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Overview of Energy Standards for Buildings

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INTRODUCTION

In countries without effective energy-efficiency programs for their buildings, current building energy use trends are (or should be) cause for concern. The building sector consumes roughly one-third of the final energy used in most countries, and it absorbs an even more significant share of electricity. Electricity use in commercial buildings is driving peak demand in the United States, Japan, and in some of the wealthier less-developed countries (LDCs). As the people in LDCs raise their standards of living and services, building electricity use is expected to continue to increase, especially in the non-residential sector.

During the past three decades, governments in both industrialized countries and LDCs have initiated policies to reduce energy consumption in buildings. Most of these policies can be grouped into one of the following three categories: economic incentives (e.g., taxes, energy pricing), informational programs (e.g., energy awareness campaigns, energy audits), or regulatory requirements (e.g., codes or standards). More recently, growth in voluntary public-private partnerships (e.g., ENERGY STAR in the US and the Energy Efficiency Accreditation Scheme in the UK) and award programs from non-governmental organizations (e.g., the US Green Building Council) have changed the landscape for improvement by setting stretch goals for the building industry and its clients.

In this paper, we focus mainly on energy standards for buildings[1], which are a widely pursued but sparsely documented approach to limiting energy consumption in buildings. Existing energy standards range from voluntary guidelines to mandatory requirements, which may apply to one or many building types. Their development is typically a complex decision-making process that can involve any combination of participants from a range of institutions, including government, academia, utilities, industry groups, and professional associations. Once a standard's basic structure has been developed and tailored to fit a country's building practices and climate, it can be augmented and tightened to reflect technological development and changes in construction practice. Well-suited to influence new construction, standards can help avoid "lost opportunities" by capturing the long term savings associated with buildings' long life-cycles and low turnover rate. Moreover, they can help overcome barriers to energy-efficient products by heightening awareness and stimulating the market. They are also increasingly being used, particularly in Europe, to address energy concerns in existing buildings undergoing major renovations.

Although standards can be a flexible and low-cost approach to energy conservation, they are

[1] We use the word "standard" to refer interchangeably to what also might be called codes, criteria, guidelines, norms, laws, protocols, provisions, recommendations, requirements, regulations, rules, or standards. Depending on the country, the "standard" may be contained in one document, be part of another larger document (such as a general building code), or comprise several documents.

complicated to develop and difficult to assess. Published information about energy standards is limited, and most existing international studies focus on residential standards in industrialized countries. Policy makers considering energy standards for non-residential buildings[2] or in less-developed countries have few avenues through which to gain insight into their development, contents, use, or effectiveness. To explore these under-represented areas of research, in the early 1990s we developed a mail survey to gather more detailed information about activities undertaken to increase the energy-efficiency of buildings, particularly non-residential buildings. The results of this survey are available at several levels of detail, including a pair of government research laboratory reports (CLASP, 2005; Kathryn B Janda & Busch, 1993) and a peer-reviewed journal article (Kathryn B. Janda & Busch, 1994).

This paper reviews the original survey results and presents initial results of an ongoing update of the original survey. The original study—which we will call the 1994 study—provided a snapshot of the legal status and coverage of energy standards in 57 countries and used results of the survey to characterize the contents, development, implementation, and assessments of specific countries. The current update—which we will call the 2007 update—expands the scope of the original study, gathering information on information in 80 countries. Plans to launch a web-based survey—which we will call the 2008 study—are underway. The 2007 update relies upon a literature review of existing documents available in print and through the internet. This change in research method from survey to document review has several implications for this report. First, it means that the 2007 update hinges on documents and websites available in the native language of the researcher (English), whereas the work in 1994 relied on country experts. These experts were able to gather information in the native language of the relevant country and translate the information into English as necessary to answer the survey, ensuring broader coverage than an English-only endeavor. Second, the current work is subject to the level of information publicly presented rather than the level of information available directly from country experts. The 1994 survey format provided an important template that channeled information from the country experts, ensuring that the same types of questions were addressed by all respondents. Because of these methodological concerns, we plan to fully update the 1994 study with a web-based survey in 2008 hosted by the Environmental Change Institute at Oxford University. The timeframe for completion of the 2007 study for the UN Energy Efficiency Forum did not allow for this survey to be produced, posted, and completed in time for inclusion in this document. Due to methodological issues, we are unable to characterize the standards in 2007 at the same level we did in 1994. However, this paper identifies and discusses trends over the past 15 years in their development, orientation, and governance. We conclude with a summary discussion of the comparative advantages of the various approaches to increasing efficiency of energy use in buildings through standards.

BACKGROUND: PRINCIPAL APPROACHES TO ENERGY STANDARDS

[2] The term "non-residential" is used to refer to buildings that could be classified in the commercial, public, or service sectors.

As a background for the study results, we briefly review the development of energy standards over time, describe research issues which complicate the analysis of both building energy use and building energy standards, and suggest topic areas where international information on energy standards could be shared.

As with other energy-efficiency policies, interest in energy standards was fueled by the oil shocks of the 1970s. Prior to that time, only a few countries had regulations affecting the energy use of buildings. These were simple, prescriptive insulation requirements that bear little resemblance to the multi-faceted performance standards used in many countries today. Over the last three decades, improvements in calculation methods, computer modeling, and building energy research have provided the means for many countries to revise their original standards and develop more comprehensive versions.

Although energy standard activities are frequently mentioned in the literature, the standards themselves are rarely described in any detail. The lack of basic information about the contents of standards reflects and perpetuates an international information gap surrounding the development, use, and effectiveness of energy standards. The demand for information is most apparent for non-residential buildings and in LDCs. A handful of studies have pulled together detailed information about energy standards across national boundaries, but they do not represent the full breadth of energy standards activities or issues. The limited coverage of the literature on energy standards reflects complexities inherent in analyzing both building energy use and building energy standards, especially in the service sector. These intricacies pose serious barriers to building energy research and complicate comparative assessments of energy standards.

Building energy use & efficiency

Understanding even a single building's energy use is an analytical challenge. A building's energy consumption depends on its physical structure and design components, but it is significantly influenced by other less tractable factors such as occupant use, equipment operation and maintenance, and climate variation. Without the aid of detailed monitoring equipment, it may be difficult to determine how much energy use is due to building functions (heating, cooling, ventilation, lighting), how much emanates from occupant use (computers, refrigerators, stoves), and how these activities influence each other. While efficient light bulbs, refrigerators, and cars undergo prototype testing before they are mass-produced, buildings are custom-built. Testing procedures for buildings are typically limited to computer simulations or scale models. Like an appliance or an automobile, a building's performance will vary over its life-cycle, which is on the order of about 50 years. Technological development and ongoing changes in building practice further compound the complications in characterizing building energy use. Uncertainties about energy use in buildings are echoed in the lack of adequate data for the building sector. Compared to industry and transportation, the other two major energy consuming sectors, international and country sources for energy statistics give little detailed information about buildings. Buildings often fall into the "other" category which lumps together the residential, commercial, public service, and agricultural sectors. The International Energy Association publishes separate figures for residential and commercial use, but the differences between these sub-sectors are more significant than a single pair of numbers can convey.

Energy use in the residential sector is more homogeneous, more clearly defined, and better understood than energy use in the service or commercial sectors. Residential buildings are used predominantly to provide shelter, but commercial buildings span twelve International Standard Industrial Classification divisions. Uses for buildings constructed for service, commercial, or other “non-residential” purposes can range from caring for the sick to treatment of sewage.‘” Residences vary in size, shape, and fuel use, but not to the same extent that non-residential buildings do. The floor area of most new residences in the United States, for instance, varies from about 1500 to 2500 square feet, but the floor area of a new commercial building could be less than 5000 square feet or more than 100,000. Residential and non-residential buildings even have different energy conservation needs. Most office buildings are internal load dominated, and they can require some cooling even in winter. Residences tend not to contain enough operating equipment or people to generate a net internal heat gain during the colder months. As a result, the heat added by a few incandescent light bulbs might be negligible or beneficial in residences, but over-lighting in an office can increase an already significant cooling load.

Building energy standards

Because a thorough understanding of the existing building stock and its energy use is essential to standards development, it follows that the less variable and better documented residential sector has been the primary focus of building energy analysis and energy standards development. In addition to being less technically complex, there are political and practical reasons which may account for the residential focus of many building energy-efficiency efforts. Many countries have governmental housing programs which make regulation in the residential sector more politically feasible than in the commercial sector. In industrialized countries, the residential sector tends to use a higher overall percent of energy than the commercial sector, so it assumed higher priority during earlier energy crises. On a per building basis, however, energy-intensive commercial buildings present a ripe target for further savings.

As a regulatory option, building energy standards might be considered similar to standards for materials or appliances, but their development, usefulness, and assessment face greater uncertainties. Parameters used in the standard must be set by professional judgment or computer models because full-size prototypes are too expensive to construct and test for each building type, let alone each design or component. Whether a standard is successful, however, may have very little to do with the provisions it codifies. Without appropriate educational programs and implementation mechanisms for the construction community, even a well designed, mandatory standard will not save energy. Even with full compliance, poor data about energy trends in existing buildings or careless monitoring of new buildings could camouflage the real impact of a stringent and otherwise successful standard.

All of these issues apply to the assessment of energy standards in any one country, but additional barriers stand in the way of cross-national comparisons. Energy standards are difficult to classify because no established nomenclature clearly identifies policies that might be considered “energy standards.” A single country may have several such standards published by different entities, and they may be self-contained or subsumed within another document (such as a general building code). Whereas a standard set for efficient refrigerators in the U.S. could be used in Singapore or Sweden, standards for energy-efficient buildings are much less transferable. Building energy standards that are stringent for one country may be ineffective in another country, depending on climate conditions, occupant behavior, existing building stock, and construction practices. To make reasonable judgments about the impact of existing standards in different countries, all of these variables plus the turnover of old buildings and rate of new construction would need to be gathered, normalized. and compared. Such an analysis would be valuable, but it is beyond the scope of most studies, including ours.

1994 SURVEY: REVIEW OF PAST TRENDS

As a possible framework for an international descriptive reference, and in response to the highly variable published information available on energy standards, we developed a 15 page informal survey to gather information about activities undertaken specifically for the purpose of increasing energy-efficiency in buildings. Responses regarding standards for non-residential buildings were specifically encouraged, but the survey did not assume all respondent countries would have energy standards in place for any building sector. Although several sections were standard-specific, the survey also asked general questions about the status of non-energy building standards, energy-efficiency testing facilities, and other programs designed to increase energy-efficiency in buildings.

To broadly characterize the worldwide status of energy standards for buildings, we combined previously published information with results of the survey. Figure 1 shows a general overview of the legal status and coverage of energy standards in 57 countries. Thirteen of the countries for which information was gathered had no energy standards for any building sector; four countries had standards only for the residential sector; nine countries developed standards exclusively for non-residential buildings; and 31 countries had standards for both. At the national level, 27 countries have mandatory energy standards for at least one building sector, and 11 have voluntary standards. Three of the 11 voluntary standards are “mixed,” meaning that they are voluntary guidelines but mandatory in limited regions or for specific building types. Six more countries have proposed but not yet adopted energy standards; half of these are non-residential standards and the rest are for both or all buildings.

Summaries of energy standards from each country did not fit easily even into these simple categories. Many countries have more than one kind of standard, depending on the building sector and issuing organization. Each of these standards may have different legal applicability and original versions may have been updated and changed several times since their introduction. We attempted to include the most up-to-date information available for this table, but we did not project into the future. A recently passed energy bill might push the United States into the ranks of countries with mandatory national energy standards for buildings in 1994,” but until then the U.S. remains a patchwork of various state-initiated policies, many of which are based upon standards developed by ASHRAE.

Because of these complexities, we did not ask survey respondents to attempt a synthesis of the entire energy standard situation in their country. Instead, respondents from countries with existing (or proposed) energy standards named a specific standard and answered several sections of the survey with respect to this standard. They were asked to specify the standard’s geographic coverage and legal status; identify the applicable building types and vintages; and note its provisions for specific building elements. Respondents were also asked to indicate the entities involved in the process of developing and revising this standard, and to describe issues pertaining to its implementation and enforcement.

The survey was sent to approximately 175 contacts in government, research, and professional positions in 65 countries. The number and distribution of these contacts reflects recommendations solicited from researchers knowledgeable about energy standards rather than a specific selection criteria or sampling methodology. Contacts in countries where published information about energy standards does not exist were pursued more vigorously than contacts in countries covered by previous reports. Given the survey's length and the need for specific expertise in several areas, the response rate of 33% (59 surveys from 42 countries) was better than anticipated.

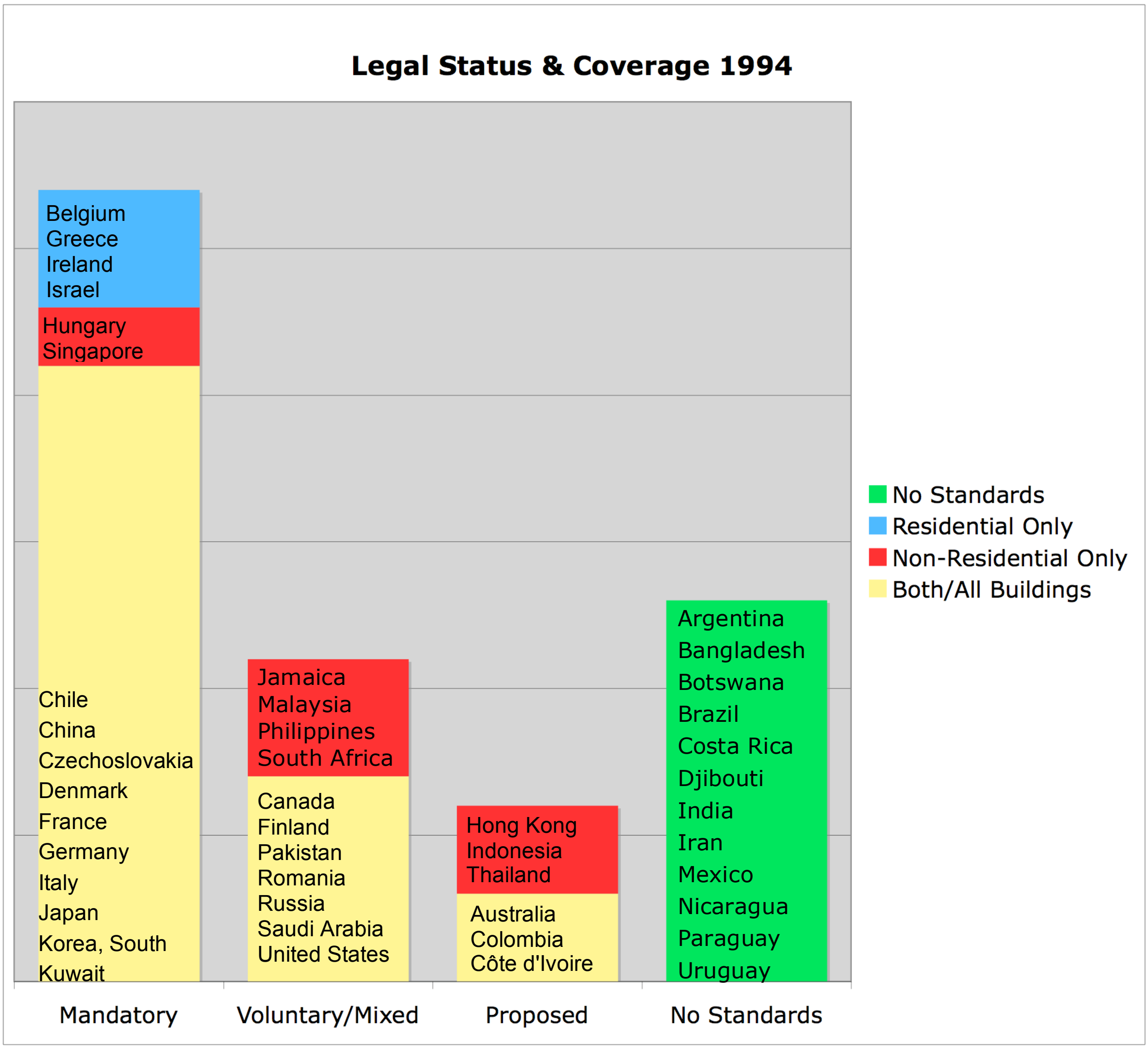

Figure 1. Worldwide Status of Standards, 1994 (after Janda & Busch 1994)

Information from survey respondents countries was organized into a database of information containing: (1) the status of energy standards for buildings in each country; (2) basic provisions of existing energy standards; (3) approaches to standards development; (4) implementation and compliance; and (5) other methods of increasing energy-efficiency in buildings. Coverage of the topics in the database depends upon the extent to which respondents in individual countries filled out our surveys. We reiterate that the database itself and information gathered is not definitive. Although efforts were made to define the researcher's sense of what an "energy standard for buildings" is, a few respondents answered with respect to a different type of standard than expected, such as a national electric code; if determined, these responses were not used for further analysis. In most cases only one survey from each country was received, but in cases where multiple surveys were returned we did not attempt to verify the information given or "correct" discrepancies between respondents from the same country.[3] Instead, we selected the survey which seemed to contain the most reliable information for our comparative analysis set. The results below cover only a few highlights from the database of surveyed information. More country detail and a list of respondents can be found in the full report."

Reflecting our initial sampling methodology, 26 of the 42 countries responding to the survey do not belong to the Organization for Economic Cooperation and Development (OECD). Seven of these countries do not have energy standards for buildings, although all seven have implemented programs to reduce energy consumption in buildings and most have devoted some attention to standards development. We will discuss these activities in a later section of this paper, after providing more detailed information from the 35 respondents who reported the presence of energy standards (either existing or proposed) in their country. Sixteen of the 35 countries analyzed belong to the OECD, and 19 do not.

General overview: countries with standards

We received responses from 25 countries with standards that cover both residential and non-residential buildings; 15 of these are mandatory, seven are voluntary (or mandatory only in specific states or regions), and three are proposed. Many of these countries have a single standard that nominally applies to both residential and non-residential buildings, but in most of these standards residential buildings are covered more comprehensively than other building types. Respondents from Belgium and Israel were the only ones to answer the survey according to standards that apply exclusively to the residential sector. Eight respondent countries have standards focused only on non-residential buildings. Table 1 summarizes survey results from these 35 countries, giving detailed information on the specific standards described by respondents.

All of the countries surveyed with standards developed specifically for non-residential buildings are non-European, and most of these standards were developed during the last 5 years. Six of these are either completely voluntary (Malaysia, Philippines, South Africa) or in the proposal process (Hong Kong, Indonesia, Thailand). Non-residential energy standards in Jamaica are mandatory for government buildings and voluntary for private sector buildings; Singapore reverses this emphasis, making standards voluntary for public buildings and

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[3] In South Africa, for instance, two respondents said there were no energy standards of any kind, while a third mentioned a voluntary standard for offices, government facilities, and hotels. All three respondents were certain, however, that energy efficiency was not a high priority, given current excess electric capacity and indigenous energy supplies.

mandatory for the private sector.

Contents of the standards

The following section discusses which kinds of buildings the standards cover, how they generally approach the objective of saving energy, and what specific measures are included in the standard.

*Applicability***.** The way in which a standard is developed and used depends on the kinds of buildings it is expected to cover. Different measures are appropriate for different building types, vintages, physical sizes, fuel uses, and an abundance of other possible building characteristics. The more specifically a standard has described its applicability, the more effective coverage it is likely to provide.

Fifteen of the surveys described standards with blanket applicability to all buildings, and 21 of the standards surveyed apply to three or more non-residential building types. These standards include 19 references to offices, 15 to hotels, 14 to public buildings (including government buildings, schools, hospitals, and churches or mosques), and 12 to commercial buildings (including retail stores and restaurants). China was the only country reporting a proposed standard that specifically targets tourist hotels; Japan and Australia each have standards solely for office buildings; and Hong Kong's proposed standard applies to both hotels and office buildings..

Roughly half the original respondents indicated their standards applied only to new buildings, and the rest indicated applicability to both new and existing buildings. No respondents answered the survey with respect to a standard exclusively for retrofitting existing buildings. Ten countries' standards apply specifically to air-conditioned buildings; proposed standards for the Ivory Coast may be the first to encourage the use of natural ventilation through special provisions for non-air-conditioned buildings. Eleven countries have defined a physical size criteria for applicability of the standard. Czechoslovakia determines the applicability based on volume, and other countries use floor area (the standard in Northern Ireland does not apply to buildings less than 30 square meters). Eleven countries have standards applying to buildings that use more than a specific amount of energy. For Jamaica, Malaysia, the Philippines, energy standards apply to buildings with a design demand greater than 10 watts per square meter (W/m2); in Northern Ireland, the demand must be larger than 50 W/m2 for the standard to apply. Singapore regulates buildings with more than 30 kilo-watts (kW) needed for air conditioning equipment, while the Thai standard applies to any building requiring 1000 kW or more. To a lesser extent than physical size or amount of energy used, type of fuel use is also a factor in determining some standards' applicability. The French standard is more restrictive for buildings employing electricity for heating than for other types of fuels, and the Swiss have one standard for energy use in buildings and another for electricity use in buildings.

Approach. In addition to defining the types of buildings a standard covers, it is important to look at the methodology employed in the standard to calculate energy use. Prescriptive standards have the advantage of being simple to follow and assess, but they tend to be inflexible. Performance standards are more complicated (like the OTTV calculations described earlier in this paper) but they allow a designer to vary building characteristics and still comply with the overall requirements. Three countries have prescriptive standards, 12 use performance methods, and 19 combine these approaches.

Provisions included. To achieve the goal of saving energy, standards set forth prescriptive measures or performance levels that can apply to the whole building or to any combination of its component systems. Achieving energy savings was the principal intent of most whole building energy requirements, over other goals such as achieving peak demand savings, reducing operating costs, or enhancing comfort. Nearly all respondents indicated that their energy standards incorporated provisions for the building envelope which influenced design choices for the roof, walls, and fenestration. To a lesser extent, infiltration and floor insulation were also addressed.

Twenty-three countries reported some efficiency requirement for mechanical equipment, while only 16 countries indicated provisions for lighting. Mechanical controls (such as energy management systems and time clocks) and ventilation requirements are included in half the countries' standards, with equipment sizing, equipment efficiency, and load calculations occurring in less than one-third of the countries responding. Limiting installed power density was the most common approach to lighting regulation. closely followed by lighting control recommendations (such as occupancy sensors) and setting illumination levels. Respondents from Indonesia, Pakistan, and Sweden noted credit given for daylighting. A small group of countries (China, Colombia, France, Korea, Jamaica, Japan, and Pakistan) suggest specific thermostat settings. Although most equipment requirements pertain to the operating efficiency of common components, a few countries require the additional installation of special equipment with specific functions. All new buildings in Poland and all new offices, hotels, and shopping centers in Singapore must install energy monitoring equipment to aid building energy data-gathering.

Development process

Energy standards development can be a complex process. The pace of the process is influenced by the political chemistry of the private and public institutions involved, the extent to which relevant information is available (or requires further research), and the intended stringency of the standard.

Institutions involved. Because of the different constituencies involved in buildings (designer, builder, renter, owner, manager) the person who pays the cost of efficiency measures may not be the one reaping the benefits. As a result, standards development can be a politically challenging process. Advocates of building energy-efficiency measures maintain that the long-term benefits of increased energy security, the reduced need for electricity capacity, and an improved market for energy efficient technologies significantly outweigh the costs of changing construction practice or purchasing more expensive and efficient equipment. In some countries, such as Australia and the United States, professional associations of building owners or engineers published the first widely applicable building energy standards. Increasingly, governments at the local, state, or national level are adapting these energy standards or developing their own versions. Energy-efficiency in buildings is gaining credence as a public good which should be encouraged by governmental policies rather than relying on market mechanisms. All survey respondents (except for South Africa) indicated at least one government agency played a role in the process of developing standards. At least eight countries have developed or are developing standards with some support from foreign development agencies. Twenty-six of the countries followed a consensus approach to their standard's development, and nine indicated that their standards were designed by agency mandate.

Information used. Developing energy standards commonly requires integrating information about physical attributes (average size, shape, materials, use) and energy use of existing buildings, as well as climate data for the geographic area. At the time of their energy standards development, 20 countries gathered additional information through audits or surveys to supplement information already available, or that had been estimated through professional judgment. Most countries seemed to begin developing standards with some general understanding of representative physical characteristics, but information on the amount of energy used was harder to come by. Only two countries, Japan and Thailand, mentioned the availability of substantial data on the energy use of existing buildings at the time standards were being developed; most of the others used professional judgment or computer simulations for estimates. About half of the countries used audits and surveys to gather additional information on building energy use for the purpose of developing standards. All countries developed their standards using weather data, which in 25 cases was already available prior to developing standards. Nine countries needed to gather additional data before standards could be developed. In the case of Malaysia, for instance, hourly temperature data in Kuala Lumpur were on file, but solar radiation had not been measured. Solar data from nearby Singapore were joined with Malaysian temperatures to make a hybrid weather file appropriate for local conditions.

More than two-thirds of the respondents said the standards in their country used standards from another country as a source of information. Energy standards developed by the ASHRAE were the most ubiquitous reference-they were cited as source material for standards in 11 countries: Australia, Canada, China, Hong Kong, Jamaica, Malaysia, New Zealand, Pakistan, the Philippines, Singapore, South Korea, and Thailand. Jamaican standards served as a source for standards in the Ivory Coast, and English standards were referred to in Hong Kong and New Zealand. German standards provided reference material for Switzerland, Russia, Czechoslovakia, and Israel, while French standards were cited by Portugal and Switzerland.

In developing standards, computer simulations are sometimes used to determine energy and economic performance of different provisions. Twenty-one countries used some form of computer program to develop their standard. Versions of DOE-2 (a building energy simulation program developed by the United States Department of Energy) were used in 11 countries, making it the most popular. The use of other programs seemed to be country-specific. Stringency. Most countries set their standards above average current practice to promote highly efficient buildings and encourage technological development. Nine countries, however, set their standards at moderate levels roughly equal to current practice, and five respondents indicated their standards were set at lower than average efficiency, to essentially eliminate the most inefficient new building designs. Nearly all respondents indicated that cost-effectiveness was one of the most influential criteria in determining the inclusion or exclusion of certain measures, but the cost-effectiveness criteria were not made explicit.

Comfort, availability of energy efficient products, and similarity to local design practice were also factors in about three-quarters of the countries surveyed. One respondent additionally stressed pressure from a local building group not to change average building practice, and another mentioned the need to avoid “undue technical risk” to the construction industry.

Implementation and compliance

Even a well-designed mandatory standard will not save energy if it is not followed. Implementing an energy standard involves a network of social systems and human interactions that stretches from the bureaucrats assigned to administer the standard to the carpenters who apply the weather-stripping. Any person or group involved in a building's development, design, and construction process can affect its final energy use, so there are an almost unlimited number of opportunities for the building to comply with or deviate from the standard's recommendations. The power of the implementing agency, the level of training provided, and the effectiveness of compliance mechanisms are all important indicators of the extent to which the standard is likely to be followed. Our project invites further study of these issues by probing the focus of the agency chosen to implement the standard, the type of training provided, and the approach and timing of compliance mechanisms.

Agencies involved. In most countries energy standards represent a new addition to the set of regulations pertaining to buildings, although in some they are treated as a new addition to energy policy. Almost all the countries responding to the survey indicated that an existing agency was chosen to implement the new regulations. Most of these agencies are branches of the federal government with control over some aspects of construction or other kinds of building standards, but eight countries implement their standards through organizations principally concerned with energy issues. In Colombia, electric utilities are slated to encourage compliance; in Thailand it is the Department of Energy Affairs. Pakistan and the Philippines put their energy standards under the auspices of broader public works programs, and England implements standards through a department that also covers the environment and land use planning. Some countries, such as Jamaica, put their bureau of standards in charge and other agencies help implement. In countries where the standards surveyed are voluntary or proposed, like China and Malaysia, no agencies have yet been designated to implement the policies.

Training. In most countries, energy standards call for changes in conventional construction practice. Architects and engineers who know how to design safe. sturdy, and attractive buildings may not know how to incorporate energy-efficient measures. Most countries surveyed indicated some type of formal process for training or educating architects, engineers, and other professionals about standards. Countries with training programs include about one-half of the countries with voluntary or proposed standards. About 75% of the countries with training programs included written guidelines and example calculations in their programs; almost all of these countries also organized seminars, conferences, or workshops on the topic. Less than half of the countries with training programs support information or resource centers, however, and the majority do not use standardized compliance forms. These findings suggest that in some countries, training may tend to be focused on introducing the standard rather than providing ongoing support for its use.

Compliance. Mandatory and voluntary standards often have mechanisms to encourage compliance. These mechanisms can fall anywhere in the spectrum between a positive incentive (builder/owner gains a reward for meeting or exceeding the standard) and a penalty (builder/owner pays a price for failing to meet requirements). Because every step in the construction process offers an opportunity for compliance with (or deviation from) recommendations made in a standard, compliance mechanisms (alone or in combination) can apply at different stages in the construction process, from the initial design to the final commissioning. The checking methodology adds an additional dimension to the complexity of compliance. France, for instance, has four levels of design compliance methods for the residential sector alone. with a different amount of computer modeling required for each. Our survey could not cover this issue in sufficient detail, but it suggests an interesting direction for a more focused study. It would be useful to learn which methods are used most frequently by what sectors of the construction industry and explore whether multiple compliance methods enable or complicate the certification process.

Of the 25 countries reporting compliance procedures, most indicated they occur in the design phase, Fewer than a third perform checks during construction, and about half verify after construction has been completed. Certification or approval was the most common form of compliance procedure, although five countries (Belgium, Czechoslovakia, the Netherlands, Romania, and Thailand) will exact a penalty if requirements are not met. Incentives were even more rare among responses: only Colombia's proposed standard suggests using this mechanism. Estimates of the percentage of buildings checked for compliance ranged from 10 to l(K)%, and respondents expressed an average confidence level of 3.5 on a scale of 5 (with 5 being the highest) on the effectiveness of compliance.

Assessments. Given the difficulty of assessing the level of compliance, assessments of the impact from energy standards are few and far between. Of the 35 countries with standards, only 17 indicated that a systematic assessment of the standards' energy-saving potential had been completed, and only a handful of these countries reported reference information for published results. Ten more countries indicated such a study was either in progress or planned. Studies of measurements of energy savings in actual buildings complying with the standards were fewer: nine countries counted them complete, with another 15 indicating they were either planned or in progress. Cost-effectiveness based on engineering or economic calculations fared similarly to the studies of energy savings in actual buildings: only 10 completed, with another 13 planned or in progress. The least amount of effort has been spent on the cost effectiveness based upon actual costs incurred and measured savings achieved (i.e., case studies): only five countries have completed such a study. Respondents from only four countries (Belgium, Canada, Norway, and Singapore) indicated that all four types of assessment studies had been completed. It is unclear whether the assessment studies contribute to or detract from the respondents' subjective sense of the standards' effectiveness, because respondents from Canada and Singapore called their standards very effective but respondents from Belgium and Norway felt their standards were only moderately so.

Further information on energy conservation

Respondents from countries both with and without energy standards were asked to note the presence of several major types of testing facilities and describe other programs used to reduce energy consumption in buildings (e.g., utility initiatives, energy awareness campaigns, energy audits).

Testing facilities. The basis for many energy standards depends on the extent to which knowledge about the basic components of buildings has been tested and codified. These components include motors, insulation, building appliances and equipment, lighting ballasts and fixtures, and materials. Because the properties and/or availability of these items may be unique to each country, the survey used the presence or absence of testing facilities and procedures to gain a feel for the existing informational infrastructure on which energy standards rely. It was our assumption that most developed countries would have a complete array of testing procedures, but many of the respondents from developed countries left sections of this question unanswered. These results probably reflect the fact that our respondents are not predominantly involved in the field of testing. Of the seven countries without energy standards, the presence of testing facilities served as a more meaningful indicator. Brazil alone indicated a full set of testing procedures, and of the seven countries surveyed without standards it is probably the closest to developing them. Botswana, Mexico, and Venezuela all test thermal properties of materials, and each also tests a few of the following areas: appliances, ballasts, insulation, and motors. Additionally, Botswana indicated the use of South Africa Bureau of Standards (SABS) criteria.

Other programs. Information programs were by far the most common form of policy or program (other than energy standards) developed to increase energy-efficiency in buildings. Seventeen countries had some kind of energy awareness program, 13 had implemented free or subsidized audits, and five indicated the availability of rebates. Time of day pricing was tried and withdrawn in South Africa; Australia, Costa Rica, Brazil, and Canada indicated the existence of appliance labeling programs.

Energy standard potential: countries without standards

In the seven countries surveyed without energy standards, Venezuela and Costa Rica seemed the least likely to pursue them. Venezuelan utilities have energy campaigns at domestic and industrial consumer level, but developing standards is likely to be an uphill battle because energy and electricity receive heavy subsidies. Although the respondent from Costa Rica indicated the presence of programs for audits and lighting, there was no other indication that suggests planning for energy standards is underway.

Respondents from Bangladesh, Botswana, Brazil, Djibouti, and Mexico expressed a general interest in improving building efficiency, as well as an interest in developing standards and some recent or ongoing activities toward this end. Bangladesh indicated a plan to develop a building energy standard during 1992. Work at the Botswana Technology Center is directed toward establishing energy standards. In Brazil, there are national recommendations for lighting levels and the installation of heating and cooling systems that only cater to safety and comfort, but these may help pave the way for energy standards. Data on building energy use is being gathered in Brazil, and a proposal to support the development of energy standards to be used in Brazil and two of its neighbors (Paraguay and Uruguay) has been drafted. Djibouti's governmental science and technology agency, ISERT, has an analog to voluntary prescriptive standards for houses. Four energy-efficient housing designs have been developed and await approval by the public works agency to be distributed to home builders free of charge. Researchers in Mexico have not prepared or proposed standards, but they have laid the groundwork by starting a subsidized energy audit program in 30 public buildings and an energy awareness campaign in about 50 non-residential and public buildings. Other countries without energy standards may also have ongoing building energy-efficiency programs or interest in developing standards. It is likely that our project only scratches the surface of the potential interest in this area.

2007 UPDATE: REVIEW OF CURRENT TRENDS

In 2007, we found that 59 countries have some form of mandatory or voluntary existing standard, twelve countries had proposed standards, and nine countries did not have standards. Primary data for the update was gathered through reports and websites (e.g., CLASP, 2005; Deringer, 2006; IEA, 2006; Koeppel & Ürge-Vorsatz, 2007; RICS, 2007).

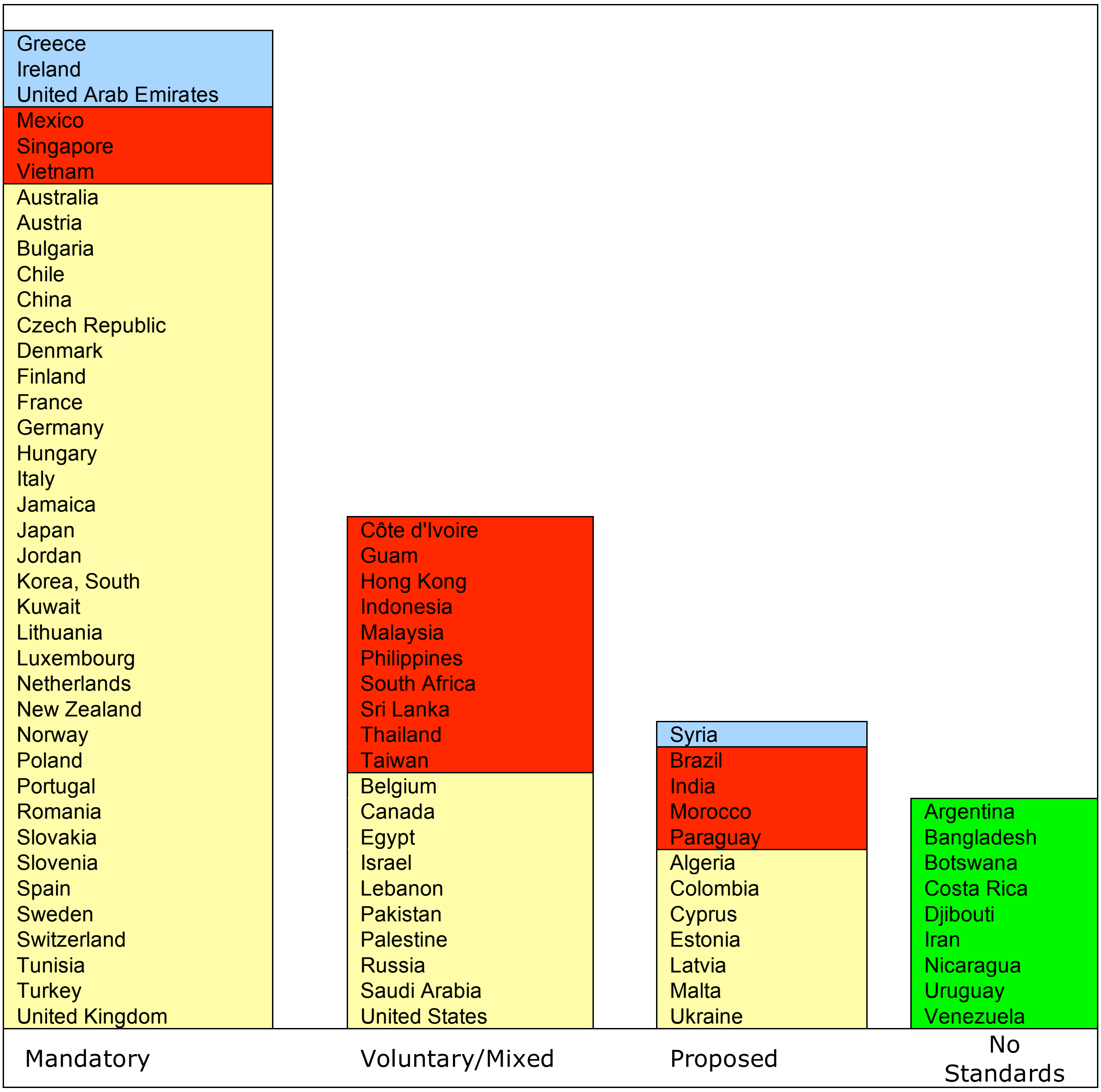

Figure 2: Status of Energy Standards in 80 countries

This growth in the number of standards is due to a number of factors, including geopolitical transitions, international agreements, international assistance, and concerns about development, energy security, and climate change.

Since the original survey, which was started in 1992, many geopolitical changes have occurred. Some countries have divided (e.g., Czechoslovakia into the Czech Republic and Slovakia in 1993, Yugoslavia into six different countries over the period 1991-2006) and others have changed their political affiliations (e.g., Hong Kong from crown colony of the United Kingdom to special administrative region of China). It is important to note that a few of the increases in the number of countries with standards has to do with this redistribution of nation-states.

Countries with Standards

At the national level, there is evidence of energy standards activity in countries on almost every continent. The World Energy Council conducted a survey of 63 countries and found that there were mandatory efficiency standards for new dwellings and buildings in all European countries (Moisan, 2005). The study found regular and recent revisions in more than half of European countries. In other regions, it found that few countries had standards for new dwellings, but approximately 60% of countries outside Europe had mandatory or voluntary standards in the non-residential sector.

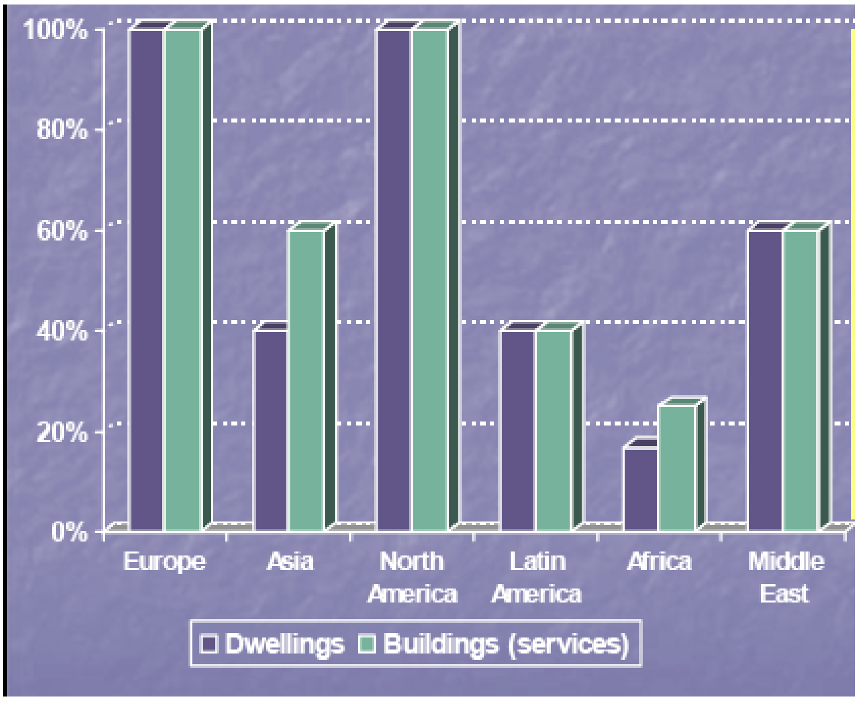

Figure 3. Thermal Building Regulations (Moisan, 2005, p. 12)

From Proposed to Adopted. Many of the countries with proposed standards in 1994 actually took the steps to adopt these standards into law, sometimes changing the standards along the way. In1994, Hong Kong's proposed standard was to have applied to office buildings and hotels. The standard Hong Kong actually passed in 1995 was different in scope than the proposed standard, applying somewhat more broadly to commercial buildings *except* for hotels and schools (Hong Kong Government, 1995). Other countries such as Australia, for example, moved from a set of proposed standards to mandatory standards for all buildings, plus a coordinated set of voluntary initiatives designed to encourage best practices in building design, construction and operation (Australian Government, 2008).

From Nothing to Something. Of the thirteen countries without standards in 1994, three (Brazil, India and Paraguay) have since proposed standards and Mexico has adopted mandatory standards for non-residential buildings (Huang, Warner, Wiel, Rivas, & de Buen, 1998).

Countries Without Standards

Even though many countries do not have energy standards for buildings, there is evidence of other kinds of programs that promote energy efficiency or energy conservation in buildings. Many countries without energy standards at the building level are participating in standards and labeling activities for appliances. The Collaborative Labeling and Appliance Standards Program (CLASP) has activities in over 27 countries, including: Argentina, Australia, Bahrain, Belize, Brazil, Chile, China, Colombia, Costa Rica, Dominican Republic, Ecuador, Egypt, El Salvador, Ghana, Guatemala, Honduras, India, Mexico, Nepal, Nicaragua, Panama, Poland, South Africa, Sri Lanka, Thailand, Tunisia, Uruguay (UNDESA, 2008). For countries without energy standards for their buildings, appliance and labeling standards offer some protection from end-use extravagance. Other countries without standards, like Iran, have developed energy efficiency offices and a range of programs designed to improve energy efficiency (IEEO-SABA, 2008).

International Standards

In addition to energy standards activity at the national level, similar activities are also taking place in international arenas. There has long been interest within the European Community to develop a European building energy standard. The Directorate General for Energy of the European Economic Community (EEC) commissioned studies in 1975, 1980, and 1987 regarding thermal insulation requirements in EEC member states. Although the International Standards Organization (ISO) did not have a technical committee on the topic of building energy standards in 1994, the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) had proposed that the ISO develop one that could encompass broader issues of energy use. By 2007, this institutional change had been implemented, and TOC 205 on "Building Environment Design" is currently developing eight different projects, four of which are directly related to energy performance or energy efficiency (ISO, 2008). However, only one standard in this TOC area (ISO 16813:2006, "Building environment design -- Indoor environment -- General principles") has been published at present.

Most importantly in the international arena, the European Parliament and Council approved in December 2002 a comprehensive directive on the energy performance of buildings (EPDB). The directive requires member countries to:

(1) develop a comprehensive methodology for calculation of the integrated energy performance of buildings and HVAC systems including heating, cooling, ventilation and lighting;
(2) set minimum requirements for energy performance of new buildings;
(3) apply requirements in existing buildings;
(4) develop an energy certification system for buildings;
(5) have heating and air-conditioning systems inspected regularly.

Although a recent report by European Energy Network suggests that the EPBD is not delivering completely on its promise (EnR, 2008), EPBD has certainly made a bold statement about not just energy standards themselves but the broader policy and market context in which they occur. The next section will develop these ideas in greater detail.

BEYOND STANDARDS: REVIEW OF ONGOING POLICY INITIATIVES & MARKET TRANSFORMATION

Recent work assessing policy effectiveness for energy efficiency in buildings has emphasized that although energy standards for buildings are frequently used, their effectiveness varies greatly from country to country (Koeppel & Ürge-Vorsatz, 2007). Koeppel & Urge-Vorsatz note that effectiveness of energy standards may be particularly low in developing countries, given difficulties with enforcement and even corruption. Even in developed countries, the estimated savings from energy codes range from 15-16% in the US to 60% in some countries in the EU. These authors and other proponents of market transformation stress that a combination of policy instruments (regulatory instruments, information instruments, financial/fiscal incentives, and voluntary agreements) is the key to achieving real reductions in the building sector. The idea behind market transformation, as the name suggests, is to use a coordinated suite of tools to transform the market in which building design, construction, and operation occurs. In practice, it is difficult to discern exactly how to coordinate these policy tools, but the idea of a multi-pronged approach does seem to fit with the diverse interests and elements in the building industry.

In addition to policy initiatives undertaken by governments, a host of non-state actors have started to engage in promoting energy efficiency in buildings. The extent to which cities, regions, and businesses have started to play a role in climate change mitigation has been the subject of several books and numerous articles on the changing nature of governance in a global world (Newell, 2000; Newell & Levy, 2005). Within this context, non-governmental organizations such as the US Green Building Council are experiencing immense growth, both in the US and around the world (USGBC; WGB, 2008). Similarly, the Clinton Climate Initiative (CCI) has chosen to partner with the 40 largest cities in the world rather than the governments of the nations in which those cities reside. Finally, the World Business Council for Sustainable Development is also focusing its attention on energy efficiency in buildings (WBCSD, 2007). Although they are not the usual originators of energy efficiency policies, cities, businesses, and non-governmental organizations are increasingly playing a voluntary role in transforming the market towards a lower-carbon future.

While some might argue that the voluntary initiatives are the way of the future, we assert that setting a stringent standard for building performance will always be of assistance by setting a floor for the market. It also serves as an enduring reminder to architects, engineers, owners, operators, and others in the building industry that certain basic elements of building performance should be included in every new design and retrofit.

RECOMMENDATIONS FOR FURTHER RESEARCH

Although the complexities associated with both building research and energy standards obstruct meaningful comparative analysis and information transfer, they do not preclude it. Greater access to the methodology, tools, and information used to support existing standards would give countries without standards a basis to choose between revising research and re-inventing it. The current information gap is already spanned by calculation methodologies, and other useful connections might be forged through an international comparison of non-residential buildings or by the development of a comprehensive reference for technical and administrative requirements of energy standards.

A historical precedent for information sharing has been set by the cooperative use of methodology and tools for calculating building energy consumption. In the 1960s France was credited with developing the first criteria that were oriented toward the performance of a whole building rather than specifying materials for its parts.' By 1975 these calculations were updated to include infiltration losses, and Germany had developed similar expressions of its own which spread across Greece, Spain, Belgium, and the Netherlands. In 1980, another iteration of standard calculations appeared in Europe and added heat gains (from solar and internal sources) to the accepted methodology. In the United States, the term "Overall Thermal Transfer Value" (OTTV) has been coined to describe this concept of determining heat gains and losses to a building (either as a whole or particular components). OTTV calculations are performance-based criteria that have been employed in both the U.S. and in Southeast Asia. Like these calculation methods, predictive computer models have also been developed for one country and used effectively in others.

Much as some research methods have crossed national boundaries, some research topics are intuitively international. Although the authors of most multi-country studies on energy standards have pursued a residential focus, comparative international analysis of some non-residential building types and standards might provide more transferable information. Residential energy use patterns within a single country may be more homogeneous than those of its service sector, but the perceived homogeneity shifts when making international comparisons about building design, construction practice, and energy use. Consider, for example, the probable appearance and pattern of energy use in two new high-rise office buildings, one in Bangkok and the other in New York. Then visualize the construction and likely energy patterns of two residences in those cities. While styles of living and types of housing vary tremendously from country to country, modern urban workplaces tend to follow a more uniform pattern. In particular, large offices and hotels share general physical characteristics, equipment requirements, and energy consumption patterns that might make comparative analysis of standards for these buildings useful. There is an international market in commercial buildings and building systems, and there are unclaimed opportunities to explore energy use, efficiency potential, and efficiency methods for this sector.
Although further study of methods or special topics would help to fill in the information gap, the key to bridging it may lie in making basic information about existing building energy standards more readily accessible. In 1994, we proposed a directory with information compiled from different countries to enable exchanges between countries with effective existing standards and countries seeking to update their standards or develop new ones. As a model for this kind of work, we pointed to an annual report done in the United States by the National Conference of States on Building Codes and Standards (NCSBCS, 1991). Internationally the same need for detailed information exists but no equivalent descriptive source for energy standards information fills the gap. Today, creating an online database of energy codes and regulations would be the obvious next step towards this goal.

CONCLUSIONS

All signs point to the conclusion that energy standards, particularly for non-residential buildings, will play an increasingly significant role in the future of national and possibly international energy-efficiency policies. The information gathered here is another step toward fostering cooperation among countries with standards and those contemplating standards or other policies for increasing energy-efficiency in buildings. While it is difficult to generalize, our work to date and proposed database provides a basis for further inquiry into the development, structure, and implementation of energy standards throughout the world. This information may be particularly useful to countries at similar stages of development, countries with common cultural roots, and/or those in comparable climates. While energy standards for buildings have been developed and adopted in at least one-third of the world's countries, the other two-thirds have few ways of learning about the existence of information on this topic, and all countries currently face barriers to accessing it. Our project does not establish a complete international reference for building energy standards, but it submits a possible framework for further inquiry. It is our hope that this project will draw attention to the need to further define the field of energy standards research and support increased communication within it.

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