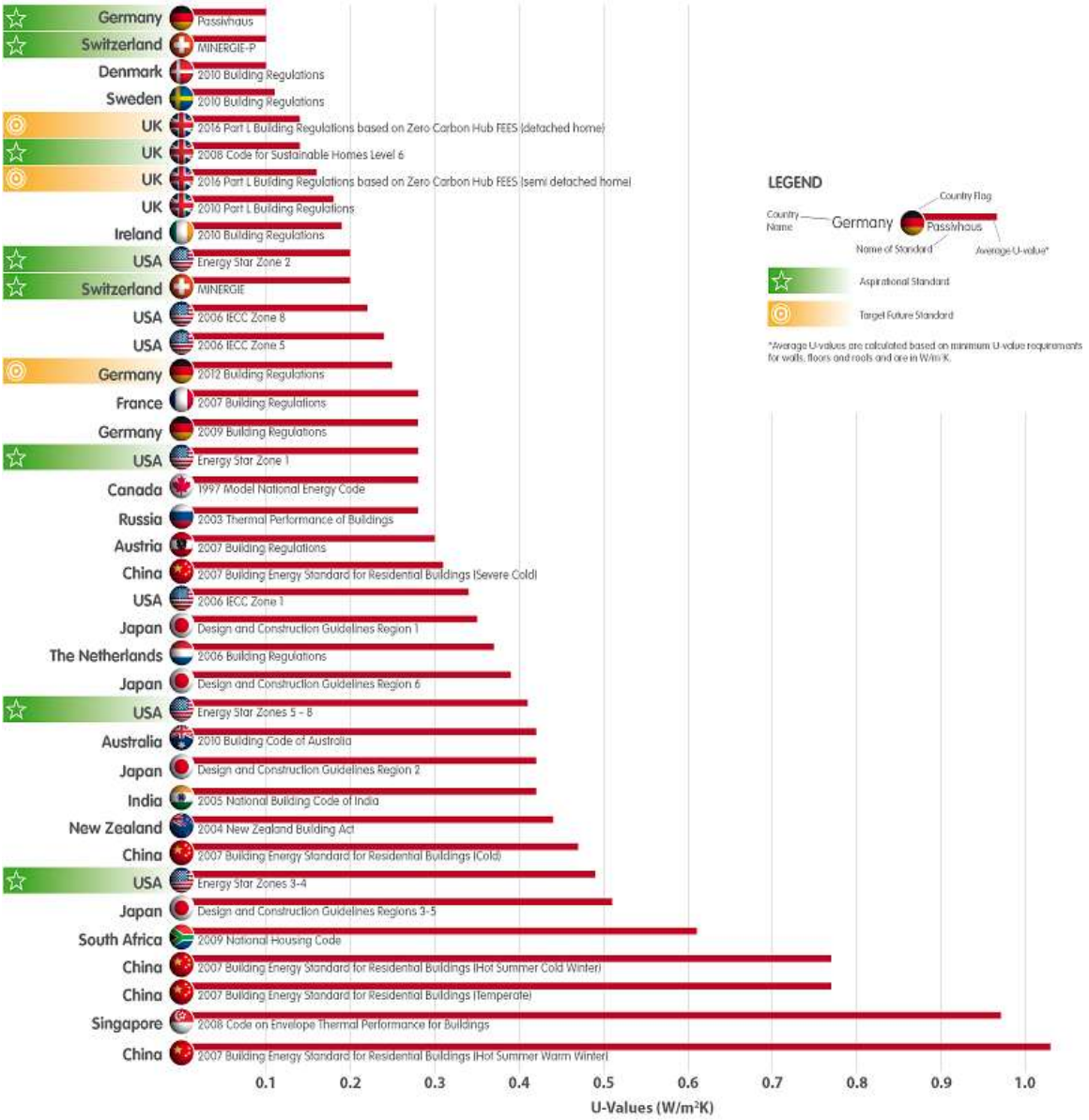


Figure 6-11. Currently Mandatory (No Color), Future Target (Orange), and Aspirational (Green) Insulation Standards across Several Countries[83]

6.2.2.8. Forward Plans for nZEB

In addition to mandating nearly zero energy new buildings from 2020 (2018 for buildings owned and occupied by public authorities), the EPBD also requires all 27 EU Member States to draw up national plans during 2012 for increasing the number of nearly zero energy buildings of both new and existing. These plans will be evaluated by the European Commission by the end of 2012, and every three years thereafter. Based on the reported plans, the commission will develop an action plan and, if necessary,

[83] http://www.lowcarbonhomesworldwide.com/

propose measures to increase the number of nearly zero energy buildings and encourage best practices that are deemed as cost-effective in transforming existing buildings into nearly zero-energy buildings.

Furthermore, in the run-up to the nearly zero energy deadlines, building codes and standards must be established on the basis of cost optimality. As reported by the Buildings Performance Institute Europe (BPIE), the requirements in the original 2002 EPBD have been instrumental in driving up performance standards in many EU member states, and indeed caused the first time introduction of standards in three member states. It is therefore clear that continuing pressure will be exerted in the coming decades to progressively reduce the energy requirements of new buildings in all member states, not just for the leading EU players.

6.2.3. Austria's Comprehensive Approach to Energy Reduction in Buildings

6.2.3.1. Setting The Scene

Austria is a small, landlocked, federal country in central Europe with a mountainous terrain and a population of around 8.5 million. It comprises nine states (Länder) that have traditionally been quite independent. Given the cold Alpine climate, Austria has had an active approach to energy efficiency for many years. In recent times, Austria's energy-efficiency plans have been heavily influenced by EU-wide obligations. It has used EU climate and energy legislations and international commitments to form the foundation of its current national plans:

- the Austrian Climate Change Strategy was revised in 2007, in large part because it was realized that it would be impossible to meet the country's Kyoto targets with current domestic measures; and
- a new energy strategy was published in 2010. The Austrian Energy Strategy addresses all sectors, including the building sector, and has the objective of stabilizing total final energy consumption at 2005 levels by 2020.

6.2.3.2. Austria's Policies, Programs and Support Mechanisms

The Austrian government has set out a vision that, by 2050, the total building stock should be free of carbon emissions over its life cycle, including the construction and operation of buildings. [84] This long-term goal is underpinned by a number of current policies, programs and legislative tools to address energy use in existing as well as new buildings. Many of these policies build on historic efforts spanning 30 years or more to improve the energy efficiency of the building stock, while others have been introduced more recently in response to European legislation.

The comprehensive toolkit to tackle energy use in buildings comprises:[85]

- progressively improving energy performance standards for new buildings;

[84] http://www.e2050.at/pdf/energie_gebauede.pdf (in German)

[85] Energy Efficiency Policies and Measures in Austria, Odyssee, and the MURE Measure Database http://www.mure2.com/

- standards for renovation of existing buildings;
- federal loans, grants, allowances and other forms of financial support for building fabric improvements and installation of more efficient heating systems;
- appliance labeling and measures to encourage the purchase of more efficient lighting fixtures and appliances;
- personal income tax deductions for energy-saving investments;
- energy performance certification of new and existing buildings;
- programs to support the increased deployment of renewable energy in buildings;
- measures to reduce energy end-use in public buildings, including an action plan for sustainable public procurement;
- promotion of connections to district heating systems;
- voluntary agreements with energy suppliers to deliver energy services and energy-saving measures to end users;
- a research & development program focused on improving the energy performance of buildings;
- energy taxation;
- and the "klima:aktiv" national program for climate protection – see box.

klima:aktiv Climate Campaign

In 2004, the Austrian Government introduced an overarching climate action campaign known as klima:aktiv ("Climate Action"). As a key component of the federal climate strategy, klima:aktiv brings all voluntary and supportive measures under one umbrella in four thematic clusters: buildings, energy efficiency, mobility, and renewable energy. Through training and education programs, setting standards, raising awareness, providing advice and support, and networking with partners, klima:aktiv aims to be a transformative and inclusive initiative, encompassing all relevant market players and stakeholders.

In the area of buildings, services include:
- development of the klima:aktiv building standard for new construction and renovations (the standard is 30% better than minimum legal requirements, and must be attained to qualify for social housing subsidies. Qualifying buildings can use the klima:aktiv quality label);
- free initial audits to identify potential energy savings in buildings;
- funding models (such as building energy performance contracting);
- online information platforms on building and renovation;
- a database of best practice examples; and
- provision of trained experts to help with the planning and realization of projects.

Although the package of programs has addressed all aspects of energy use in buildings, the area where Austria has been particularly strong is in the uptake of very low energy residential and commercial new buildings as well as renovations. The "Building of Tomorrow" program, initiated in 1999, provided much of the underpinning R&D that has resulted in the country having the highest per capita number of low energy *Passivhaus* buildings. [86] In 2010, there were approximately 12,000 *Passivhaus* buildings in Austria—a figure that has grown rapidly over the preceding 5 years, as illustrated previously in Figure

[86] http://www.e2050.at/pdf/energie_gebauede.pdf(in German).

6-9. The addition of nearly 5,000 *Passivhaus* units in 2010 represents about 7% of the estimated total number of new buildings constructed in that year, yet the total of 12,000 remains a tiny fraction of the total Austrian building stock of some 3.6 million.

6.2.3.3. Evaluation of Austrian Approach

In 2011, the Austrian government published its second National Energy Efficiency Action Plan as required under the EU's Energy End-use Efficiency & Energy Services Directive ("ESD").[87] Under this Directive, Austria has an indicative target of a 9% improvement in energy efficiency between 2005 and 2016, requiring annual energy end-use savings of 80 PJ in 2016.

Approximately 75% of the total savings (60 PJ) are expected to come from the building sector. Compared to total energy consumption of 409 PJ in the building sector in 2010, this represents a 15% saving.[88] It can be seen that the building sector is forecast to make a disproportionately higher share of the target savings than industry or transport sector.

Energy savings in the building sector result mainly from measures to improve the thermal quality of the building envelope, efficiency of heating systems, and tightening the requirements set by building regulations. Table 6-11 below provides an overview of the main measures and the resulting annual savings.

[87] http://ec.europa.eu/energy/efficiency/end-use_en.htm

[88] http://www.statistik.at/web_en/statistics/energy_environment/energy/index.html

Table 6-11. Breakdown of Energy-saving Target for Austria to 2010 (achieved) and 2016 (expected)

No	Energy efficiency measure	Affected energy consumption	Final energy savings 2010 (TJ)	Expected final energy savings 2016 (TJ)
G.1.	Residential building subsidy — building shell	New buildings and renovation of buildings	13 905	22 705
G. 2.	Residential building subsidy — efficient heating systems	New buildings and renovation of buildings	10 292	18 821
G.3.	Tightening construction law requirements	New buildings and renovation of buildings	14 805	18 676
G.4.	National recovery plan/Renovation voucher	Renovation of buildings	Technical measures still in process of implementation	Technical measures still in process of implementation
G.5	Statutory provisions to promote district heating	Residential and non-residential buildings	Savings cannot be projected by bottom-up calculation	Savings cannot be projected by bottom-up calculation
G. 6.	Energy advice for households	Private households	145	145
	Total savings		**39 147**	**60 347**

Source: Austria's Second National Energy Efficiency Action Plan (NEEAP), 2011.[89]

The impact of the measures on improved energy efficiency in the residential buildings can be seen in Figure 6-12. Despite the fact that the total floor area of the residential building stock has increased by over 30% since 1995, total energy use for space heating has remained more or less constant. Adjusting for weather variations, energy use per m^2 of floor area has decreased by 20% over the period 1995–2009.

[89] http://ec.europa.eu/energy/efficiency/end-use_en.htm

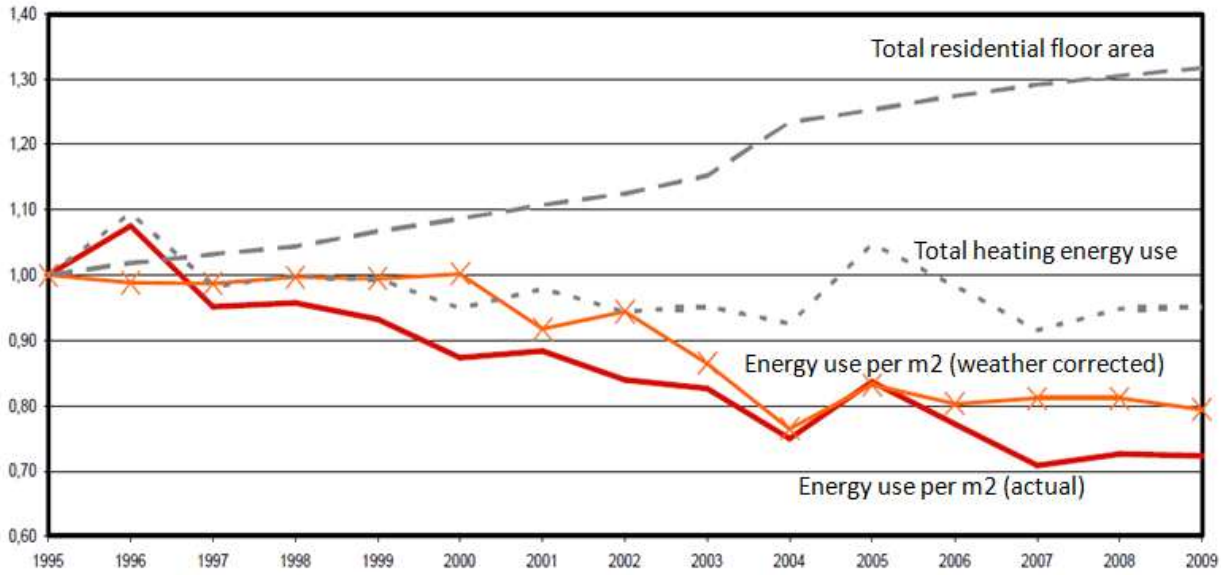


Figure 6-12. Energy Consumption for Residential Space Heating per m², 1995–2009

Across all end use sectors, Austria has consistently outperformed the rest of the EU countries since 1995, as illustrated in Figure 6-13.

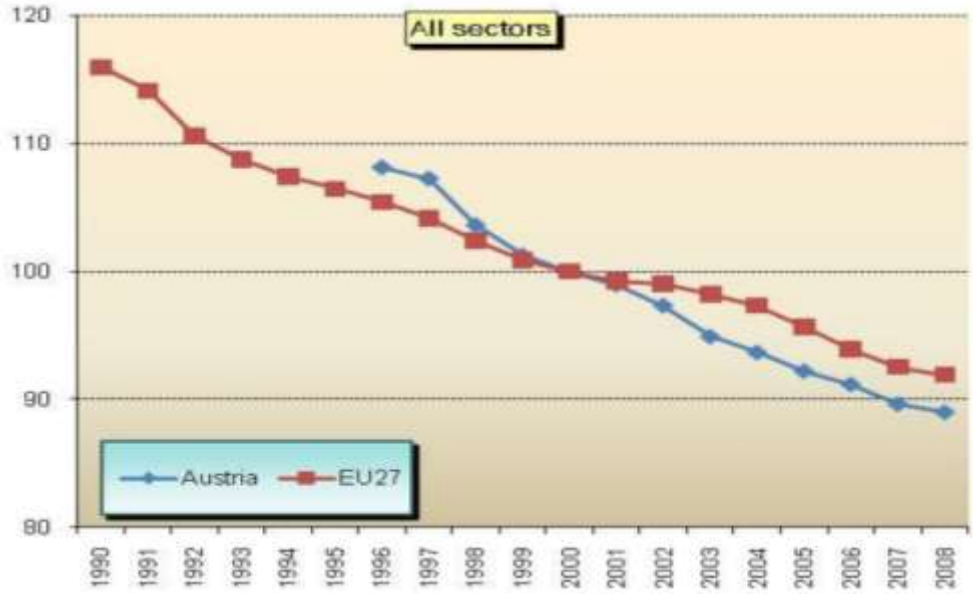


Figure 6-13. Comparison of Energy Efficiency Index - Austria & EU (base 100=2000)

6.2.4. Indicators of Best Practice from EU Case Studies

The subsections below describe lessons learned from three EU case studies: the KfW program in Germany, programs in Austria, and EU near-zero-energy buildings programs.

The German KfW Program

Germany took advantage of the existence of the KfW development bank, using it as a vehicle to support high-efficiency new construction and building renovation. As was the case in other European Union (EU) member states, the EU's carbon dioxide (CO_2) emissions reduction and energy-saving targets, including a raft of energy-saving directives, provided much of the impetus for Germany's KfW program.

The key to KfW's success is the recognition that investment in energy-saving measures provides a net benefit to the government. Rather than considering subsidies as a drain on public resources, the German government takes a holistic perspective, and the stimulus provided through loans and grants pays for itself more than four times over, as a result of additional tax income resulting from the efficiency improvements as well as reduced social costs in the form of increased production of energy-saving materials and the associated employment that this industry generates.

Although other countries might not have an equivalent to the KfW development bank, this program can be replicated. The renovation of the existing global building stock that is necessary to reduce energy use and GHG emissions will require substantial investment that can only be provided by the private sector. Using the model of the KfW program, governments can provide the incentives to leverage private investment by:

- Providing a framework for improving building energy performance through a combination of progressively tighter minimum efficiency standards, financial incentives such as those delivered through KfW, and supporting measures to build capacity and raise awareness;
- Devising loan/grant schemes of sufficient scale and lifespan that they become part of the recognized infrastructure of the country/territory;
- Reducing risk (and hence financing costs) by providing a clear framework for the program, including certification of experts to assess and implement the investments, as well as providing guarantees for the products installed;
- Enabling building owners and investors to borrow at below-market rates for investments that have a high energy-performance rating;
- Weighting incentives against investments that achieve the deepest retrofits and thus deliver maximized savings;
- Working with lenders to leverage their contacts with individuals and businesses;
- Taking a holistic view of the net impact of incentives on public finance, i.e., factoring in tax and employment benefits from increased investment in the building stock;
- Increasing the visibility of the higher property values of high-energy-performance buildings, thereby further strengthening the economic case for building owners/investors (this feature was not part of the German KfW scheme).

European Near-zero-energy Building Programs

For decades, a number of European countries have increased the stringency of building codes and standards to lower energy use in new buildings. During the past five years, particular attention has been given to the goal of near-zero and ultimately net-zero energy use. Countries such as Denmark, Germany, Austria, Switzerland, and Sweden, historically the most progressive in the area of energy efficiency, have continued to be leading players. In Denmark, standards to achieve near-zero energy use in all new buildings by 2020 have already been approved by Parliament. Voluntary standards such as Passive House and Minergie P have been instrumental in driving this agenda in Europe. These two standards have increased the number of high-performance residential and non-residential buildings at costs that are not prohibitively more expensive than those of standard buildings. Adoption of such voluntary standards as de facto mandatory requirements by particular localities, cities, or regions also helped to encourage national governments as well as EU authorities to commit to a future where, within a decade, all new buildings across the region will be constructed in compliance with near-zero energy requirements.

Economic, social, environmental, energy security, and technological factors have all played a part in stimulating individuals, organizations, nations, and now the entire European Union to recognize the long-term benefit of drastically reducing energy use by and CO_2 emissions from new buildings.

The Austrian Approach

Within Europe, Austria has one of the most proactive and comprehensive approaches to reducing energy use in buildings, which has resulted in significant energy-efficiency improvements during the past 20 years. However, despite the success of Austria's historic programs and initiatives, the rate of improvement needs to dramatically increase if the national objective of eliminating fossil fuel use in the buildings sector is to be realized. The new energy strategy adopted by the Austrian Council of the Ministers in 2010 targets a 3% annual retrofit rate for the building stock by 2020, up from the current rate of 1%.[90] As a move toward this goal, the government introduced several new housing and construction measures. Given Austria's federal structure, these measures will be delivered regionally through a formal agreement between the federal government and Austria's states (Länder).[91] Public procurement guidelines include ambitious standards for new buildings and retrofits. Meanwhile, higher thresholds for obtaining housing subsidies were introduced for single- and multi-family buildings to accelerate the phasing-out of oil heating and to improve energy efficiency in building renovation through new regulations on space and water heating. The government measures focus on heating and insulation measures in buildings built between 1945 and 1980. For new buildings to qualify for subsidies, single-family buildings will be expected to meet an annual threshold of 36 kWh/m^2; multi-family buildings will have an annual threshold of 20 kWh/m^2. Furthermore, the 2011 budget included €100 million for thermal renovation of buildings: €70 million for private households and €30 million for businesses.

[90] http://www.climatepolicytracker.eu/austria

[91] The Federal Constitutional Law allows treaties or agreements between the federation and the Länder or among the Länder on matters within their respective spheres of competence. There have been many such agreements related to energy efficiency.

Although Austria's focus on improving the energy performance of buildings predated its accession to the European Union in 1995, the country's program is now to a large extent based on implementing the suite of EU Directives that target improving energy efficiency. Nonetheless, the Austrian government continues to aim for its long-term goal of a fossil-free building sector by 2050, continuing Austria's leading role in cutting GHG emissions from buildings. Of particular note is Austria's leadership in the construction of very-low-energy buildings.

6.2.5. Conclusions

Although the EU case studies highlighted here differ in the ways in which they save energy in buildings, they are all significant initiatives supported by national institutions with reinforcement by EU legislation.

EU legislation on energy saving in buildings is increasingly the most significant driver of efficiency improvements in new buildings. The renovation market, however, is less well served by mandatory national or EU policies. Because the overwhelming majority of building energy use will be in the existing stock for the foreseeable future, it is vital that the best practices for the renovation market such as those described in Germany and Austria continue in those countries and serve as a basis for new initiatives (no doubt altered to fit local conditions) in other countries.

6.3. China Best Practice Case Studies

6.3.1. China's Comprehensive Building Energy-Efficiency Policy Approaches

The growing importance of buildings as an energy consuming sector in China and the central government's increasing focus on energy efficiency have both helped push building energy efficiency to the forefront of local policies in China. The scope and scale of these local building energy efficiency policies vary, but all are equally impressive in the extent to which codes and standards, labeling, and financial incentive programs are incorporated in comprehensive local approaches to increasing the energy efficiency of new and retrofitted Chinese buildings. Four case studies of Jiangsu province, Shanghai, Beijing and the sub-provincial city of Ningbo are presented below to illustrate the wide scope and depth of policies focused on building energy efficiency across different levels of local government and the cross-cutting nature of some of the policy packages adopted. For some provinces such as Jiangsu, building energy efficiency policies have evolved from the first building design code and supplementary standards in the 1990s to financial incentives for building integrated renewables and regulatory support, resulting in the province becoming home to highest number of projects receiving the national Green Building Label. For major cities like Shanghai and Beijing, building energy efficiency has been encompassed in comprehensive regulations and an increasingly large number of specific policy targets with quantifiable energy-savings potential. Even at the smaller sub-provincial level, cities such as Ningbo have, with international assistance, strengthened policy tools and measures for improving building energy efficiency.

6.3.1.1. Jiangsu's Provincial Approach to Comprehensive Building Energy Efficiency Policies

Jiangsu Province, a coastal province in eastern China, falls mostly within the Hot Summer Cold Winter climate zone and has been one of the country's most active provinces in promoting building energy efficiency. Jiangsu has a long history of enacting local building energy codes since the 1990s, with the first standard implemented in 1995 for residential buildings following the national standard requirement of a 50% reduction in heating energy intensity.[92] While a 50% reduction in heating energy intensity continues be the benchmark for the existing national residential standard for the Hot Summer Cold Winter climate zone, Jiangsu's current design standard promulgated in 2009 is set at the more stringent level of a 65% reduction in heating energy intensity. Jiangsu Province has also developed various other local standards, ranging from standards on the testing and acceptance[93] of key building components (DBJ/J 19-2007), specific laboratory and site testing standards for verifying the energy efficiency of construction and retrofit projects (DBJ32/J 23-2006), and technical standards on building integrated

[92] As described in detail in the previous Chapter 4, Section 2 on China's building codes, China uses the "heating energy intensity reduction rate" compared to a baseline building of 1980s construction without insulation or any other building efficiency measure as the basic metric for thermal integrity. The current national residential standards and public building standard are based on a 50% heating intensity reduction.

[93] Testing and acceptance is the final stage in the new construction approval process that precedes formal approval for building occupancy. This stage consists of testing building components by following national guidelines issued in the 2007 National Code for Acceptance of Energy Efficient Building Construction.

designs for solar water heaters (DBJ32/TJ 08-2005) (Xu, Zhang, & Huang, 2010). At the same time, Construction Administrative Bureaus in local governments above the county-level are tasked with carrying out monitoring and analysis of actual building energy use to strengthen the basis for code development, the local green building evaluation standard, and the labeling program (Jiangsu Provincial Government, 2009). In addition, various provincial governments and quasi-government agencies including urban planning departments, drawing and design examination agencies and project quality supervision agencies are involved in the implementation and enforcement of provincial building standards.[94]

In recent years, Jiangsu Province has expanded its policy efforts from codes and standards to promoting green buildings and the use of financial incentives to support building energy efficiency. Most of these new policies are included in the 2009 *Building Energy Management Regulations* (BEMR), which provide a comprehensive framework covering cross-cutting policies ranging from building code enforcement to green building labeling programs and the use of financial incentives. For example, the BEMR lays out specific fines for failing to comply with building energy codes, including fines of 2,000 to 30,000 Yuan (USD $300–$4000[95]) for not meeting design code requirements (Jiangsu Provincial Government, 2009). In promoting financial incentives for building efficiency, the regulation calls on local governments above the county level to arrange special funds to support building energy efficiency, retrofits, and the integration of renewable energy applications and green buildings. The BEMR also establishes income and tax incentives for enterprises involved in the manufacture and use of energy efficient construction material. For green buildings, Jiangsu Province has adopted a local *Evaluation Standard for Green Buildings* (DGJ32/TJ 76-2009), which follows the same rating system as China's national standard but includes stricter requirements for elements such as building use of renewable energy (Xu, Zhang, & Huang, 2010). The local green building standard, along with strong provincial government support for green buildings, has enabled Jiangsu to become home to the highest number of projects nationwide to receive the national Green Building Energy Label, with 54 qualifying projects by August 2011 (Cheng, 2011). To further promote renewable energy technologies, the Jiangsu Construction Bureau also issued the *Notification for Promotion and Management of Solar Water Heating Systems*, requiring all new hotels, restaurants, and residential buildings under 12 floors that supply hot water to design and install solar hot water heating systems and to encourage all existing buildings to install solar hot water heating systems (Xu, Zhang, & Huang, 2010).

6.3.1.2. Shanghai's Comprehensive Building Energy Efficiency Regulation

Shanghai's 2007 *Implementation Plan for Energy Conservation and Emission Reduction* includes a binding energy-saving standard for new buildings with a 50% reduction in heating energy intensity in line with the national standard and a likely future target of a 65% reduction in heating energy intensity. In order to strengthen supervision and administration by municipal and district administrative construction departments, Shanghai issued the *Procedures of Shanghai Municipality on the*

[94] More details on provincial and local code enforcement are provided in the third set of case studies on code compliance and enforcement.

[95] USD equivalent is based on approximate conversion using 2010 average currency exchange rate of 6.7695 Yuan per USD.

Administration of Building Energy Conservation on June 13, 2005 (Kung, 2011). This set of procedures encourages compliance with efficiency standards in all stages of building construction and calls for the establishment of an energy efficiency supervision system for government office buildings and large public buildings. Likewise, a separate *Procedures of Shanghai Municipality on the Administration of Special Funds for Energy Conservation and Emission Reduction* was also issued in June of 2008 and provides for the use of funds to support building energy efficiency and contract-based energy service companies in the building sector (Shanghai Municipal Government, 2010).

More recently on September 17, 2010, the Shanghai municipal government adopted the *Regulations of Shanghai Municipality on Building Energy Conservation*, a comprehensive set of building energy efficiency policies that covers all aspects of building energy efficiency and includes regulatory, market-based, and financial measures. The Shanghai municipal government uses this regulation to emphasize the importance of building energy efficiency through Article 5 by including building energy efficiency as a criterion for the examination and evaluation of the overall performance of municipal construction departments and local government officials in improving energy efficiency (Shanghai Municipal Government, 2010). Moreover, this regulation represents Shanghai's approach to a comprehensive policy package focused on building energy efficiency and green buildings. Going beyond the scope of mandatory design codes for solar water heating systems, this regulation also introduces financial incentives for building energy efficiency improvements, integrates renewable and energy service companies (ESCOs), and promotes the green building labeling program. The regulation went into effect on January 1, 2011 and provides specific details and regulatory requirements for the use of energy efficient materials and technologies in new buildings, energy efficiency assessments and disclosure, retrofits for subsidized buildings, and subsidies and financial incentives for building energy efficiency projects and green buildings. In particular, the regulation mandates that (Shanghai Municipal Government, 2010):

- energy efficient construction materials and technologies are to be classified as "encouraged" in the municipal catalog and should be the first choice for construction within the municipality;
- new residential or public buildings with hot water supply and less than six floors are required to develop a uniform plan for solar water heating systems and solar water heating systems are encouraged in buildings with more than seven floors;
- for government or large public buildings, an energy efficiency assessment by a third-party assessor must be completed one year after the final inspection and the results must be posted for public disclosure;
- a building's energy consumption index and energy efficiency measures must be disclosed in sales contracts for new building sales;
- energy efficient retrofits must be undertaken if a government subsidy is used to support the renovation or expansion of existing residential buildings;
- the Shanghai Energy Efficiency Fund is to be used to provide financial incentives for building projects that exceed current standards, energy efficiency retrofits, and building integrated renewable energy technologies, with the specific procedures to be formulated by the Municipal

Construction Department, the Municipal Development and Reform Commission, and the Finance Department;

- preferential tax treatment are to be created for building energy efficiency projects;
- preferential financial policies are to be formulated to encourage the use of non-government funds, to promote renewable energy use in buildings and energy efficiency retrofits;
- monetary support, preferential tax treatment, and financial incentives are to be created for ESCOs working on retrofits; and
- green building development and applications for the Green Building Label are to be encouraged.

Because the regulation has been in effect for only one year, the extent of its implementation and the actual energy savings are not readily known. Nevertheless, it showcases Shanghai's efforts to provide a regulatory basis for a comprehensive set of policies aimed at increasing the overall level of building efficiency through diverse measures that include mandatory design code requirements, financial incentives, and promotion of green building labeling programs.

6.3.1.3. Quantifying Beijing's Leadership in Building Energy Efficiency

As China's capital, Beijing has been a leader in building energy efficiency. By the end of 2009, total building floor space in Beijing reached 605.9 million m^2, with 373.2 million m^2 residential buildings and 232.7 million m^2 commercial buildings. In that same year, residential and commercial buildings consumed a total of 19.5 million tonnes of coal equivalent (Mtce[96]), or nearly 30% of the city's total energy consumption (Government of Beijing, 2011). Beijing has achieved notable energy savings from its comprehensive efforts to improve building energy efficiency, which include implementation of a more stringent local building energy code mandating 65% heating intensity reductions relative to the baseline1980s buildings in the same climate zone, financial incentives for renewables and energy efficiency retrofits, and active promotion of the Green Building Labeling program during the 11th FYP period.

Beijing exceeded its 11th FYP average heating intensity per m^2 reduction goal of 17% by reducing the average heating energy consumption per m^2 by 20.6%, (from 20.77 kgce per m^2 in 2005 to 16.49 kgce per m^2 in 2009) (Government of Beijing, 2011). This achievement was driven in large part by the fact that all of the 79.85 million m^2 of new residential buildings constructed during the 11th FYP period, or 21% of Beijing's total residential building stock, met the 65% heating intensity reduction standard. Moreover, Beijing has also emerged as a leader in green buildings with 1.62 million m^2 of certified green buildings, including 19 projects certified by both the Chinese Green Building Label and the international Leadership in Energy and Environmental Design program and 14 projects designated as national green building demonstration projects (Government of Beijing, 2011). In regards to energy efficiency retrofits, Beijing has far exceeded its target of 25 million m^2 of retrofits with 71.24 million m^2 and 74.65 million m^2 of residential and commercial building retrofits completed, respectively, by the end of 2010. With average energy savings of 10.1 kgce/m^2/year from retrofitting, Beijing's retrofits resulted in total energy

[96] Mtce is the standard unit for energy in China and is equal to 29.27 x 1015 Joules (i.e., million GJ).

savings of 1.46 Mtce per year and 4.04 Mt CO_2 emissions reductions (Government of Beijing, 2011).[97] For building renewable energy technologies, Beijing has also been successful in integrating renewable technologies in 18.2% of annual new construction by the end of 2009, with demonstration renewables-integrated green building floor space growing to 1 million m^2 in 2011.

For the next five years, Beijing will continue to lead building energy efficiency efforts with 12th FYP commitments to implement the most stringent building code in the country, continuing energy efficiency retrofits and the retirement of inefficient building stock, the adoption of renewable energy building applications, and other related efficiency improvements. In addition to implementing the 75% mandatory heating energy intensity reduction standard for residential buildings, Beijing is also mandating the installation of solar water heaters for buildings with less than 12 floors and the installation of water and electricity heat meters for consumption-based billing (Ma, 2011). For green buildings, Beijing has set a target of 35 million m^2 of green building floor space by 2015, including 15 million m^2 of green building demonstration projects (Government of Beijing, 2011). The other major building energy efficiency measures that Beijing has included in its 12th FYP and the expected energy savings are listed in Table 6-12. If Beijing is able to meet all of these targets and realize all potential energy savings between 2011 and 2015, it could save the equivalent of nearly one-third of Beijing's 2009 annual building energy consumption and up to 17 Mt CO_2 emissions.[98]

[97] CO_2 emissions are estimated using the IPCC carbon emissions coefficient for bituminous coal, assuming the Mtce of energy saved is derived solely from primary coal energy use in which 1 Mtce produces 2.77 Mt CO_2 emissions. This is likely an overestimate as some of the energy saved could be derived from other fuels with lower CO_2 emission coefficient than coal, such as electricity, natural gas or district heating.

[98] As stated previously, Beijing's annual energy consumption from buildings in 2009 was 19.5 Mtce. Since total possible savings of all planned building efficiency measures during the 12th FYP total 6.2 Mtce, this is equal to 32% of the 2009 annual building energy consumption total. CO2 emissions are estimated using the 2.77 Mt CO2 emission coefficient for 1 Mtce of coal energy.

Table 6-12. Beijing's 12th FYP Building Energy Efficiency Policy Targets and Potential Energy savings

No.	Building Energy Efficiency Measure	12th FYP Targets	Potential Energy savings	
1	Building Energy Efficiency of New Construction	New residential and commercial building floor space of 200 million m^2, with full implementation of energy efficiency design standards, including improved residential energy efficiency design standards.	1.72 Mtce	
2	Removal of Existing Inefficient Buildings	Demolition and removal of 10 million m^2 of inefficient urban buildings and 40 million m^2 of rural buildings; with reconstruction of energy-efficient buildings.	0.89 Mtce	
3	Energy Efficiency Retrofits of Existing Buildings	Retrofits of 30 million m^2 of residential buildings and 30 million m^2 of public buildings.	0.61 Mtce	
4	Building Applications for Renewable Energy	The use of shallow geothermal or water source heat pump heating and cooling by 18 million m^2 of civil building floor space.	0.14 Mtce	0.569 Mtce
		Solar PV integrated building roof area of 1 million m^2 with 40,000 kilowatts of photovoltaic power generation capacity.	0.03 Mtce	
		Solar hot water system covering building construction area of 11 million m^2 with total collector area of 5.5 million m^2.	0.39 Mtce	
		Solar thermal systems for heating covering a building construction area of 160,000 m^2 with total collector area of 40,000 m^2.	0.0037 Mtce	
5	Building Energy Efficiency in Rural Areas	Improved efficiency of new rural housing and retrofits of existing rural housing for total of 200,000 households.	0.24 Mtce	
6	Public Buildings Energy-saving Operation	Implementation of energy consumption quota and differential power tariffs quotas, 12% reduction in electricity consumption per m^2 in city's public buildings.	0.97 Mtce	
7	Heat Supply System Efficiency Improvements	Integration of heating resources, energy-saving heating systems, and adjustment of heating supply structure	0.99 Mtce	
Total			**5.99 Mtce**	
8	Behavior Change		0.21 Mtce	
Total			**6.2 Mtce**	

Source: (Government of Beijing, 2011)

Note: Mtce = million tonnes of coal equivalent = 29.27 million GJ CO_2 emissions. CO_2 emissions reductions associated with energy savings can be estimated using a CO_2 emission coefficient of 2.77 Mt CO_2/Mtce if all energy saved is assumed to be from bituminous coal.

6.3.1.4. Ningbo's Multi-Faceted Approach to Building Energy Efficiency as a Sub-Provincial City

The city of Ningbo in Zhejiang Province has demonstrated leadership in undertaking a comprehensive approach to building energy efficiency through building energy code implementation and enforcement, the promotion of green buildings, and the use of financial incentives to promote building integrated renewable energy technologies. Ningbo is a port city south of Shanghai, located in the Hot Summer Cold Winter climate zone. It is the second largest city in Zhejiang province with a population of 2.2 million and an export-oriented economy with a per capita GDP three times the national average (Shui, et

al., 2011). As a rapidly growing city, building energy consumption accounted for an estimated 27% of the city's total energy consumption of 72.3 Mtce in 2009 (Yao & Zhu, 2011). In recent years, Ningbo has recognized the importance of supporting building energy efficiency by conducting annual surveys on energy consumption of large-scale public buildings to support the development and revision of building energy codes and to identify targets for retrofit projects (Yao & Zhu, 2011). In addition, the city has also established an exemplary energy efficiency supervision system for large-scale public buildings and strengthened its code supervision and enforcement capacities through the use of third-party verification companies (Evans, Shui, Halverson, & Delgado, 2010). These efforts are described in greater detail as a case study of effective building code enforcement and compliance in Chapter 7 Section 3.3.2, below.

The city of Ningbo is also noteworthy in adopting a "carrots and sticks" approach to promoting building-integrated renewable energy technologies such as geothermal heat pumps, solar water heaters, and solar PV systems. The city of Ningbo recently passed two compulsory regulations, the *Administrative Regulation for Civil Architectural Energy Savings in Ningbo* and the *Energy Conservation Regulation of Ningbo*, requiring all newly constructed buildings to incorporate at least one type of renewable energy (Government of Ningbo, 2010). Building developers that do not incorporate renewable energy technologies will fail the final acceptance check and thus will be denied occupancy permits, and may also face a fine of up to USD $30,000 (200,000 Yuan) (Yao & Zhu, 2011). The government of Ningbo has concurrently taken steps to address challenges with implementing the mandatory renewable requirement for new buildings — namely developers' attempts to circumvent the renewable requirement by installing a very small amount of low-cost solar water heating — by requiring experts to check and verify the integration of sufficient renewable capacity in the code enforcement process (Yao & Zhu, 2011). Ningbo has also offered developers incentives to adopt significant renewable energy technologies by providing total subsidies of USD $23 million (155 million Yuan) to offset the incremental costs of 50 to 100 building renewable demonstration projects over the next two years (Yao & Zhu, 2011).

6.3.2. Building Codes and Standards Development: Beijing and Tianjin

Since the 1990s, Beijing and Tianjin have both been pioneers in local building code development with the establishment of local residential building codes modeled after the 1995 national residential standard for cold and severe cold climate zones. Beijing and Tianjin's subsequent experience with continuously strengthening its design standards over time and unprecedented leadership in introducing additional requirements such as mandatory heat metering and consumption-based billing can also be considered examples of best practice in local code development. During the 11th FYP, both cities emerged as leaders in developing more stringent local building codes by mandating significant reductions in heating energy consumption intensity for residential buildings.[99] Compared to the baseline of inefficient buildings constructed in the 1980s, the revised local standards in Beijing and Tianjin mandate a reduction of 65% in building heat energy consumption, exceeding the 50% reduction

[99] Building heat consumption intensity represents the sum of net heat losses through all building envelope components and infiltration (Energy Sector Management Assistance Program, 2011). This intensity enables the simplification of building energy analysis for heating in code development, but generally underestimates actual heat consumption because the methodology is applied to ideal or generalized operating conditions (Li, Colombier, & Giraud, 2009).

mandated by China's national residential design standard for cold and severe cold zones. More recently for the 12th FYP period, both cities have also indicated that they will adopt a 75% mandatory heating intensity reduction standard for residential buildings through a revised residential building code and the mandatory installation of solar water heaters for buildings with less than 12 floors. The two case studies below present a retrospective look at Tianjin's leadership in effectively implementing its more stringent residential building code and the estimated energy savings as well as a prospective look at unprecedented policies being launched by Beijing for the next five years.

6.3.2.1. Tianjin: Implementing Leading Local Building Code and Estimated Savings

As one of China's largest municipal areas in the northern heating district and cold climate zone, Tianjin has emerged as one of the earliest leaders in improving local building energy efficiency in China with the development of a more stringent local building code and a supporting compliance enforcement structure. As early as 1997, Tianjin introduced DBJ 29-1-97, one of the first mandatory local residential building energy codes, modeled upon China's first national residential code for the cold climate zone introduced two years earlier. Beginning in 2003, Tianjin began revising its residential code with international assistance from the World Bank and the Global Environment Facility as a pilot city under the *China Heat Reform and Building Energy Efficiency Project*. A key change in the revised residential building code introduced on July 1, 2004 (DBJ 29-1-2004) was the 30% more stringent threshold building heat consumption intensity (14.4 W/m^2 of construction floor area relative to the 1997 standard's intensity of 20.5 W/m^2) (Energy Sector Management Assistance Program, 2011). In other words, the revised allowable heating intensity is 65% lower than inefficient buildings built in the 1980s. (Li, Colombier, & Giraud, 2009). The 2004 revised standard became mandatory for all new residential buildings in Tianjin on January 1, 2005, and was further updated in 2007 as DBJ 29-1-2007 with additional provisions for cooling and ventilation, sun shading, and structural integrity beyond the basic thermal integrity requirements of DBJ 29-1-2004. A comparison of the major differences between DBJ 29-1-98 and DBJ 29-1-2007 is shown in Table 6-13. Tianjin government's quick response to address issues that arose in implementing the revised code from 2005 to 2007 reflects its policy leadership and dedication to improving building energy efficiency (Energy Sector Management Assistance Program, 2011).

Table 6-13. Comparison of Key Parameters of Tianjin's Residential Energy Design Codes

	DBJ 29-1-97		DBJ 29-1-2007	
Overall Building Threshold BHCI	**20.5** W/m^2 of construction floor area		**14.4** W/m^2 of construction floor area	
Building Envelop Component Requirement	**U Factor** (W/m^2-K)		**U Factor** (W/m^2-K)	
	Shape coefficient* <= 0.30	0.30<Shape coefficient <=0.35	Buildings with 4 or more stories	Buildings with 3 or fewer stories
Roof	0.80	0.60	0.50	0.40
Exterior wall	1.16	0.82	0.60	0.45
Un-heated stairwell				
Partition wall	1.70	1.70	1.50	1.50
Apartment entry door	1.70	1.70	1.50	1.50
Window	4.00	4.00	2.70	2.50
Balcony door				
Glazed portion	4.00	4.00	2.70	2.50
Non-glazed portion	1.70	1.70	1.50	1.50
Building entry door				
Glazed portion	NA	NA	4.00	4.00
Non-glazed portion	1.70	1.70	1.50	1.50
Ground floor exposed to outside air	0.50	0.50	0.50	0.50
Ground floor above unheated basement	0.55	0.55	0.55	0.55

* Shape coefficient is defined as the exterior surface area of a building divided by the enclosed volume. A higher value indicates a larger area for heat loss per unit interior volume. This condition is simplified in the current BEEC by dividing buildings into two categories by the number of floors.

Source: (Energy Sector Management Assistance Program, 2011).

Note: BEEC = Building Energy Efficiency Code; BHCI = Building Heating Consumption Index.

Moreover, Tianjin is remarkable in its parallel efforts to introduce consumption-based billing alongside the adoption of a more stringent building design code. As early as 2005, the city government established a separate regulation for the mandatory installation of thermostatic radiation valves for temperature control and apartment-level heat meters for consumption-based billing. This was later incorporated into DBJ 29-1-2007, resulting in 26 million m^2 of residential floor space having successfully installed heat meters for consumption-based billing by 2009 (Energy Sector Management Assistance Program, 2011). In one pilot community in Tianjin, over 60% of residents reported lower heating costs after heat meter installations with reported household savings of 2000 Yuan (USD $300) per year (World Bank, 2011). In light of these economic savings and increased overall thermal comfort of residents with heat meters, Tianjin has set a 2015 target of setting up controllable heat systems and consumption-based billing for 100 million m^2 of housing, covering 35% of existing buildings and 100% of new residential buildings, by 2015 (World Bank, 2011).

In addition to the adoption of more stringent design codes and heat reform requirements, Tianjin has also continuously strengthened its compliance enforcement process under the leadership of the Tianjin Construction Commission. As the designated regulatory agency for overseeing the municipal construction permitting and code implementation process, the Tianjin Construction Commission has actively worked with and carefully monitored the licensed third-party professionals responsible for each stage of the implementation and enforcement process. This third-party compliance approach has proven to be effective in Tianjin as well as other cities such as Ningbo, and is discussed in more detail in the following subsection. By 2008, MOHURD reports indicate that Tianjin's code compliance rates for

new residential and commercial buildings were close to 100%, much higher than the average rate of 80% across three dozen large cities inspected by MOHURD (Energy Sector Management Assistance Program, 2011).

Given near full compliance with the revised building code which went into effect in 2005, the energy savings of the more stringent 2004 and 2007 revised standards can be estimated. Between 2005 and 2009, an estimated 50 million m^2 of construction in Tianjin was built following the revised design standards (a 65% reduction in heating intensity) (Energy Sector Management Assistance Program, 2011). In 2009, the 50 million m^2 of floor space compliant with the more stringent revised standard equaled 25% of the estimated 200 million m^2 of urban residential building stock in Tianjin. Using the old 1997 standard as the baseline for measuring savings, full implementation of the revised standard resulted in average heat demand reductions of 6.1 W/m^2 or 17.4 kWh of heat energy saved per m^2 of floor space. By 2009, the annual savings from implementing the more stringent revised standard totaled 870 GWh, the equivalent of 0.2 Mtce and 400,000 metric tons of CO_2 emission reduction per year (Energy Sector Management Assistance Program, 2011). The incremental cost of compliance with the more stringent building code in Tianjin is estimated to be 10 to 15 yuan/m^2 (USD \$2.22/m^2), based on expert-verified construction costs for two typical apartment buildings. Compared to the avoided annual heating service cost of 2.2 yuan/m^2 (USD \$0.32/m^2), the simple payback period for construction complying with the more stringent 2004 and 2007 building codes is estimated to be 5 to 7 years (Energy Sector Management Assistance Program, 2011). The relatively short payback period along with the co-benefits of reducing CO_2 and other air pollutants from avoided heat consumption in Tianjin demonstrates the economic and technical feasibility of more stringent local building design requirements.

6.3.2.2. Beijing's Leading Building Energy Standards

In 2012, Beijing became the first region in China to adopt a residential building energy design standard which mandates a 75% reduction in heating energy consumption intensity compared to buildings constructed in the 1980s. The 75% reduction in heating energy intensity is resulted from mandates to implement windows and doors with international practice-based heat transfer coefficients and heat pipe thermal efficiencies that are on par with existing international levels (Government of Beijing, 2011). This revised heating energy intensity mandate for residential buildings is much higher than the current national residential building code that mandates a 50% reduction in heating energy intensity relative to 1980s buildings. In addition to these more stringent requirements for heating energy consumption, Beijing has also mandated that all buildings with less than twelve floors should install building shading measures, solar water heaters, and high efficiency lighting products. As shown in Table 6-12 previously, full implementation of leading building energy standards for new buildings are expected to save 1.72 Mtce with 4.76 Mt CO_2 emissions reduction during the 12th FYP period. In addition, Beijing's 12th FYP for Building Energy Efficiency also states that commercial building energy design standards as well as lighting, air conditioning power consumption, and heat pipe thermal efficiency and commercial building heat transfer energy standards will be revised or developed before 2015.

6.3.3. Building Code Compliance and Enforcement: Ningbo and Shanghai

As the national average rate of building code compliance rises over time, the framework for implementing and enforcing building codes has also been significantly strengthened in some cities. In leading cities such as Shanghai, the improved structure for enforcing code compliance has naturally evolved out of the city's recognition of the need for greater deterrence of building energy code violations. As a municipality, Shanghai's municipal government has significant authority over policy making and has used its political influence to enact and implement regulations that are much more stringent than existing national regulations. In other smaller sub-provincial cities such as Ningbo where local policymaking authority is more limited, the regulatory support for implementing building energy codes has taken on other forms. For Ningbo specifically, international assistance and capacity building have contributed greatly to solidifying the role of third-party professionals in implementing building energy codes and enforcing compliance. In essence, the two following case studies represent the emergence of both top-down regulatory support for code compliance and bottom-up stakeholder support for carrying out building code enforcement.

6.3.3.1. Shanghai: Deterring Non-Compliance with Legal Sanctions and Liability

Shanghai is unique in that it has clearly stipulated the sanctions for violating mandatory building energy codes as well as related building energy efficiency regulations in the *Regulations of Shanghai Municipality on Building Energy Efficiency*, adopted by the Shanghai Municipal People's Congress on September 17, 2010. This regulation not only includes new requirements for building energy efficiency and renewable energy measures as previously discussed, but also explicitly outlines the regulatory, financial, and even legal ramifications of code violations or non-compliance for each stakeholder in the building industry. For each violation, the violator will be given notice as well as recommendations for necessary changes but may also be subject to a fine that ranges from 10,000 Yuan (USD $1500) for minor violations to half a million Yuan (USD $74,000) for major violations.

Table 6-14 shows the range of fines that apply to each type of violation and violator. In addition to the wide-ranging but also very high monetary fines for various violations, Shanghai's regulation also aim to deter corruption among building regulators by imposing criminal liability on government officials that knowingly or even negligently neglect to fulfill their obligations to enforce the regulations through supervision and inspection. While this particular regulation and the related fines only went into effect on January 1, 2011 and actual instances of enforcement and issuance of fines are not readily known, Shanghai's attempt to codify and legalize severe sanctions for violating or not complying with building energy efficiency regulations is nevertheless a very impressive and noteworthy example for China.

Table 6-14. Specified Sanctions for Building Energy Efficiency Violations by Violator

Violator	Violation	Possible Fine
Developer	Failure to comply with solar water heating system or renewable energy system installation requirement.	50,000 – 500,000 Yuan (USD $7400 – $74,000)
	Expressly or implicitly telling design or construction companies to violate mandatory building energy codes.	200,000 – 500,000 Yuan (USD $30,000 – $74,000)
	Failure to publicize energy conservation information for a new building after 1 year or during sales.	10,000 – 30,000 Yuan (USD $1500 – $4400)
Design Company	Failure to comply with energy efficiency laws, rule, regulations, or codes in their design.	100,000 – 300,000 Yuan (USD $15,000 – $44,000)
Drawings and Design Examination Agency	Issue false examination report in violation of standards.	30,000 Yuan (USD $4400)
Quality Testing Agency	Failure to apply standards when conducting testing, failure to input testing data in a timely manner, failure to issue testing report or issuance of a false testing report,	10,000 – 30,000 Yuan (USD $1500 – $4400)
Construction Company	Use of substandard energy efficient materials.	20,000 – 200,000 Yuan (USD $3000 – $30,000); person-in-charge may also be fined 5,000 – 50,000 Yuan (USD $740 – $7400)
	Failure to take necessary measures that result in not meeting energy codes.	10,000 – 100,000 Yuan (USD $1500 – $15,000)
	Failure to have running account of energy consumption or failure to make satisfactory statistical report of energy consumption.	10,000 – 30,000 Yuan (USD $1500 – $4400)
Municipal/District/County Construction Department	Issue permits or impose penalties in violation of law.	Criminal liability
	Failure to perform duty of supervision and inspection as required.	
	Failure to promptly investigate or punish illegal acts, or cover-up illegal acts.	
	Other acts of neglect, abuse of power or committing fraud for personal gain.	

Source: (Shanghai Municipal Government, 2010).

6.3.3.2. Ningbo: Successful Integration of Third-Party Professionals in Building Code Implementation

Besides its recent comprehensive approach to improving building energy efficiency, Ningbo has also demonstrated success in developing a strict supervision system for overseeing third-party verification companies involved in building code implementation. As one of two pilot cities that received technical assistance from the Pacific Northwest National Laboratory with support from the U.S. Department of Energy, the U.S. Department of State, and the Chinese Academy for Building Research, Ningbo successfully established a supervision system for processes spanning from building design to final

acceptance of construction (Yao & Zhu, 2011). While the Ningbo construction administration department is responsible for local oversight of code enforcement, the actual implementation and enforcement processes are carried out by third-party professionals and other building industry stakeholders. As described in previous sections, the code implementation process begins after the developer is granted a land use permit. The developer then seeks bids from licensed architects and other certified third-party professionals including construction companies, design verification and construction supervision companies. In Ningbo, there are five drawing inspection companies and dozens of construction supervision companies (Shui, et al., 2011). These third-party professionals have to successfully complete training courses and pass the national licensing exams to receive their licenses directly from MOHURD. Because the third-party professionals are hired directly by developers and may face conflicts of interest in code enforcement, cities such as Ningbo have provided strong deterrents against fraud and corruption in the form of heavy fines, liability, and suspension or revoking of licenses.

The code implementation process begins with the architects and the design verification company using an integrated design and code compliance software, such as PKPM-Energy which dominates the market with 50%–70% market share, to check for compliance while designing the building and includes trade-off options for meeting code requirements (Evans, Shui, Halverson, & Delgado, 2010). After the project design has been finalized and verified by the drawing verification company to meet building energy code requirements, the next steps of the code implementation process and the division of responsibilities in the construction phase are illustrated in Figure 6-14.

In addition to hiring a construction supervision company to supervise and oversee code compliance during construction, construction companies in Ningbo must also develop a quality control system. For large building projects in Ningbo, construction supervision companies typically provide a team of on-site supervisors or inspectors to continuously oversee construction and ensure compliance throughout the process (Evans, Shui, Halverson, & Delgado, 2010). The construction supervision company will also send building components and materials to testing labs, which are certified by the central government. Although Ningbo only has four testing labs, there are hundreds of certified testing labs across China as it is a relatively lucrative business and the certification process is relatively simple. The quality control and testing stations, which are funded and authorized by the local government, are responsible for conducting both scheduled and random inspections. The Ningbo quality control and testing station has a total staff of 40 to 50, including three to five staff members with detailed energy expertise and backgrounds. Staff conduct on-site inspections during major milestones in the construction process such as the pouring of the foundation and the completion of main structure (Evans, Shui, Halverson, & Delgado, 2010).

Figure 6-14. Roles and Responsibilities in Code Implementation and Enforcement in the Construction Process

Source: (Evans, Shui, Halverson, & Delgado, 2010)

Ningbo's effective enforcement of building codes is also distinct in that it uses information technology to further prevent data tampering and fraud in code enforcement. The information captured at each stage of the code implementation process is integrated and protected by encrypted electronic files generated from PKPM software (Yao & Zhu, 2011). The encrypted files help protect records of the energy efficiency measures, construction, and inspection results and can only be accessed by supervisors in each stage of the code implementation process. In addition to provincial inspections undertaken by Zhejiang province, Ningbo also conducts annual inspection surveys of building designs and construction compliance documents similar in scope to the national surveys conducted by MOHURD.

Ningbo's comprehensive code implementation process with effective integration and oversight of third-parties has contributed to high compliance rates. Officials from the local construction administration commission have reported design and construction compliance rates of over 98% in urban areas (Shui, et al., 2011). However, these officials have also acknowledged remaining challenges with code implementation and enforcement in nearby small townships and rural areas which lack local construction departments or quality supervision stations.

6.3.4. China Low Energy Building Case Studies

Increasing support from governments at the national, provincial, and local level – combined with the growing popularity of the Three Star Program and LEED as well as the development and promulgation of the Green Building Standard – portend well for the future of green buildings in China. We have elsewhere noted that particular difficulty of achieving very low energy in commercial buildings. Here we

provide two case studies, both from Shenzhen, that are among the best low energy commercial (public) buildings in China.

6.3.4.1. Shenzhen Institute of Building Research Headquarters Building

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 a total floor space 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 and as a leading Three Star building under the Five Star China Building Energy Efficiency Labeling program (IBR, 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^2/year (IBR, 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^2/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 (IBR, 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 intensity of only 12 kWh/m^2/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, for an estimated total cost of RMB 720 million (Malone, 2010; IBR, 2011).

6.3.4.2. Retrofit of Sanyang Complex in Shenzhen, China

The Sanyang complex in Shenzhen, China, represents a successful example of energy efficient building retrofits that resulted in relatively low energy buildings. Originally built in 1983, the Sanyang complex was designed as an industrial building complex with a total floor space of 95,815 square meters across six buildings, each with four floors. Under the direction of the China Merchants Property Development Company, the complex underwent extensive retrofits and was converted into retail, office and other commercial space. Overall, the retrofitted complex was able to achieve total energy savings of 65%, when compared to the building code baseline of 1980s buildings (China Merchants Property, 2012).[100]

[100] For reference, the existing building code for public buildings (i.e. non-residential) buildings in China require 50% reduction in heating, cooling and lighting energy intensity per square meter relative to the baseline of 1980s inefficient buildings.

The total energy savings of 65% can be divided up as follows:

- Space enclosure improvements: 12%;
- Air Conditioning & Cooling: 30%;
- Natural Ventilation: 6%;
- Lighting: 16%;
- Solar Photovoltaic System: 2%.

While cost information was not provided and thus cost-effectiveness of the retrofit project cannot be directly assessed, the Sanyang project nevertheless demonstrates that important energy savings are achievable through the integration of energy efficient technologies and measures in the retrofits of old buildings.

6.3.5. Indicators of Best Practice from China's Case Studies

6.3.5.1. Comprehensive Building Efficiency Policy Approaches

Beijing's success and leadership in implementing wide-ranging building efficiency policies have resulted in substantial savings over the 11th FYP, including:

- 20.6% reduction in average hating energy intensity per square meter
- 21% of total residential building stock meeting the more stringent local building code
- 1.62 million m2 of certified green buildings
- Retrofits completed for over 140 million m2 of residential and commercial buildings
- 18.2% of annual new construction has integrated renewable technologies

Altogether, Beijing's ambitious policies on the green buildings labeling program, building integrated renewable technologies and energy efficiency retrofits could result in substantial energy savings on the order of saving 10% of the city's total annual energy consumption over five years.

Ningbo has taken a carrots and stick approach to promoting building efficiency. Ningbo has effectively integrated third-party professionals into its building code implementation and enforcement structure, resulting in average design and construction compliance rates of over 98%. Ningbo has also offered total financial incentives of 155 million Yuan (USD $23 million) to develop 50 to 100 building renewable demonstration projects over only two years.

6.3.5.2. China: Leading Local Building Energy Codes

The consistent development and revision of more stringent building energy codes in Tianjin and Beijing have resulted in significant energy savings. In Tianjin, more stringent heating intensity reductions adopted in 2004 and 2007 have saved 870 GWh, or 0.2 Mtce annually with relatively short simple payback of 5 to 7 years. In Beijing, full implementation of more stringent building codes adopted in 2012 is expected to save 1.72 Mtce and reduce 4.76 Mt CO_2 emissions by 2015.

6.3.5.3. New Low Energy Commercial Buildings

Three examples of newly constructed or recently retrofitted commercial buildings demonstrate the enormous – and often cost-effective - energy savings potential of properly designed, whole-systems buildings with the latest technology options in China. The Guangzhou Pearl River Tower reduced its annual energy consumption by 58%, with 10% higher incremental construction cost and short payback period of 4.8 years. The Shenzhen Institute of Building Research building achieved overall energy savings of 66% and total investment actually decreased by 33% relative to comparable construction costs in the area. The retrofit of Sanyang industrial complex in Shenzhen also demonstrated that retrofits can save as much as 65% compared to the existing building code baseline.

6.3.6. Conclusions

As building energy efficiency receives increasingly greater attention from national policymakers, some provincial and city-level policymakers have gone further in launching comprehensive building policy approaches that include more stringent local building standards, local building evaluation and labeling programs and incentives for efficiency retrofits and integrated renewables. These local leaders have all demonstrated longstanding commitment to consistently updating and strengthening building standards, allocating local funding to incentives and establishing unprecedented building efficiency and integrated renewable policies and regulatory institutions to support implementation.

Specific lessons learned from these successful case studies of building energy efficiency policies and low energy buildings include:

- **Significant energy savings can be achieved by adopting more stringent local building codes:** Tianjin and Beijing have shown that it is possible to achieve significant energy savings on the order of 30% heating intensity reduction per square meter and total savings of 1.72 Mtce over the 12th Five-Year Plan period, respectively, on a local level by continually adopting more stringent local building standards
- **Local mechanisms for strengthening code enforcement and raising compliance can be effective:** Ningbo and Shanghai have proven that code compliance can be bolstered through strong monetary deterrents to non-compliance and integration of third-party professionals in code implementation structure
- **New ultra-efficient buildings capable of achieving significant energy savings have demonstrated that cost-effective low energy buildings are possible in China:** several new commercial buildings – designed both domestically and by international firms - and a recently retrofitted commercial complex demonstrate the emergence of new ultra-efficient buildings capable of achieving significant energy savings at a reasonable cost in China

Overall, these case studies demonstrate different aspects of China's continuing progress in raising the efficiency of its building sector through improved and even innovative policies, strengthened institutions, and adoption of cutting-edge technologies. Together these case studies illustrate that local actions can have significant energy and emission reduction impact even as China continues to undergo economic

development and as national policies are iteratively refined. For rapidly growing countries like China that are facing challenges to successful coordination and implementation of national building efficiency policies, local actions can thus be an important first step to achieving sizable energy savings and demonstrating the elements needed for national-scale implementation.

Chapter 7 – Regional Comparisons, Policy Assessment and Opportunities for the Future

7.1. Status of Policy Development in the Four Regions

Overall, government programs in the United States and the European Union are active in implementing and updating building energy standards for new construction, developing and disseminating whole building energy labels, collecting building energy use data and target the specific needs of subsectors of the buildings market through tailored incentive and financing programs. Although variation exists, many sub-regional governments have considerable experience with building regulation, and many engaged stakeholders know the multiple benefits of energy efficiency and are looking for opportunities to become market leaders. Leading jurisdictions in Europe and the United States are especially distinguished by their successes in aligning the interests of key stakeholders, especially through energy utility regulation in many states in the United States, and public-private bank partnerships in certain European countries. Both regions are actively pursuing zero net-energy buildings, the development of which would be a watershed innovation for the new construction sector.

Building energy use in these developed regions, however, is dominated by existing buildings and many challenges remain in increasing the speed and scale of retrofit efforts. The European Union is attacking this issue with mandatory energy ratings for all buildings and units on the market. Both regions however have found it difficult to successfully encourage deep retrofits and establish stable means of financing the retrofits.

China and India are less experienced in the development and implementation of building energy efficiency policy packages than the United States or the European Union, and both will face different policy contexts in moving forward. Both India and China face a booming new construction industry and relatively less governmental and professional experience with energy efficiency in buildings. While the energy intensity of new construction is generally falling in the United States and the European Union, it is rising in China and India. However the potential savings are huge, considering that most of these countries' building stock in 2050 will be built between now and then.

In India, subsidized energy prices that greatly reduce the economic attractiveness of energy efficiency in buildings are likely to continue for the foreseeable future. Without government support, there is not a sustainable business model for private purveyors of energy efficiency in India without government support[101]

[101] Or China, whose energy prices are generally not subsidized, for that matter.

For both countries, the strength of government efforts – whose instruments may be private firms responding to policy – will be the primary determinant of the pace of building energy efficiency measure deployment. Both countries are on a promising development trajectory. In China, the strength of central and provincial level government efforts and the recent priority given to improving energy efficiency in buildings is beginning to drive energy efficiency investment in buildings.

7.1.1. Building Energy Codes

All regions have developed sophisticated building energy codes through centralized efforts. Codes often require integration into local laws (as is the case in all four regions). In all regions, limitations in local capacities result in a lag between standard developments and implementation. All regions allow local level regulations to be more stringent than standards established at higher levels.

In the United States and the European Union, experiences of progressive jurisdictions have become important testing grounds for less active jurisdictions to develop the administrative and workforce capacities to better implement new codes. China has as a result of policy initiatives in the 11th Five Year Plan (2000-2010) rapidly increased its capacity to implement codes. India is at the initial stages of building this capacity. In both counties, but for different reasons, there is active consideration to changing the underlying approach to the standards. India's code, developed with guidance from United States experts, is very ambitious and has some requirements that are better suited to the United States than to India. In China, the standards are based on the comfort conditions that prevail in the United States, partly as a result of advice from U.S. experts. Standards set under these assumptions are not likely to reduce energy use in buildings significantly. Standards for rural buildings are non-existent in both countries. Both countries are increasing administrative capacity and stakeholder awareness.

A comparison of the successes, barriers, and next steps in the four regions is found in Table 7-1

Table 7-1. Status of Codes Development and Implementation in the Four Regions

	SUCCESS:	Leader and laggard MSs have worked together and now all MSs have new and retrofit energy codes; country-level climate change plans increasingly focusing on the building sector; wide consensus on the development of zero-net energy buildings codes for 2018 and 2020.
	BARRIERS:	Retrofit codes are not often enforced in many MSs; compliance rates are relatively unknown.
	NEXT:	Publication of near zero buildings roadmaps; testing of code improvements in progressive MSs; development and testing of mandated retrofits policy.
	SUCCESS:	Most states have new construction codes; national level model codes developed with high degree of industry support and inspiration by leader jurisdictions like California; some states are integrating code compliance development efforts into utility program evaluation.
	BARRIERS:	Federal government cannot mandate states to develop codes; retrofit codes are rare; code compliance varies widely and compliance data is generally lacking.
	NEXT:	Capacity and program development for all states to meet goal of 100% code development and 90% implementation across states by 2017; development of code compliance best practices.
	SUCCESS:	Nationally-developed building codes for new construction and retrofits in all sectors in most climate regions; development of advanced codes in code leader jurisdictions like Shanghai, Tianjin, Beijing and other major cities; high-speed capacity development through triple-checking system with dramatically increased compliance rates in recent years.
	BARRIERS:	Codes as developed may not be appropriate for local comfort conditions; no rural codes.
	NEXT:	Reevaluation of codes according to domestic thermal comfort standards; updating older codes to take new technology into consideration; spreading lessons from leading code jurisdictions like Beijing and Tianjin, verification of compliance rates and evaluation of capacity development best practices.
	SUCCESS:	Development of the country's first commercial building energy code for new construction and retrofits and some local regulatory development; implementation in government buildings.
	BARRIERS:	No low-rise residential or rural buildings codes; codes may be too advanced for capacity levels; local level integration is time consuming; enforcement of building codes is rare; and product testing is almost non-existent.
	NEXT:	Developing code leader jurisdictions and implementation best practices through concerted action to gather stakeholders together and inform market.

7.1.2. Labels

Building energy labeling programs, formulated at the national level, have supported local authorities promoting energy efficiency in all regions. In the United States and the European Union, they have provided the basis for incentives for buildings that exceed the standards. They are also useful elements in training programs for building code officials and other building energy professional.

Table 7-2 describes the status of building energy labeling programs in the four regions.

Table 7-2. State of the Art of Building Labels Development and Implementation in the Four Regions

	SUCCESS:	EU-wide mandate for energy labeling for all buildings at time of transaction, rating labels increasingly include retrofit recommendations; real estate market premiums apparent in some countries; training programs established with sharing of best-practices; computerized records for quality assurance and data-assisted policy design; early development of low-energy building endorsement standards push codes towards nearly zero-net energy buildings.
	BARRIERS:	Newness of labels in some countries may prevent realization of market premiums in short term; lag in certifier training hindered EPBD program deployment; quality of certification and design of different labels in countries not yet proven.
	NEXT:	Evaluation of mandatory labels for best practices and consumer understanding; sharing of best practices on multiple means of training certifiers; empirical analysis of utility of asset versus operational ratings for different building types.
	SUCCESS:	Some endorsement labels (e.g., Energy Star™) are credible to a large fraction of consumers and are showing market premiums; label programs increasingly deliver information on the value of savings and retrofit options; ENERGY STAR commercial programs often use nationally-developed models for standardization for mandatory and voluntary programs; use of survey-based databases to assist benchmarking.
	BARRIERS:	Many energy labels tied to incentive programs with uncertain real estate market demand; label market is saturated with many different labels; label programs not being fully used to develop standardized national buildings benchmarking database.
	NEXT:	City and state-level mandatory label expansion and program testing.
	SUCCESS:	Enthusiastic development of locally-relevant labels; early application of LEED and China 5 Star Rating system programs to require labels in government buildings and some limited areas; high uptake in leading code jurisdictions.
	BARRIERS:	Jurisdictionally-fractured government code development with authority vested in multiple regional and municipal agencies; LEED dominated real estate market with limited penetration of government-sponsored energy labels.
	NEXT:	Clarify label regime through efforts to consolidate programs; expand upon areas like Jiangsu's strong labeling programs by tying labels to government incentives.
	SUCCESS:	Very early-stage LEED penetration with strong growth in recent years; development of locally-relevant label (GRIHA); programs to require domestically-developed labels in government buildings; use of building energy ratings to create benchmarking database.
	BARRIERS:	Label competition may be an issue; dominance of "green" labels which do not clearly indicate energy use; limited market demand for building labels.
	NEXT:	Letting the market decide which is best—local labels likely to win with government support.

The EU Buildings Directive mandates that all buildings and units possess and display energy labels, called Energy Performance Certificates (EPCs), at time of sale or rent. The labels are designed to be easily understood. Many include advice on how to make improvements and their value. Some countries in the EU require continuous education for inspectors, re-certification, and computer-based certification error checking.

Most labels in United States are voluntary. However, a few cities and states using the ENERGY STAR program have begun to implement EU-like mandatory rating schemes for buildings at the time of sale.

With the exception of mandatory requirements for energy labels for government buildings, almost all building label programs in China and India are voluntary.

In the United States and the European Union, rating systems are often tied to financial incentives. In the United States this is exemplified by the use of the ENERGY STAR commercial building programs as a basis for utility incentive programs with their DSM portfolio (and thus be reimbursed for the efforts by ratepayers). Europe's increasingly popular zero-energy buildings policies have relied on voluntary low-energy labeling programs such as Effinergie and Passive House to assess feasibility of very low energy buildings. Rating is the first step to attaining a loan or grant from the KfW system in Germany.

In all regions there are multiple labeling programs aimed to accomplish similar objectives. This can be a barrier to consumer acceptance and understanding of labels. The mandate in the European Union for labels has had the effect of encouraging standardized and simplified labeling within countries.

7.1.3. Incentives

The United States and the European Union have experimented with a plethora of incentive schemes and financing mechanisms. Most come in one of three forms: loans from private and government-associated banks; grants and loans from public utilities or third parties distributing utilities'rate payer funds; and tax rebates from government funds. In many cases, the most successful programs tap different funding streams through a single deliverer, such as the KfW scheme in Germany that offers government-backed loan financing, grants, and tax rebates through retail banks. Additionally, the best incentive programs ensure that the deepest energy savings are given the highest incentives (called "tiering"). Incentive programs are also policy delivery mechanisms, in that they can substantially raise awareness of building energy efficiency opportunities to many stakeholders in the building sector, especially in the residential construction sector.

Many incentive programs are part of a coordinated energy and climate-change strategy. The New York City, Jiangsu province, California state, and Austria case studies provide examples of incentive programs that are either a part of a broader strategy or are explicitly linked to other policies.

Incentive programs funded by governments often rise and fall as governments change and fall as public money becomes scarce. The recognition of this situation has led to creative approaches to financing of energy efficiency programs. The KfW program in Germany demonstrates how building energy efficiency incentive programs can generate net-positive income for the government. Indeed, some of the most successful efficiency incentive policies in Europe and the United States increasingly rely upon well-regulated non-governmental entities (investor-owned utilities in the United States and to a certain extent commercial banks in Europe) for the distribution of incentives. The concurrent development of energy and climate change goals, building codes, and energy efficiency incentives, all administered by a small cohort of state-level regulatory agencies, has proven particularly effective in California.

Financing and incentive mechanisms in China and India are more circumscribed than those in the United States and the European Union but efforts in China are quickly growing and becoming more comprehensive. Chinese government grants and subsidies are starting to compel comprehensive retrofits. The government has recently mandated a 10 to 15% reduction in energy intensity of commercial buildings in urban areas. It is providing full funding for very large-scale retrofit of government buildings. In early May, 2012, China announced incentives for green buildings that increase as their rating on the green buildings energy label goes from two to three stars.

Table 7-3. State of the Art of Financing Mechanisms in the Four Regions

	SUCCESS:	Most successful tax breaks have been tied with utility mandates for energy savings; retail banks enthusiastically joining some programs like the KfW scheme in Germany; tiered incentives are increasingly the norm; packages delivered by many national governments incorporate all types of incentives with specific market targeting; net positive income is proven achievable by the KfW scheme.
	BARRIERS:	Replicability of KfW scheme will depend upon willingness of local banks; utility building programs largely untested in most countries; establishing sustainable revolving funds is difficult.
	NEXT:	Experiments with different types of incentives other than for homeowners, and delivery through utilities; spread of certification scheme best practices.
	SUCCESS:	Demand Side Management (DSM) programs tied to utility EE mandates have been very successful in states in which utility profits and sales are decoupled; national model commercial program templates substantially ease burdens of local-level program administrators; tying incentives to certification schemes has increased certification.
	BARRIERS:	Many state regulatory commissions and utilities oppose DSM because it raises electricity rates (as distinct from customer bills); uncertain project-level cost recovery of deep retrofits, especially for residential market.
	NEXT:	Testing and analysis of novel approaches being tried out (PACE, on-fill financing programs, etc.); program evaluation processes benefit from standardization.
	SUCCESS:	Large incentives for industry during last five years has created the infrastructure and skills to implement similar program for buildings; packaging of incentive information within building codes and regulations appears to be a good strategy to increase awareness and uptake.
	BARRIERS:	Previous incentives in residential housing were not tiered well; diverse stock of buildings results in high transaction costs; most programs limited to easy-to-implement lighting and renewable energy measure-based subsidies.
	NEXT:	Funding through ESCOs; utility energy saving mandates in new Five Year Plan; continued expansion of incentive programs beyond low-income housing and government buildings.
	SUCCESS:	Lighting program and certain renewable energy programs are most developed; early linkage between domestic label program (GRIHA) and incentives.
	BARRIERS:	Building incentive programs are very limited and constrained by complexity of Indian bureaucracy, limited funds, relatively low priority and limited government awareness.
	NEXT:	Developing data regarding costs and benefits of energy savings measures for more building types and climates should be the first priority before dramatically increasing financing.

Chapter 8 – Findings and Recommendations

This report addresses the single largest source of greenhouse gas emissions and the greatest opportunity to reduce these emissions. The IPCC 4th Assessment Report estimates that globally 35% to 40% of all energy-related CO_2 emissions (relative to a growing baseline) result from energy use in buildings. Emissions reductions from a combination of energy efficiency and conservation (using less energy) in buildings have the potential to cut emissions as much as all other energy-using sectors combined. This is especially the case for China, India and other developing countries that are expected to account for 80% or more of growth in building energy use worldwide over the coming decades. In short, buildings constitute the largest opportunity to mitigate climate change and special attention needs to be devoted to developing countries.

At the same time, the buildings sector has been particularly resistant to achieving this potential. Technology in other sectors has advanced more rapidly than in buildings. In the recent past, automobile companies have made large investments in designing, engineering, and marketing energy efficient and alternative fuel vehicles that reduce greenhouse gas emissions. At the same time, the buildings sector – dependent on millions and millions of decisions by consumers and homeowners – face a large variety of market barriers that cause very substantial underinvestment in energy efficiency.

How can the trajectory of energy use in buildings be changed to reduce the associated CO_2 emissions? Is it possible to greatly accelerate this change? The answer to these questions depends on policy, technology, and behavior. Can policies be crafted and implemented to drive the trajectory down? Can the use of existing energy efficiency technologies be increased greatly and new technologies developed and brought to market? And what is the role of behavior in reducing or increasing energy use in buildings?

These are the three overarching issues. The information assembled in this study and the knowledge derived from it needs to be brought to bear on these three questions. And thus we turn to some of the insights from the study, presented in the form of findings and recommendation. Of the many findings that could be presented we have chosen the few that we consider to be particularly important. Others reading this report would undoubtedly choose a different set. The reader is encouraged to do so.

8.1. Findings: Policy

8.1.1. Building Energy Standards

Building energy standards are ubiquitous in the United States, the European Union, and China. They are the most potent of all policies in reducing energy use from heating and cooling of buildings. Almost all of the standards thus far promulgated in three regions have been cost-effective. There is a long (multi-

decade) tradition of building standards in all of the regions. This is especially true of the north of Europe with extreme cold weather and countries wealthy enough to invest in energy efficiency.

To date, most standards have been applied only to new buildings. The problem of high energy use of existing buildings – of great importance in the two regions (the United States and the European Union) in which the building stock is growing slowly – has not been well addressed and standards have played little role. There is increasing interest and activity in applying standards at point of sale.

The most important issues in making standards more effective are (1) increasing training (of code officials, builders, and other building professionals), (2) the rigorous updating of the standards to promote the development and use of new, efficient technology, (3) announcing new codes early on so that the industry can prepare for more stringent codes and, (4) demonstrating the feasibility of constructing progressively more efficient buildings that are cost effective.

8.1.2. Building Energy Labels

Whole building energy labels have been particularly effective in three ways. They provide the necessary knowledge to the building owner or occupant to motivate decisions to invest in energy efficiency (for buildings receiving low ratings). Some of the labels recommend measures for reducing energy use (e.g., the European Union). The effectiveness of this application of labels is strongly dependent on consumers' view of their trustworthiness.

A second application of labels is to provide information about the building's energy-efficiency or energy use at the point of transaction (e.g., as required for example by France). The premise is that such knowledge is likely to be useful and used when the building is sold or rented.

The third use of labels is in our judgment the most important. The combination of standards (setting a floor on efficiency or energy use), a label (serving as a measuring stick), and financial incentives (to improve building performance beyond existing standards) is an extremely powerful means of increasing energy efficiency. If all three policies are well integrated with each other (e.g., California), they can drive efficiency aggressively and over a long period of time. The incentive and labeling policies will promote state of the art energy efficiency on which updates to standards can be based. This is effective as a policy design for new buildings but also can be applied to retrofits of existing buildings.

8.1.3. Building Energy Incentives

The fundamental issue of incentive programs is how to maintain funding, particularly if the funds come from governments. There are many innovative approaches to the problem that have potential for success. There are at least two approaches that have been successful on a large scale: utility demand side management (DSM) in the United States (funds from ratepayers who are the beneficiaries of the lowered total cost of supplying energy for the utility system) and in Germany (the KfW program where

the increased taxes resulting from the program cover the costs of administering the program plus the cost of the incentives).

8.1.4. Policy Packages

As noted in section 8.1.2, combining incentives with labels and standards produces a particularly effective means of reducing energy use in buildings as well as encouraging the development and use of advanced energy-efficiency technologies. Three prime examples of the strong synergy among the three policies are California's utility and standards programs, Germany's KfW loan program, and several innovative municipal programs in China. The approach of packaging policies that can be implemented in many different configurations (e.g. levels of standards and incentives; different rating systems; agents responsible for implementation; form and identity of beneficiary of the incentives, etc.) has the potential for greatly expanding the reach and impact of the individual policies.

8.2. Findings: Technology

8.2.1. Opportunities with Existing Technologies and Systems

The biggest opportunity for saving energy in buildings in the coming decade(s) in all four regions (even those with the highest rate of construction) is adopting already available energy efficiency technology. The existence of many underutilized energy efficiency technologies and the associated market barriers strongly justify government policies.

Systems rather than technologies offer the greatest promise of energy savings. They typically underperform and in the process use excessive amounts of energy. This is particularly the case for space conditioning systems in large buildings. Improving system performance has large potential for energy saving in the near time.

For those developing countries with large numbers of poor people in cold regions, the single most important means for reducing greenhouse emissions for heating (cooking and water heating in all climates) is the replacement of inefficient biomass and/or coal burning stoves with modern fuels and equipment.

8.2.2. Creating Future Technologies

In spite of the plethora of underutilized high-efficiency technology today, research and development (R&D) is needed to achieve technologies and systems with lower costs or better performance. There are numerous R&D opportunities to achieve these goals.

Current R&D programs unfortunately give very little emphasis to systems as distinct from technologies. Passive solar houses, with a combination of many technologies[102], illustrate the importance of systems in reducing energy use. Integrated design[i] is arguably the most important system (in reality, a "system of systems") for designing large buildings with very low energy use. An especially good example of the results of an integrated design process is the seven-story building housing the Institute for Building Research (IBR) in Shenzhen China. The building delivers substantial energy savings (greater than 50%) at construction cost lower than that of comparable buildings.[103] We believe that the integrated design process, with one knowledgeable person or organization having control over all aspects of the design process (architectural and engineering), construction, commissioning, and use of the building played an important role in the success of this building.

Thus R&D needs to focus much more strongly than it does today on designing, creating, testing, and producing techniques to assure effective performance of systems.

8.3. Findings: Behavior, Comfort Preferences, and the Operation of Buildings

Research going back to the 1970s has shown the variation of energy use as a function of occupant behavior. Studies of identical houses in close proximity to each other showed a factor of two difference in heating energy use between houses with the lowest and highest energy.[104] Numerous measurements and simulations have confirmed this variation or greater in commercial and residential buildings in the United States, China, Europe, and elsewhere throughout the world.[105] The body of this work shows that the effect of behavior and operational practices on energy use in buildings can be and often is greater than that of technology. Unfortunately, policies and programs have not demonstrated an ability to capture a significant portion of this occupant-related variation in energy. A miniscule portion of research on energy efficiency addresses how behavioral issues can best be addressed to achieve long-term energy savings.

8.4. Policy Research Needs

There is a need for experimentation, demonstrations, policy research, data and/or analysis on:

- Impacts of policies on heating and cooling energy use and costs (treated broadly[106]) based on quantitative and reproducible research.

[102] Importantly, the passive house as any complex system needs to be operated properly to be successful.

[103] Current estimates are that the construction cost may have been 1/3 less per square meter less than that of a comparable building.

[104] Stated more precisely, the factor of two is the ratio of the highest decile of heating energy use to the lowest decile.

[105] Annex 53 International Energy Agency (IEA), with participants from Asia, Europe, and the United States, has been studying this phenomenon for the past several years with a report scheduled for 2013.

[106] Including costs to consumers, energy suppliers, builders, the environment, etc.

- The effects of behavior on energy use in buildings and policies that encourage energy-conserving behavior.
- Well-documented costs and energy savings of buildings with very low heating and cooling energy.
- Quantitative effects of employing multiple policies (policy packages) to reduce building energy use.
- Sharing policy experience on building energy efficiency policies in actionable forms to developing countries.
- Effective methods to communicate information not widely known or understood to policy makers and the public.

8.5. Recommendations

Earlier[107] we identified the high-level issues that are the intellectual challenge underlying the research on which this report is based. It is our intent that the recommendations collectively provide insight into the issues. They are repeated below.

> *How can the trajectory of energy use in buildings be changed to reduce the associated CO2 emissions? Is it possible to greatly accelerate this change? The answer to these questions depends on policy, technology, and behavior. Can policies be crafted and implemented to drive the trajectory down? Can the use of existing energy efficiency technologies be increased greatly and new technologies developed and brought to market? And what is the role of behavior in reducing or increasing energy use in buildings?*

To increase the effectiveness and energy savings of building energy standards, we recommend that governmental organizations with authority over energy use in buildings should:

- As a matter of highest priority create (if they do not already exist) or strengthen building energy standards and their enforcement in measureable ways.
- Regularly update the standards as new technology or practices are demonstrated to cost-effectively save energy for space conditioning in buildings.
- Provide sufficient advance notice of the specifics and timing of the updates so that industry can prepare for the updates.
- Assure that demonstrations of improved practices and advanced systems and technology take place frequently and are of sufficient quality to support standards updates.

To increase effectiveness of labels, organizations responsible for them should:

- Assure that they are designed and promulgated to be easy to use.
- Are consistent with actual energy use or efficiency of the building to which it is applied.

[107] Third paragraph of this Chapter.

- Are communicated to consumers, builders, and other building professionals in a manner to assure their trustworthiness.

For financial incentives programs to have large and sustaining impacts, they need to be long-lived and at assured minimal levels.

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Endnotes:

Explanation of Integrated Design

[i]The integrated design process may be defined as one in which the design variables that interact with one another are treated together (i.e., iteratively), producing a design that comes close to achieving the objectives established for the design ("optimal"). The sequence of steps that is typically followed today often leads to solutions that are far from optimal. For example, HVAC capacity and equipment are often decided before the major contributors to the internal loads of a building are known.

Significant interactions take place among all design elements of a building affect heating and cooling loads (e.g., window size, placement, and thermal characteristics; window shading types and placement; lighting locations, efficacy and local controls; building orientation; number and wattage of plug loads; and the volume of outside air that is circulated into a building).

Advanced technology options (e.g., on- site generation, passive ventilation, thermal mass with night ventilation, chilled ceiling displacement ventilation, dehumidification and day-lighting) need to be taken into consideration. Control strategies and operating conditions of the equipment in the building strongly affect the effectiveness of the design and technology choices for the building.

Finally, all of these complex design and engineering issues must themselves be integrated with decisions on structural issues, space planning, site context, materials selection and other issues, all within the context of tight budgets and schedules.

To address these interactions among the different components of a building, integrated design and operation requires cooperation among the major decision makers in a building project—architects, engineers, and builders—to evaluate the projected energy consumption for a variety of designs. Building professionals must also enjoy a comfort level in using results of computer tools to underpin important design decisions. Software that is understandable to everyone involved is needed, so that the group's collective knowledge is codified and used as different problems and solutions are addressed in the design, construction, and eventually the operation of the building.