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useful knowledge for greener cities

Decoding the Code

How Can NYC's 2007 Building Code Help Meet PlaNYC 2030 Energy/Carbon Reduction Goals?

A REPORT BY
THE CITY UNIVERSITY OF NEW YORK
BUILDING PERFORMANCE LAB

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How Can NYC's Building Code Help Meet PlaNYC 2030 Energy/Carbon Reduction Goals?

A Report Prepared By

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Commissioned By

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Executive Summary

A CUNY team led by the Building Performance Lab was asked by the Sallan Foundation to assess the potential impact of the 2007 NYC Building Code on energy/carbon reduction.

Projected Impact The main finding of this work is that the 2007 New York City Building Code, as introduced and through the normal workings of the real estate and construction industries, will have only limited impact on progress towards the carbon reduction goals of PlaNYC2030. The report details why this is so and describes a spreadsheet-based tool for quantitatively assessing the impact under various assumptions and scenarios. We estimate that not more than a third of the 30% carbon reduction targeted by the plan from more efficient buildings can be expected from the new code in its present form.

Other Policy Tools A significant implication of this projected impact is that the Building Code cannot be expected to carry the load of 2030 carbon objectives by itself, independent of other policies and policy tools. This observation will not come as news to those who have been hard at work on both the Building Code and PlaNYC2030. Coordinated application of a range of tools – incentives, technology acceleration, demonstrations, performance reporting, workforce development, training, education and public information – will be necessary in concert with laws, building code and programs developed in consultation with other market participants. The best mix of tools and progress monitoring should be determined by a formally appointed Mayoral working group.

Revision Cycle A critically important aspect of the new building code is its mandatory three-year revision cycle. A consistent projection for "raising the bar" of building energy efficiency is key to market expectations and the industry's ability to plan and adopt new technologies. An assortment of technologies has been identified as important to progress in energy/carbon reduction. Attention needs to be focused on such technologies, collectively and one-by-one, in order to accurately assess their potential and to plan and facilitate their introduction through the code process. Funding for such assessments is key.

Lags in the Underlying References In its revision process the building code will look to key references that establish energy efficiency requirements. These are identified and discussed in the body of the report. The New York State Energy Conservation Construction Code (NYSECCC) and American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) standards are themselves under continuous cycles of revision. This process has its own barriers and lags that must be taken into account in assessing impacts and timing. Whether the Building Code should exceed the minimum requirements set by these documents, for example by incorporating reference to LEED certifications, is a discussion that is presently in the wings for NYC as it is being actively tested in other cities.

Existing Building Alterations Another aspect of the building code identified for possible address is its limited approach to existing buildings. Existing buildings are required to meet energy conservation requirements when they undergo alteration. There is on-going discussion of how the NYSECCC applies when alterations occur in a piecemeal manner. The so-called "50% Rule" of the NYSECCC and its enabling legislation, needs clarification as soon as possible.

Existing Building Reporting Finally, the NYSECCC applies to the design of buildings rather than to their actual performance. Significant elements of energy use – "plug loads" and data centers, for example – lie outside control of the building design and are therefore unregulated. While NYC building code allows for inspection and reporting requirements for existing buildings, this capability is used judiciously and has not been applied to energy performance reporting.

None of these considerations will be seen as new by those who have been working on the new building code and its relation to energy, carbon and sustainability. We hope that bringing them together in one place can help focus the public policy issues and the deliberative process.

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Foreword

Act as if it matters.

– William James

In overhauling its Building Code for the first time in nearly four decades, New York City not only achieved a major milestone in 2007; it created a sturdy platform and mechanism for future improvements in the Code.

Much rides on this.

As stated in its groundbreaking proposal, PlaNYC 2030, the City aims to reduce total greenhouse gas emissions 30% from 2005 levels by the year 2030. Carbon dioxide dominates them, and nearly 80% of carbon emissions are related to our building stock – specifically, to energy consumed for lighting, heating, cooling, and ventilation, and for "plug load" functions (that array of computers and other electronic necessities of modern life).

Reducing carbon emissions won't be easy. By 2030, the city's population is projected to grow by roughly 900,000 people. Energy demand is projected to rise by 28%. But incentives for lowering demand are significant. Lower energy consumption will yield cost savings, particularly as the costs of heating oil, natural gas, and electricity relentlessly rise. Moreover, New York must maintain a reliable, affordable, and cleaner supply of electricity to remain a global competitor. Minimizing demand can help avoid the need to build costly new power plants that would boost high rates higher still. It can also help ease the burden on our aging electric grid, thereby avoiding blackouts and brownouts.

The Building Code does not cover "plug loads," which may account for up to 25% of buildings' energy consumption. What it does cover is the lighting, heating, cooling, and ventilation systems installed in the course of (1) new construction, and (2) alterations to existing buildings that are extensive enough to fall within certain regulatory parameters. And it also covers them by relying on the State energy code, which it incorporates by reference.

The link between the City and State codes extends to their revision cycles: Every three years the City will revisit, reassess, and possibly refine its own code, and it could help the State do the same for its energy conservation code. With building-performance standards, energy-system technologies, and building operating practices all in play, these cycles can permit timely capture of new knowledge. In effect, they can institutionalize learning.

The first triennial Building Code revision will occur in 2010. How productive might it be? Fully realizing the code's potential would require the participation of citizens who understand the code and can contribute their local knowledge, technical expertise, policy judgment, and insight. But the technical arcana of building and energy codes and standards can deflect all but the most highly motivated readers.

Surveying this overall situation, the Sallan Foundation decided to commission a study that would assess what it is reasonable to expect the City's revised building code to actually deliver. The study is a component of Sallan's campaign to make high performance buildings New York's "new normal." Scale matters.

We selected CUNY's Building Performance Lab to undertake this work. Beyond the bottom-line value of this assessment, we hoped the Lab's study would provide the basic information and analyses needed to expand the universe of knowledgeable citizens, so that, over time, they can help make the Building Code an increasingly powerful driver for reducing carbon emissions. This capacity-building extends to helping all affected parties understand not only the potential of the Building Code but its limitations, so they can determine what additional tools – such as other local laws, tax policies, and innovative incentives – could be deployed to achieve greater efficiencies at lower costs while reducing our carbon footprint.

Sallan also hoped that, from what CUNY researchers learned in assessing the Building Code's potential, they would formulate a set of constructive recommendations that all parties concerned with carbon reductions could take into consideration.

The Lab's report delivers all that was hoped for – and more. To conduct a quantitative analysis of the building code's potential for achieving carbon reductions, the Lab's researchers created an ingenious spreadsheet model that estimates how much construction and alteration would be necessary to achieve carbon-reduction targets on various kinds of construction and alteration projects. Crucially, this provides a means of converting carbon-reduction goals into construction objectives that can be tracked and monitored.

The Building Performance Lab and Sallan Foundation are making the spreadsheet modeling tool freely available to researchers who want to go further in exploring the range of possible outcomes or who want to take this tool to the next research level. Given the urgency of the City's "30 by 30" carbon dioxide reduction goals, good modeling tools must be able to morph as needed.

This example of a publicly available tool, as well as the analyses, discussion, and recommendations presented in this report, are exactly the kinds of "useful knowledge for greener cities" that the Sallan Foundation was created to advance. We commend the Lab for its contributions, and we hope the readers of this report will benefit from them and share them widely.

Nancy Anderson, Ph.D.
Executive Director, the Sallan Foundation

Acknowledgments

First and foremost, thanks are due to the Sallan Foundation and its Executive Director, Nancy Anderson, Ph.D, who conceived of, provided funding for, and contributed to this study. The Sallan Foundation's commitment to strengthening the public policies that shape building performance informs this entire undertaking. Nancy has been project manager, guide, critic, contributor, all in one – and as valuable an intellectual collaborator as could be asked for.

Dr. Robert Paaswell, Distinguished Professor of Civil Engineering at the City College of New York and Director of the CUNY Institute for Urban Systems, has been instrumental in the Lab's development. His commitment to academic research that engages real-world, 21st century management challenges, especially for New York City, guided us in undertaking this work.

Many professional colleagues have contributed to the thinking-through of this work, by discussing it with us, referring us to other sources of information, reviewing draft text, and engaging in yet more discussion. Foremost among these is Adam Hinge, PE, of Sustainable Energy Partnerships. Christopher Garvin of Cook + Fox Architects and the NY Chapter of the USGBC provided most helpful insights. Others include Charles Copeland, PE, a principal of Goldman Copeland Associates and a State-approved instructor on New York State Energy Conservation Construction Code, Saul Shapiro, an MIT-educated engineer who is head of the Metropolitan Television Alliance, and Carol Rosenfeld, an environmental scientist and a colleague through the New York Academy of Sciences who is presently an Analyst in Corporate Environment, Health and Safety at Exelon Corporation and was previously a High Meadows Fellow in the Living Cities Program at Environmental Defense Fund.

We also recognize the institutional initiatives that have made this work matter. Mayor Michael Bloomberg has squarely taken on the city's environmental challenges, mobilizing thought and action. In creating the Office of Long-term Planning and Sustainability, he has provided a focal point for essential policy discussion. Rohit Aggarwala and his staff conducted far-reaching research and policy analysis that is embodied in the PlaNYC2030 report that underlies our work.

The NYC Department of Buildings must also be recognized. The task of overhauling the NYC Building Code was Herculean, involving hundreds of professionals and experts over the course of over four years. Small wonder that this had not been done in nearly four decades. This "opening up" of the Building Code made possible the discussion of its role in achieving PlaNYC2030's carbon/energy reduction goals.

The New York State Energy Research and Development Authority (NYSERDA) has supported this study indirectly but importantly through its seed funding of the Building Performance Lab.

As the city's only public university, CUNY has a special mission to serve the city. Its Sustainability Initiative – guided by Ron Spalter, the University's Deputy Chief Operating Officer, and Tria Case, Director of the Center for Sustainable Energy at Bronx Community College – has launched a university-wide process to spur the application of CUNY's intellectual resources to the city's sustainability efforts. This study is just one example of the results.

The experience that CUNY students are gaining is another. Dr. William Solecki, a member of the Department of Geography and Urban Planning at Hunter College and Director of CUNY's Center for Sustainable Cities, referred students to our project. Petra Caines, Jose Pillich,

and Catherine Garcia have all gained substantial research experience and made important contributions to the project. We hope that they, and future students, will apply their knowledge to the benefit of our city for many years to come.

1. Introduction: Purpose and Objective

This study was commissioned by the Sallan Foundation to assess the potential for the 2007 New York City Building Code to contribute to the energy/carbon reduction goals set forth by the City's first comprehensive, long-term sustainability plan, PlaNYC2030. It was understood from the outset that building code's application to energy conservation objectives was an area of considerable complexity, with interdependent documents and authorities evolving over time. It is hoped that this study will contribute to a wider and better understanding of this process and will enable realistic expectations to provide a solid platform for policy making.

1.1 Background

Growing public concerns about climate change, carbon emissions and energy have moved the issue of energy use in the built environment front and center. New York City's PlaNYC 2030 establishes ambitious long-term sustainability goals. Chief among them is reduction of the city's carbon emissions by 30% from 2005 levels, by 2030. The challenge of this goal is compounded by projection that by 2030 population will grow by roughly 900,000 people and, with business as usual, energy consumption would rise by 28%.

It's estimated that roughly 80% of the city's carbon emissions are related to the consumption of energy in buildings, to provide lighting, ventilation, heat and cooling, and running appliances. [30] New York City's 2007 Building Code revision, the first major revision since 1968, presents a prime opportunity to "green the code," an opportunity that has been embraced by the City's Department of Buildings (DOB), which enforces the Building Code, and the growing community of parties who are working hard to achieve a greener city. "Greening the Code" is one of many energy policy recommendations in PlaNYC2030.

Beyond reducing carbon emissions, achieving greater energy efficiency obviously yields cost savings. It yields other important benefits, too. To remain competitive, New York City must maintain an affordable, reliable supply of electricity. The City's electricity rates are high now, and demand is rising. Controlling peak demand can help avoid the need to build costly new power plants that would raise rates higher still. It can also help minimize the burden on our aging electric grid. This raises the stakes yet another notch.

1.2 Objectives of Our Study

What energy/carbon results is it reasonable to expect the 2007 NYC Building Code to deliver? At the request of, and with the support of, the Sallan Foundation, we undertook a study to answer that question.

As a first objective, we started with a narrow focus on identifying New York City Building Code provisions that regulate energy use and the baseline of practice that produces our buildings' energy use outcomes. These provisions quickly led us to expand our focus to encompass the New York State Energy Conservation Construction Code (NYSECCC), and to the "model code" and technical standards that underlie it. It became apparent that to properly understand what can be expected of the 2007 NYC Building Code, it is necessary to understand the structure of requirements, compliance and the evolution of these underlying documents. In doing so, we have identified certain key issues of interpretation and enforcement that significantly affect the prediction of outcomes.

In exploring these inter-related documents, we realized that, along with answering the question of what can be expected of the Building Code, our study could also further public understanding of this complex subject. The technical details of various codes and standards, interrelationships among them, how they're variously interpreted by state and municipal government, and how they're enforced, makes for a subject that is not for the faint of heart. But it yields to patient persistence, and it must be understood if there is to be intelligent, informed and productive public discussion of how to reach the City's energy and carbon reduction objectives.

An important new provision of the 2007 NYC Building Code is a three-year revision cycle. The NYSECCC has a similar cycle. These revision cycles offer opportunities for continuing improvements to advance energy and carbon objectives. Contributing to an understanding of how best to use this revision process, including identifying target areas and specific technologies for consideration, is a second objective of our work.

Just as important as understanding the potential of code is to understand its limitations and boundaries. A third objective is to better understand how building code-based action relates to other policy tools. Policy makers and citizens must be able to determine what other tools – such as requirements for reporting energy consumption, requirements for periodic tests and tune-ups of building equipment and systems, training and certification requirements for building operating personnel, incentive programs and tax policies that encourage green construction and alterations – should be employed to achieve carbon goals. Some of these may be considered to become part of the Building Code via the revision cycle. Some may use Code requirements as a baseline to exceed. Some may be best implemented as separate local laws or as funded programs without need of legislation or code inclusion.

Our fourth and final objective was a quantitative answer to the original question. Our approach to this involved creating a spreadsheet-based calculation tool, as is discussed in the next section.

1.3 Quantitative Tools

There is an established framework and methodology for evaluating the cost-effectiveness of energy codes and standards and of the potential impact of individual measures. They are typically conducted at the state level with substantial budgets. [1], [33] Such studies may be an important tool in the evolution of the NYC Building Code to address energy/carbon reduction concerns. But our quantitative task was different – to develop a first-cut understanding of the potential and the issues affecting this potential.

To conduct this quantitative analysis we created a spreadsheet model that estimates (a) how much energy reduction is likely under various assumptions about construction and code-required energy reduction and (b) how much construction and alteration would be necessary to achieve the city's energy reduction target. This model allowed us to project likely outcomes by comparing results under scenarios based on variables about which there is uncertainty. The spreadsheet modeling tool is described and discussed in section 4 of the report. It is, quite frankly, a tool that is intended as a simplification, to provide a way to understand, at low cost, the range of realistic possibilities.

There is much work still to do in creating scenarios, tuning variables, establishing sensitivities, and elaborating the tool itself. We have done enough only to reach initial, provisional quantification. We have realized that modeling results converting energy/carbon reduction goals into construction objectives could be used to track and monitor progress towards the city's goals.

We hope that others may wish to pursue further research along these lines. Our knowledge and tools will be available for those who do and we encourage potential research collaborators to contact us.

1.4 A Methodological Note on Carbon and Energy

For purposes of this study we have taken "carbon" reductions as equivalent to energy use reductions. Carbon, in forms such as carbon dioxide (CO_2) and methane (CH_4), is the principal greenhouse gas (GHG). Carbon dioxide results from our combustion of organic matter, including fuels. We directly burn fuels in our vehicles and for heat and hot water in our homes. About half of the electricity we use is made by burning fuels, including coal in plants distant from the city. The other half of our electricity comes from nuclear power, hydro power and much smaller amounts of wind and other renewable sources. Thus, while there is a strong relationship between our energy use and our GHG emissions, it is not strictly one-to-one. Savings in electricity only partially trace back to fuel burning and carbon dioxide reduction.

Our use of energy reductions as a proxy for carbon reductions slightly over-estimates the contribution of energy reduction to GHG reduction. A 30% energy reduction at buildings will yield something less than a 30% carbon reduction. Precisely how much less depends on the specifics of the energy saved – primarily how much electricity versus how much oil and gas is saved. This will not, however, significantly affect our broadly drawn initial results. The assumption of equivalence is close enough for our present first-cut purposes. Greater precision in carbon reduction under varying scenarios is left for future work.

We use this simplification because energy codes, standards and databases all use energy units. Moreover, the translation into accurate carbon units varies based not only on the mix of energy sources saved but also on the mix of energy sources in the production of electricity. This varies from region to region and over time. Carbon conversion tools are becoming increasingly available. An extension of our spreadsheet tools to incorporate carbon conversion based on recognized sources would be a useful future step.

There is also need for methodological clarity about the so-called site value of energy, especially electricity, versus its source value. Site value represents the thermal content (in BTU) of a unit (KWH) of electricity as it is delivered and available to the building. The source value represents the thermal (fuel) inputs at well-head or power plant to make and deliver that unit of energy. Only about one third of the input energy (source value) is reflected in the site value of electricity, due to losses in distribution, transmission, and, the largest portion, production. The source value is thus the true value of the relationship of electricity to fuel used in its production and carbon dioxide emitted. However, to avoid the confusing impact of different regional power mixes, energy standards and associated modeling use the site value of electricity. We provide both kinds of conversion in Appendix 1, where we translate the PlaNYC2030 carbon target into energy units. In comparing projections to the target, we use the site values.

2. Building Codes and Energy

Building codes are seen by many as a powerful regulatory tool for improving building stocks. Among mankind's oldest laws, they date back some four thousand years to Hammurabi's legal code in Babylonia. New York City's first Building Code was adopted in 1850. Established to protect public health and safety, municipal building codes typically require parties who want to undertake new construction projects or alter existing buildings to obtain a City permit. Through its building code, the City stipulates conditions that must be met to obtain a permit and occupy a building.

"Code" may be broadly interpreted as referring to a collection of laws, administrative rules, and programs. Some of these will be touched upon below. However, our purpose here is to focus on the implications of the Building Code, narrowly defined, rather than the full panoply of regulatory tools.

2.1 What Building Codes Are About: Health and Safety

Building codes traditionally and predominantly seek to establish minimum standards for health and safety in buildings. What is considered germane to health and safety may vary between localities. In general, and especially in dense urban areas, topics within this domain include ventilation, sanitation, fire protections, structural aspects of buildings, construction safety, and licensing of tradesmen. Codes cover structural, mechanical, plumbing, and electrical aspects of buildings. Buildings' economic performance is considered the business of the owner and not regulated by code.

Thus energy conservation, seen as an operating cost, has not traditionally been covered by building codes. Various building services that can be considered as related to health and safety – the supply of heat and hot water, ventilation air, illumination – require energy to be used in their provision. These have traditionally been required as a standard of service, without respect to the method or amount of energy used in achieving the standard. Consequently, energy conservation or energy efficiency has been a late addition to the purview of building codes, entering only with the emerging perception that energy supply is a societal issue in which the decisions of individual builders impacts the general welfare of the community.

Building codes generally seek to express a consensus view of what is acceptable practice within the construction industry. While sometimes viewed as a tool for "raising the bar", it should be kept in mind that they generally do not put forward "best practice" but set the level at which "if it were built any cheaper, it would be illegal."

2.1.1. Building Code and Reference Standards

Codes are complex and require rigorous and specialized technical knowledge. Consequently, they are written based upon the expertise and template documents of specialized bodies at the national level. These are described in Figure 1.

FIGURE 1. **SPECIALIZED CODE AND STANDARDS BODIES** (an abbreviated list)

National Fire Protection Association (NFPA)	National Life Safety Code (multiple volumes) National Fuel Gas Code (multiple volumes) National Electric Code (NEC)	Recognized and referenced authority for fire/life safety and electrical codes. Comprehensive building code is a competitor to ICC.
International Code Council (ICC)	International Building Code, International Mechanical Code, International Plumbing Code International Existing Buildings Code – relatively new product to govern alterations For its Energy Conservation Code, the ICC uses guidance from ASHRAE 90.1 and 90.2	Unification, as of 1994, of Building Officials and Code Administrators (BOCA), International Conference of Building Officials (ICBO) and Southern Building Code Conference that had served regional markets with separate code products. ICC "Model Codes" are the most widely used basis for local building codes. NYC's 2007 Code adopts and adapts the ICC system.
American Society of Heating, Air Conditioning and Refrigeration Engineers (ASHRAE)	A large number of standards prepared to guide professional HVAC, primarily design. Ones of particular interest to us here are described below, in Figure 2.	Professional engineering society Operates with an extensive structure of technical committees comprised of members working on a volunteer basis.
Illuminating Engineering Society of North America (IESNA)	Lighting design handbook and guidance materials. Collaborates with ASHRAE in the development of lighting standards	Professional engineering society.
American National Standards Institute (ANSI)	Documents on many, diverse topics are found as reference standards to building codes.	The organization does not provide content. Instead provides a process for creating, approving, and maintaining technical standards.
US Green Building Council (USGBC)	Leadership in Energy and Environmental Design (LEED), a point-based building rating system	A non-profit membership organization that maintains and administers the LEED building certification system and certifies Approved Professionals ("LEED AP").

Publications of the technical bodies shown in Figure 1 have no force of law. Rather, they provide the basis for what can be incorporated into local building codes. It is only the latter that are enforceable as law.

Building codes may also list specific documents as Reference Standards, which makes them an enforceable part of the code. Many NFPA documents are referenced in this way. The ICC model codes, however, serve as the template basis for direct adoption as local code. ICC documents are written in "code-ready language" to facilitate such adoption. Larger cities with special requirements may edit the base document extensively to suite its particular needs. For many of its Standards, ASHRAE has now also assumed the practice of using code-ready language.

LEED, promulgated by the US Green Building Council, was not intended to be the basis of code but rather a rating system for voluntary best practice. Nevertheless it is being adopted by many states and municipalities as a requirement or reference point for new government buildings and some municipalities are trying to integrate it as a code requirement. See section 2.3 below.

2.1.2. When Building Code Applies

Building codes broadly may be considered to govern over the health and safety implications throughout all phases of buildings' existence. More narrowly understood, however, the building code governs construction and comes into effect primarily when new buildings are built or existing buildings are altered.[1]

In an alteration, the new work must meet current code requirements but unaffected parts of the same building do not have to be brought to current code. However, if alterations during a 12-month period exceed a set percentage value (e.g., 60%) of the building, then the whole building may have to be brought to current code. Cosmetic renovations, such as painting, are usually not subject to code nor is most repair work unless it entails major reconstruction or replacement of building elements.

Code is brought into play when a Permit is required from the local Department of Buildings. Electric and gas utility companies will require Building Department approval before installing or upgrading services. Master tradesmen, including plumbers, electricians, and riggers are licensed under the building code, to assure that they understand required construction but also that they know when filings and permits are required.

2.1.3. Overview of the Building Code Enforcement Process

Local building officials enforce the building code. Local laws take precedence over higher levels. Thus, for example, NYC Building Code governs in New York City rather than the State's Building Code.

The Code compliance and enforcement process starts with application for a building permit that establishes the scope of the job. In some cases separate filings are required for various aspects of the work. The process proceeds with a review of building plans to verify that the design meets Code requirements. Approval is traditionally based on this review by the Code enforcement official, in NYC a "Plan Examiner." However, many localities, and since 1995 NYC, use a "self-certification" process in which the Registered Architect (RA) or licensed Professional Engineer (PE) may affirm that the plans meet local code requirements, with only a limited review by a code official. RA and PE are licensed by State agency (NYS Education Department) and are required to enforce all applicable laws and codes. The enforcement process continues during construction with a series of site inspections to verify that construction techniques and product installation practices meet Code requirements.

[1] "Alteration" is defined in the specific building code. It generally refers to renovation that changes the layout or functioning of a building. Thus, repairs and maintenance, including common improvements like painting and carpeting, are subject to code at a reduced level, if at all.

Compliance requirements are generally embodied in procedural "check-off" forms that guide the reviewers and inspectors attention and serve as documentation. Because of the extensive scope and detail in a construction project, plan examiners and field inspectors will focus on what they believe to be the most important enforcement issues. Based on research on the practices and prioritization of code officials [16], energy conservation has not traditionally been among those most important issues even when energy conservation code is in place. One of the best ways to promote compliance with energy code is to emphasize its importance through education and training of building officials, designers, architects, contractors and builders about the requirements of the code and compliance procedures.

2.2 Energy Standards and Codes

Historically, energy conservation was viewed as an economic matter of concern only to the building owner and therefore not a matter for building code. This began to change in the mid-1970s following the first OPEC oil embargos; energy standards and energy model codes began to be developed as energy use began to be seen as a matter of national security. Thus building codes have only relatively recently incorporated energy conservation or energy efficiency.

As with many other technical aspects of building codes, local officials rely on national code agencies and professional organizations to define the appropriate technical approach and procedures. As noted above, for energy conservation and efficiency, the most important professional association has been the American Society of Heating, Refrigeration and Air-Conditioning Engineers or "ASHRAE." More recently, the US Green Building Council (USGBC), through their Leadership in Energy and Environmental Design (LEED) protocol, has become an important reference point, especially for municipalities considering "greening" their building codes.

Energy codes that are well designed, implemented and enforced are believed capable of locking-in cost-effective energy savings of 30 to 40 percent at the time of building construction compared to standard practices [14]. In addition to lowering energy bills, energy codes can reduce load growth and the need for new energy generation, while limiting air pollution and greenhouse gas emissions.

2.2.1. The Creation and Introduction of Energy Standards and Codes

Energy standards and energy model codes began to be developed in the late 1970's, following the first OPEC oil embargos. The need for conservation was evident, not only for economic reasons but was also perceived as a matter of national security. ASHRAE draft standards for energy conservation in buildings date to 1975. Energy codes at the state level were mandated by the National Energy Conservation Policy Act of 1978. The national Energy Policy Act of 2005 required states to adopt energy codes based on ASHRAE 90.1-1999. Implementation in New York State is discussed in Section 3.

2.2.1.1 Advanced Energy Codes The most advanced state energy code in the nation is California's 2005 version of Part 6 (Energy Code) of Title 24 (California Building Standards Code). While using the same basic format and structure of other state codes, following ICC model code, California's version pushes out the frontier of best practice in energy codes. Advanced energy codes have also been promulgated in Europe. The International Energy Agency is a good starting place for the study of these codes.

2.2.1.2 A Note on the Use of the Term "Energy Standards" In this study the term "energy standards" is used narrowly to refer to reference documents (in particular those developed, promulgated, and supported by the American Society of Heating, Refrigeration and Air-Conditioning Engineers, ASHRAE) that are discussed in the following section. However, the term is also used more broadly, referring to national rating standards associated with appliance and building labeling (eg - "Energy Star", "Home Energy Rating System" or HERS) and voluntary programs such as the US Green Building Council's LEED "products." We focus in this work on the former usage as it relates directly to the underpinning of energy codes in the context of local building codes. While limiting our attention in this way for present purposes, we recognize the importance of broader "energy standards." In fact, local codes can usefully reference ratings and labels as a way of articulating requirements. The relationship of LEED to ASHRAE standards and to local energy and building codes is discussed further in Section 2.3 below.

"Beyond Code" programs encourage and incentivize projects to exceed the minimum code requirement by specified amounts, usually expressed as a percentage beyond the modeled energy performance required by code. Complementary policies such as voluntary programs (e.g., LEED or Energy Star), financial incentives, technology procurement initiatives and utility demand-side programs can be important supports for pressing the boundaries of the industry. This voluntary dimension is very important because what is incorporated into energy code may be limited by what can be demonstrated to be cost-effective. There are established frameworks for rigorously conducting such evaluation analyses.[2]

2.2.1.3 The Standards-setting Process In setting standards, cost-effectiveness and industry acceptance are key. Efficiency levels are based upon cost-effective energy savings. These represent limits to what standard or code efficiency may seek from available technical potential.[23] However, this limitation is dynamic over time. As energy prices rise and/or as technology prices fall, more expensive efficiency measures become economically justified.[3] It is important, therefore, that energy standards and codes be continuously maintained and updated.

Two alternative approaches are used for setting the level of standards: statistical and technical/economic. Using the statistical approach, the efficiency of existing products on the market is examined, and a line is drawn somewhere along this distribution to establish a standard. For example, EPA's "Energy Star Commercial Buildings" labeling program uses this approach, awarding a plaque for buildings in the top 25th percentile evaluated against a national sample.[4]

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2 As an example of such a study see [1]. There is a substantial body of work on energy program evaluation. Perhaps the best way to access this literature is through the Proceedings of the bi-annual International Energy Program Evaluation Conference that has been running for over twenty years.

3 The extended fight over window-unit air conditioner SEER is a good example of this. The incremental costs of the higher SEER model was argued to be not cost-effective in northern states. But this changed over time and eventually the required SEER level was raised by DOE.

4 The national sample is the Commercial Building Energy Consumption Survey, CBECS, maintained by the US Energy Information Agency.

This approach is relatively easy to implement but typically results in modest energy savings because standards are generally set at levels that can be met by existing products or buildings. The technical/economic approach involves an analysis of technical opportunities for improving product or building efficiency and the economics of doing so. Due to the complexity of the analyses, the technical/economic approach generally requires more time and resources than the statistical approach, and it often engenders more controversy but generally results in stronger standards. A successful project along these lines was conducted in the early 1990's when potential refrigerator savings were identified and an "industry challenge" process was conducted, with a guaranteed market for the winning products, resulting in several manufacturers bringing new, substantially more efficient models into the market.

Negotiations are an important element of the code-setting process. Negotiation between manufacturers, government and interested parties (e.g., energy efficiency advocates) fosters a collaborative environment that leads to more creative and effective solutions. Negotiations tend to work best when there is a credible threat that government will impose a solution if interested partied do not reach agreement. Technical levels that are first achieved by voluntary industry collaboration with government and public policy goals, can then later become an accepted minimum, to be expected by the marketplace and embodied in code.

2.2.2. Energy Standards Documents (ASHRAE)

ASHRAE has taken the lead on matters of energy conservation and energy efficiency in buildings and building systems. ASHRAE is the largest professional engineering society in the United States and draws from this large membership to maintain an extensive structure of committees that create and maintain specialized standards documents. We discuss here only a small selection of these documents that is most directly related to energy conservation and energy codes.

FIGURE 2. SUMMARY DESCRIPTION OF RELEVANT ASHRAE STANDARDS

ASHRAE 90.1 Energy Standard for Buildings except Low-Rise Residential Buildings	ASHRAE's flagship energy efficiency standard for commercial and high-rise buildings, establishes detailed prescriptive standards by building component in envelope, mechanical and electrical systems and establishes the guideline framework for a compliance pathway by modeled equivalence. *References and defers to 62.1 for ventilation requirements.* Basis for a simplified version reflected in the ICC's International Energy Conservation Code. Under "continuous maintenance" with 3-year review and revision; most recent version is 2007, approved January 2008.
ASHRAE 90.2 Energy Efficient Design of Low-Rise Residential Buildings	Follows pattern of 90.1 but for low-rise residential. Low-rise is defined as up to and including three stories.
ASHRAE 189 Draft Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings	Guidance for "green high-performance" buildings. It's program includes exceeding 90.1 energy requirements b 30%. While written in "code-appropriate language", its structure and content depart significantly from 90.1, 90.2, IECC and existing State energy codes.
ASHRAE 62.1 Ventilation for Acceptable Indoor Air Quality,	Minimum ventilation requirements, for various types of facilities and functional spaces within them. Detailed calculation procedures are defined as well as required base design outcomes. Guidance has changed substantially from revision to revision, from very low "energy conservation" requirements (1979) to much higher levels of air supply (1989) to quite complex calculations (2004) to assure proper air to end-use spaces.
ASHRAE 100 Standard for Energy Conservation in Existing Buildings	Provides procedures and methods for evaluating, planning, and improving energy use in Existing Buildings. Written as guidance rather than in "Code-appropriate" language, recognizing the fact that building codes do not regulate the operation of existing buildings.
ASHRAE 180 Standard Practice for Inspection and Maintenance of Commercial Building HVAC Equipment	A new standard that is significant in its focus specifically on inspection and maintenance of HVAC equipment. It is however too soon to know how influential this standard might be.

2.2.3. General Structure of Model Energy Code and Standards

The ICC Model Energy Conservation Code follows the same structure and draws upon the content guidance of ASHRAE Standards 90.1 and 90.2. Similarly structured but separate provisions are made for low-rise residential construction and all other types of construction. This distinction is made by ASHRAE in their standards 90.1 and 90.2. In the ICC Model Energy Conservation Code and in state codes based upon it, this distinction is reflected in separate chapters within the single code. Multifamily buildings four or more stories above grade are considered commercial buildings. In mixed use, when over ten percent of the area of any floor of residential building is used for commercial purposes, the portion of the building used for commercial purposes must meet the commercial building requirements.

Provisions apply to the design of building envelopes for adequate thermal resistance (insulation) and low air leakage and to the design and selection of mechanical, electric, service water-heating and illumination systems and equipment as shown in Figure 3. Requirements refer only to those aspects of the building that are under the control of the designer; energy that results from occupant fixtures and use, so-called "plug-loads", are not covered. Also not covered are the "embedded energy" characteristics of building materials.[5]

Figure 3 is compiled as a sample to show the general structure of prescriptive energy code requirements and the kinds of technical terminology that is used.

FIGURE 3. MAIN ELEMENTS OF COMPONENT PRESCRIPTIVE STANDARDS

BUILDING ENVELOPE		
WALLS	Detached 1- and 2- Family	$Uo \le 0.14$
	R-2 and R-4 Townhouses	$Uo \le 0.215$
ROOF/CEILING	$Uo \le 0.031$	
BASEMENT WALLS	$Uo \le 0.10$	
FENESTRATION	$Uo \le 0.55 – 2.00$	$Uo \le 0.4$
	SHGC 0.44-0.78	
AIR LEAKAGE	CAULKING, SEALANTS and GASKETING	
BUILDING MECHANICAL SYSTEMS		
Air-cooled Heat Pumps Heating Mode <65,000 Btu/h[a]	Split Systems	6.8 HSPF
	Single Package	6.6 HSPF
Gas-Fired or Oil-Fired Furnace <225,000 Btu/h	Annual fuel utilization efficiency, AFUE, of min 78%, as available from DOE appliance labeling program	
	where no labeling available, tested thermal efficiency of minimum 80% as shown by prescribed methodology	
Air-Cooled AC and Heat Pumps	Split Systems	10.0 SEER
	Single Package	9.7 SEER
DUCT INSTALLATION for Unconditioned Spaces	P45 Table 503.3.3.3	$R \ge 5.5$
SERVICE WATER HEATING		
Equipment by type, size, and fuel	NACEA Water Heating Equipment P47, Table 504.2	Thermal efficiencies and insulation of storage
ELECTRIC POWER & LIGHTING		
HVAC Motors	Motor hp to total CFM ratio	
LIGHTING	Watts per square foot by type of building / usage	

Source: Building Performance Lab, compiled from NYSECCC, ICC IECC, and ASHRAE 90.1,90.2

2.2.3.1 Requirements The standards and model code documents provide a set of requirements for the design of buildings and alternative methods for assessing and demonstrating compliance. Detailed requirements are set forth in a series of tables governing:

- the building's thermal envelope (the walls, windows, doors, and roof)

[5] "Embedded energy" is the energy that is used in the production and shipping of a material. This has become an important part of life cycle cost assessment.

- equipment efficiencies for various optional types of HVAC equipment
- power (motors) and lighting power density (the amount of electrical energy used for lighting per square foot of building area)

The greatest detail is provided for building envelope components, primarily with respect to conduction (insulation) values. Requirements are differentiated by climate region. Air-sealing, the resistance of the building envelope to uncontrolled air flows, is also required but with much less specification and detail.

It should be noted that the requirements do not specify performance in terms of energy use (BTU) per square foot. This "energy intensity" measure is commonly used in comparing building performance. Code requirements can be modeled to assess outcomes in terms of resulting energy intensity. An energy modeling procedure using the code-required building elements can provide a projected energy use or "energy budget" from which BTU per square foot can be derived.[6] The model only includes that energy which is part of the building design and under the control of the architect and engineer; energy-using appliances – televisions, computers, etc – that are not part of the design are not captured by the energy budget.[7]

2.2.3.2 General Compliance Concepts and Pathways Designers can meet code requirements by any of several methods: based on the specifications of individual components for thermal performance (resistance, R, or its inverse, conductance, U), on the calculated thermal performance of composite assemblies or on the building's overall energy performance, as demonstrated through one of several approaches:

1. Building systems and subsystems that use renewable sources and/or otherwise can be shown to meet a "low-energy" criteria (design rate of energy use less than 3.4 btuh/sf)
2. A prescriptive approach by individual component in which individual building envelope components or composites of materials in a specific assembly meet performance levels, based on material specifications. There are also "acceptable practice" and "simplified prescriptive specification" versions of this approach.
3. A performance approach that considers the thermal performance of the overall building envelope, calculated based on surface areas and thermal performance of assemblies.
4. The Energy Cost Budget method that uses a computerized model to compare a proposed design to the performance of a specified "standard" design.

Matching of components or assemblies requires little or no calculation on the part of the designer, just an understanding and documentation of material and equipment specifications. This approach does, however, limit the designer's freedom.

The most design freedom is afforded by compliance approach 4 (above), by developing a building model and showing that the proposed design performs as well as or better than the model

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6 This modeling is provided for ASHRAE by the Pacific Northwest National Lab (PNNL) and the National Renewable Energy Lab (NREL) to assess the impact of changes in the 90.1 and 90.2 standards. See [32], [33], [34] for examples.

7 This results in a lack of comparability when modeled numbers are compared to actual used energy data from billing histories, such as the data in CBECS and RECS (see Section 4).

run with prescribed components. The procedure for modeling is provided in Appendix G of Standard 90.1. This is known as the Appendix G Energy Cost Budget Method (in ASHRAE terminology) or Total Building Performance (in ICC terminology). Using this method, a design can "trade-off" between an aspect of the proposed building that does not meet prescriptive requirements by exceeding performance through another aspect of the proposed building. The design team gains more freedom at the expense of more computerized modeling. This approach is most often used for commercial buildings.

It should be noted that most of the discussion above relates to the thermal properties of the building envelope. Mechanical equipment is specified by equipment efficiencies, from labeled ratings where available. This has become an area of substantial concern among manufacturers. Lighting is specified by a maximum allowable "power density" (watts per square foot) and, at least until recently, could be readily met by industry standard equipment. It is this area where reductions have been most aggressively achieved.

The ICC provides published aids to compliance, for use by both designers and enforcement officials. Manual calculation sheets and computer-based software are available, as ResCheck for residential buildings and ComCheck for commercial buildings. ICC provides customized products fitted to individual State codes.

2.2.4. Maintenance of Standards: Revision and Updating Procedures

The reference standards and model codes are kept up to date in a near-continuous cycle of review and revision. This activity presently results in a roughly three year cycle. ASHRAE Standards have the four digit year following the number of the standard. Thus, ASHRAE 90.1-2004 is the more current version than ASHRAE 90.1-2001; ASHRAE 90.1-2007 received final approval for public release in January 2008.

However, since the various standards, model codes and local building codes provide a chain of guidance, their cycles overlap. The most current guidance will not normally be reflected in code. Thus, the NYSECCC 2002 version was in effect until January 2008. It reflected guidance from ASHRAE 90.1-2001. Many State energy codes still reflect ASHRAE 90.1-1999, per the extant federal requirement from the Energy Policy Act of 1995. The NYSECCC 2007 reflects guidance from ASHRAE 90.1-2004. Such overlaps and lags obviously present a problem in having local code reflect most recent standards.

ASHRAE Standards are maintained by an open, committee-based method. Standing committees are comprised of volunteer professionals coordinated by a staff person. The committee members provide the substantive practice-based knowledge of the field. ASHRAE's committee process does ensure that the Standards remain informed by practitioners and that resulting standards are supported by the industry. It does, however, also make for a slow process in which many interests can come into play over a myriad of details. Product manufacturers often have their concerns injected into deliberations. This process, then, is marked by what has been described as an "Information Bottleneck" typical of environmental regulation:

> Establishing and enforcing detailed, prescriptive regulatory standards is an extremely information-intensive enterprise… This is typically a painfully slow, step-wise, highly technical process, and it places extreme information demands on regulatory agencies.(p4)… I call this problem the "information bottleneck" in environmental regulation [24] (p6)

2.2.4.1 Revision Cycles and Energy Goals Despite this bottleneck effect, ASHRAE maintains aggressive objectives for continuing reductions of energy use through its revisions of Standards 90.1 and 90.2. As previously pointed out, the Standards are not written in such a way that a resulting performance metric is readily apparent from individual changes in elements of the standard. To obtain such a metric, a modeling procedure is applied to compute the energy budgets for different prescriptive performance levels and produce a resulting metric in BTU / square foot. ASHRAE works with the Pacific Northwest Lab (PNL) and the National Renewable Energy Lab (NREL) to perform this modeling, so that ASHRAE can see if its revisions are achieving its objectives. [32] [33] [34]

The triennial revisions provide clear targets for the committee members and a systematic, orderly process for the market to anticipate, moving towards a stated goal of "Net Zero Energy" buildings by 2030. However, ASHRAE's record of reductions achieved in its 90.1 revisions does not match its objectives; the history and projected targets for modeled energy consumption from 90.1 requirements is shown in Figure 4.

FIGURE 4. ASHRAE STANDARD 90.1 HISTORY AND PROJECTION OF ENERGY REDUCTION

YEAR of 90.1 Release	MBTU/SF	% Reduction from Previous Release	% Reduction from 1999 Standard
1999	53.3		
2001	51.6	3.8%	3.8%
2004	47.0	11.1%	11.8%
2007	44.0	6.6%	17.5%
2010	36.0	13.2%	32.5%
2013	30.0	16.7%	43.7%
2020	18.0	40.0%	66.2%
2025	10.0	44.5%	81.2%
2030	Net Zero[8]	100%	100%

Source: Holness ASHRAE Journal 2008 [20]

Figure 4 shows historical reductions in the modeled outcomes ranging from less than 5% to just over 10%. To achieve a 30% reduction from the 1999 level will take more than ten years and four standards revisions.

The triennial standards review and revision process provides a mechanism for such improvement. To date, most progress has been made in lighting technology. The power density allowance (watts per square foot) has been steadily reduced by significant amounts. The lighting industry has been able to keep up with this pace of change. Revision cycles have not, however, been so successful in achieving change in thermal envelope performance or in mechanical equipment.

[8] "Net Zero" refers to the overall net energy impact of the building with enough on-site renewable generation to offset what is purchased from the grid.

2.2.4.2 Plug Loads: A Source of Error in Data Interpretation Another difficulty in the use of performance metrics from ASHRAE Standards 90.1 and 90.2 is what is included in the BTU/square foot calculation. The standards and codes only govern what is included in a building design. Not included are all those "plug loads" – computers, lamps, home entertainment, various appliances – that are estimated to represent as much as 25% of building energy use; neither is discretionary usage by occupants, things like overtime hours, leaving lights on, thermostat settings. These presently escape regulation by building code[9] and are not included in ASHRAE and energy code computations.

This can cause a significant error in data comparisons. When surveying building energy usage, based on actual billed consumption, plug-loads are included. This usage rate, then, will be significantly higher than the calculation of the standard or code allowed usage which does not include the plug loads. The widely used Commercial Building Energy Consumption Survey (CBECS) data, for example, is based on actual billed energy use. Comparing this to the standard's projected use and concluding that the standard or code saves "x %" is obviously in error. It is important to remember this when seeking to understand code's reduction potential from a baseline of existing usage.

2.2.4.3 Tenant Use The issue of plug loads and occupant usage relates to the long-standing discussion of tenant energy usage. If an owner is to be held accountable for the energy performance of a building with leased space, how can he or she control the behavior of those tenants? Where tenants have their own electric and/or gas accounts directly with the utility, is their energy usage included in the building's reported data?[10] This data issue, then, brings us to leasing issues and what has begun to be discussed as part of so-called "green lease" provisions. Under "green leases", both owners and tenants undertake responsibilities for various steps that will improve the building's environmental performance. This is not presently a building code issue[11] but it does relate to voluntary programs that seek to go beyond code, such as LEED.

2.3 Relation of Energy Standards to LEED

LEED is commonly considered a building standard although it differs radically from those documents we have been discussing as underlying energy code. It is a voluntary building rating and labeling program, based on a point system for a large number of environmental attributes, from energy efficiency to water, materials, location, and recycling practices. The various versions of the rating system that address different types of construction are called "products." Thus there are related products for New Construction, Core-and-Shell New Construction, Commercial Interiors, Existing Buildings, Homes, and others under development.

There is considerable attention and on-going experimentation around using LEED as a part of city building codes. This trend began with states and cities, including New York State, mandating or strongly encouraging LEED certification for the construction of new government buildings. NYC, under Local Law 86 of 2007, requires new public construction to meet a LEED

[9] Many of them are covered by national appliance energy rating and labeling programs but such programs have their effects after the building is occupied and are beyond the control of the designer. Free of regulation, it is thought that this area of plug-load electricity may be the fastest growing area of energy consumption in buildings.

[10] It should be, of course, but there are difficulties and complications in accomplishing this. Tenants do not presently have to and may not want to share their utility records with their landlord.

[11] If building energy performance reporting were to become a code-mandated requirement, then this issue would need to be addressed.

standard, although LEED certification is not required. Many cities are now moving beyond their public buildings to introduce green elements into their building codes. San Francisco is requiring a LEED certification for larger buildings. Washington DC and Boston have instituted green provisions into their building codes but have stopped short of the LEED certification requirement. The range of options being explored by different cities is worthy of detailed investigation as this discussion will surely be raised in NYC.

LEED's flagship products are for new buildings and major whole-building renovations, New Construction (NC) and Core-and-Shell, use ASHRAE 90.1 as the baseline for demonstrating satisfactory energy performance. Demonstration of compliance is a requirement (prerequisite). Points are awarded for exceeding the 90.1 by percentages in steps up to a total of 10 points for 42% below modeled baseline 90.1 compliance, as demonstrated by computerized modeling. The current version of 90.1 is called for, so the reference is presently changing from 90.1-2004 to 90.1 2008.[12]

Because of LEED's rapidly widening acceptance and the perceived importance of high-performance "green building", ASHRAE and the USGBC have developed a working relationship between their national offices. Recognizing that engineering designers need better understanding of how to exceed 90.1 for purposes of LEED, ASHRAE has begun development of a series of "Advanced Energy Design Guides" for specific building types; the first three of this series, for small office buildings, schools, and retail, are presently available from ASHRAE at no charge.

ASHRAE has also initiated development of a new Standard189, Standard for the Design of High-Performance Green Buildings, that is intended to provide the engineering standards for creating a building that would gain LEED certification. Standard 189 is presently in draft form and under active development through ASHRAE's committee and public review process. It is written in code-appropriate language. While it could be adopted into code, in much the way Standards 90.1 and 90.2 have become the underpinning of state energy codes, its structure and content are very different and its adoption would thus require a major change in the ICC Energy Conservation Code and all the state codes that follow it. In fact, USGBC, ASHRAE and the ICC have joined together to plan educational efforts aimed at building code officials to address this issue.

2.4 Design and Performance: Not A Necessary Connection

A final consideration to address is that design to a standard or code determined level of energy use does not necessarily mean that that level of performance will be achieved. Failure to meet modeled performance is not unusual. ASHRAE's 90.1 Appendix G specifically states that the modeling done for compliance (or for exceeding code) cannot be used as a projection of actual energy performance. There are many factors that can cause under-performance, some well recognized, such as poor adjustment of equipment, some less so, such as control interactions and operator decision-making. Thus we find that, for example, in a population of LEED buildings, designed to ASHRAE 90.1 or better, there is an overall indication of lower-than-average energy use, but the range of energy use across the sample is great. For any individual building in the sample, the energy outcome is unpredictable and may be much higher than the norm of the sample and even than the average of the general population of similar non-LEED buildings.[36] Commissioning practices should be able to help here but commissioning, especially new building commissioning, has been slow to integrate measured energy performance into its procedures.

[12] For current and detailed information on the various LEED guidelines, refer to the website of the US Green Building Council, http://www.usgbc.org.

Moreover, getting the building to perform as projected when it is commissioned and put into operation is only the first step in a long process. ***This performance must be maintained over the life of the building.*** The area of long-term energy reporting has yet to be touched upon by energy standards or codes. ASHRAE Standards 62.1-2005 and 180-2007 are breaking new ground with requirements for on-going maintenance and inspection of HVAC equipment. But the adoption of energy reporting and maintenance provisions into local codes and enforcement, seems some distance into the future.

2.5 Summary Points for Section 2

- Building codes are most importantly about health and safety. Energy conservation may get only secondary attention; it is the subject of separate energy codes at the State level.
- Building codes set minimum allowable levels. They provide a baseline, not a best practice. They can, however, be used to "raise the bar", directly, as exemplified by California's State Energy Code (Title 24, chapter 6) or else indirectly, as the baseline reference for programs that encourage exceeding code.
- Building codes come into affect primarily at points of construction (new or alteration) and apply only to the new work (unless more than a specified percentage of the building is impacted, in which case the whole building may have to be brought up to current code provisions).
- Complexity of the energy standards/codes process makes change occur in smaller increments than might be targeted and with time-lags at getting the most advanced measures introduced and adopted across the interlocking chain from standards to local codes. A newer approach being explored by municipalities is to adopt reference to the LEED building rating system as a code provision.
- Energy standards and codes apply only to the elements that are part of the design. A substantial amount of energy consumption, discretionary usage and "plug-loads", that is not within the control of the design, is generally not captured.
- Building and energy codes govern design but have not as yet established regulation over the actual performance of buildings. Methods and requirements for energy-quantified commissioning, monitoring and reporting are an important next frontier.

3. New York City Building Code and New York State Energy Conservation Construction Code

As noted previously, building code has existed in New York City since the 1850's in various forms. An Energy Conservation Construction Code was first enacted into force in New York State in 1979 through the "State Energy Conservation Construction Code Act," which is Article 11 of the New York State Energy Law. The relationship between these two codes is fundamental to energy outcomes from construction in New York City.

3.1 Construction Code Authority Structure

Building codes are legislated and enforced at the local level. Governance resides at the level of local government, usually a municipality. Most states promulgate their own building codes, which govern when there is no local governing authority. Many smaller municipalities choose to adopt the State Building Code but responsibility for enforcement of the Code remains local. In New York State, the state's Building Code is administered and supported by the Department of State (DOS). The DOS also administers the separately created New York State Energy Conservation Construction Code (NYS ECCC). The NYS ECCC is related to but separate from the State Building Code and, in contrast to it, is legislated as applying in all municipalities.[12]

As is typical of larger cities, New York City, since the latter part of the 19th century, has developed its own building code. Given the nature of buildings, construction, health and safety issues in New York City, its Building Code is much more specialized and elaborate than the basic ICC model code or the typical state building code. The New York City Department of Buildings (DOB) is charged with implementing the NYC Building Code. Although technically responsible under New York State Article 11 for implementing the NYSECCC, NYC DOB took a limited approach to its enforcement until a Commissioner's Directive in August 2007 and the inclusion by specific reference into the 2007 NYC Building Code.

3.2 NYC Building Code

New York City's Building Code is authorized under the City's overall Administrative Code, the body of the City's local laws. Local laws are legislated by the City Council and are implemented by the City's executive branch, the Office of the Mayor and the "line" agencies that report to the chief executive.

3.2.1. Summary history of the NYC Building Code

First adopted in 1850, the NYC Building Code, like most building codes, has generally been a reactive document, with its most important modifications occurring after a catastrophe, such as a deadly fire or building collapse, or following economic hardship, such as the Great Depression.

What might be regarded as the city's first "modern" building code was adopted in 1938. The last major overhaul of the New York City Building Code occurred in 1968. Since then it has been continuously adjusted by interpretations, rulings, precedents and directives from the DOB. This created a situation that many viewed as rife with redundancies, conflicting rules and loopholes. [27]

In 1987 the building code was re-structured, without changing content, to reflect structure and numbering under a revised city Administrative Code. Title 26 Housing and Buildings, Chapter 1 defines the Department of Buildings, its duties, responsibilities, and authority, including Licenses, Permits, Fees, Inspections, Violations and Punishments. It is noteworthy that this Chapter provides the DOB with comprehensive authority over all buildings, not just construction: "The department shall keep records of every building in the city." (26-103). Title 27 Construction and Maintenance Chapter 1 defines the Building Code. While these two chapters were printed and distributed together, Title 27 Chapter 1 properly comprises the NYC Building Code. Section 27-103 defines the scope of the building code as:

> The construction, alteration, repair, demolition, removal, maintenance, occupancy and use of new and existing buildings in the city of New York, including the installation, alteration, repair, maintenance, and use of service equipment therein.

Subsequent sections on maintenance, owner responsibility, inspection requirements, minor alterations and repairs make clear that the DOB retains authority over existing building operations, where matters of public health and safety are involved. Thus, the DOB maintains departments for elevator, boiler and exterior façade inspections. This role notwithstanding, the building code strongly emphasizes the regulation of construction work, new or alteration, through the mechanism of permits, filings and plan review.

The most recent Building Code revision process was initiated in 2003 with the idea of modernizing and streamlining it. Making the code consistent with the International Code Council Model Codes was a major part of the work, involving a substantially revised structure and numbering system. Much of the specialized content of the existing (1968/1987) Building Code needed to be written back into the Model Code structure and harmonized with Model Code content. This process involved hundreds of experts and professionals, providing thousands of hours of volunteer work over more than four years. Pursuant to Local Law 99 of 2005, Titles 26 and 27 of the City Administrative Code were replaced by Title 28 which makes provision for the 2007 Building Code. The 2007 Building Code becomes effective July 2008 and for a one year period will co-exist with the older (1968/1987) building code. The older Building Code will remain an option for use until July 2009, at which time it will go out of force.

The first five chapters of Title 28 (available in its entirety on the DOB website) essentially replace Title 26, enumerating the responsibilities and authority of the DOB. One of these chapters covers maintenance, drawing together in one place, the various owner responsibilities and inspection requirements for the on-going operation of buildings. Following these five chapters are four further chapters, essentially replacing Title 27, the Building Code. These four chapters are the plumbing code, building code, mechanical code and fuel gas code, following the International Code Council format. The ICC Existing Building Model Code was not adopted at this time and is slated for consideration as part of the first three-year revision cycle. An extensive (225 page) document presenting the case for the new building code and detailing changes section-by-section, was prepared by the DOB and is available on the department's website [27].

3.2.2. Related Codes

While the Building Code has power over certain aspects of operating buildings, other codes are specifically aimed at regulating existing building conditions, especially in the housing sector. The Multiple Dwelling Law and the Housing Maintenance Code define specific operating conditions and procedures. Violations and complaints of various codes and laws go before the

Environmental Control Board for adjudication. As in many municipalities, the Fire Department has its own requirements, inspection and approval processes. Fire Department procedures are less connected to plans and construction permits and generally come into play late in the construction process. [11 p.6] They are not limited to Building Code provisions and reference internal guidelines that can be traced back to NFPA guidance or interpretation thereof. This, for example, resulted in a difficult situation in 2006 - 2007 when the Fire Department objected to an installation of newly installed micro-turbine cogeneration units because of their treatment of medium-pressure gas even though Building Department approvals had been properly received. This effectively "froze" the micro-turbine market in NYC for over a year while the issues were resolved.

3.2.3. Energy in the 1968-1987 New York City Building Code

The 1968-1987 New York City Building Code made no direct reference to energy conservation or energy efficiency. A reference to compliance with the NYSECCC existed with respect to the installation of fireplaces (27.848). It is suggested [18] that a Directive was issued at some point requiring enforcement of the NYSECCC, as required by New York State law. Any enforcement pursuant to such a Directive, however, seems to have been limited to, at most, the Statement, required by the NYSECCC to be stamped and sealed on the plans by the Engineer-of-Record that "to the best of his or her knowledge, the plans meet the requirements of the NYSECCC." Even this level of enforcement is in question [11]. It was not until August 2007 that the DOB issued a memorandum (Directive) requiring the presentation of data and acceptable calculations fully demonstrating NYSECCC compliance.

It is difficult, if not impossible, to judge from the absence of NYSECCC enforcement what the level of energy efficiency may have been in typical or in any specific building design. Without NYC DOB enforcement, designers used their own discretion in following NYSECCC and ASHRAE 90.1. As State-licensed professionals they are responsible for complying with relevant State laws. The author's experience is that the energy efficiency performance required by NYSECCC 1999 or 2002 or ASHRAE 90.1-2001 and even 2004, were not far beyond industry standard practices and that designs would meet or be close to these levels of energy performance even if not filing a compliance Statement.

3.2.4. Energy in the 2007 NYC Building Code

In the 2007 NYC Building Code, reference to the NYSECCC is clear and specific. Section 13 consists of stating the requirement that:

> … for the design of building envelopes for adequate thermal resistance and low air leakage and for the design and selection of mechanical, electrical, service water heating and illumination systems and equipment which enables effective use of energy in new building construction are set forth in a publication entitled Energy Conservation Construction Code of New York State (August, 2007 Edition), published by the International Code Council, Inc.

This specific reference is very significant. In effect, it makes the NYS ECCC a part of the NYC Building Code. The requirement that the NYC DOB enforce the NYSECCC is clear and unavoidable. Specific requirements for NYSECCC compliance information to be submitted as part of Plan Review documents are provided in an earlier section. So while these provisions are short, the implication is significant: the professional design community and DOB enforcement officials – plan examiners to inspectors – must master the full scope and detail of the State energy code. If experience in other locales is any guide [16], given the work loads, understandings, knowledge, and prioritization by code officials, close and fully detailed enforcement of the NYSECCC may be a challenge.

3.2.4.1 Other Materials, Equipment and Systems Opportunities Other sections of the code bear on materials and systems whose significant energy implications remain unaddressed by code requirements. These represent important areas for investigation and analysis so that they can be brought forward in the Building Code's three-year revision cycle.

For example, ventilation requirements have large energy consequences. A clear understanding of these requirements is important because of the major role that ventilation air plays in heating and cooling requirements. As buildings increase in size, volume increases more than outside surface areas. Therefore ventilation (which can be thought of as "air-changes per hour") and internal loads become increasingly more important than envelope conduction.

Ventilation for commercial spaces under the 19681987 NYC Code was set by calculation of the "Building Index." This ventilation calculation typically resulted in rates greater than that required by the governing ASHRAE Standard, 62.1. However, it should be noted that ASHRAE 62.1 has changed significantly over the years. 62.1-1989 represented an increase from a prior "energy conservation" version that had pushed rates down to as low as ten cubic feet per minute (10cfm) per occupant, a rate that was ultimately felt to be too low for consistently good indoor air quality. The current standard, 62.1-2004 provides a considerably more complex ventilation calculation.

It has been suggested,[13] but to the best of our knowledge not conclusively investigated, that the ventilation procedure under the 2007 NYC Building Code provides for a rate that is less than the old ventilation rate index procedure and also less than the current ASHRAE 62.1-2004. This needs comparative modeling for a variety of building situations to compare outcomes.[9] [17] The use of air-to-air heat recovery needs consideration as do issues of compartmentalization and reduction of stack effects [25] and duct leakage and noxious gas migration [13].

Concrete is another area with large energy consequences. Like ventilation, concrete is noted in PlaNYC2030 as an area where the Building Code will contribute to energy reduction. However, the Code as introduced does not address alternative concrete mixes for energy performance.

[13] Comments by then-DOB Commissioner Patricia Lancaster at a USGBC public event at the New School, February 2008.

These and potentially other technology opportunities can help NYC buildings meet the requirements of the NYSECCC as well as 2030 carbon goals. A sample list of relevant technologies is provided in the textbox. Many of these may be adopted by the marketplace and will require Building Code provisions to govern details of their installation. Some of these could eventually become provisions of the city's Building Code.

The 2007 Code provides a more streamlined process for accepting new materials and equipment, replacing the former Mechanical Equipment Approval (MEA) process conducted within the DOB. This streamlining can be very important in introducing new technologies through the marketplace. But bringing new technologies into the system at an accelerated pace will pose challenges for code enforcement and the DOB needs to be prepared to meet what could well be a heightened need for code interpretation.

The combination of City goals, a more dynamic code updating process, and streamlined introduction of new materials and equipment does, indeed, suggest that the 2007 Code can support the city in moving towards sustainability. But given the number of possible technologies, there needs to be a process for sequencing what will be considered and a guideline for what kind of assessments need to be performed.

Sample Energy-related Technologies for Possible Code Consideration

- Ventilation configurations and control
- Air duct leakage and sealing
- Envelope air leakage, testing and sealing
- Curtain wall design
- Advanced fenestration (windows and glazing)
- Underfloor air distribution (UFAD)
- Heat recovery (various types)
- Cogeneration
- Fuel Cells
- Advanced meters
- Appliance standards (various)
- Daylighting
- Green roofs
- Solar photovoltaics ("PV")
- Solar thermal systems
- DC electrical systems
- Low-energy concrete
- Low-energy glazings
- Water recycling
- Alternative/multi-fuel boilers
- Exterior wall insulation
- Testing and reporting procedures

3.3 NYS Energy Conservation Construction Code (NYSECCC)

The NYSECCC was first developed and introduced in 1977 by the New York State Energy Office (NYSEO, which was abolished in 1995). Like the NYS Building Code, it is maintained and administered by the NYS Department of State (DOS). It is, however, separate and independent from the NYS Building Code. The NYSECC is unusual, with respect to building codes, in that it was legislated, by the State's Energy Law, Article 11, as having effect throughout the State, independent of local building codes.

Prior to the abolishment of the NYSEO in 1995, New York State had developed and administered its own Energy Code distinctly different from the model codes. An early initiative in the Pataki administration was to move toward new building (and energy) codes, based on national model codes. The process of adapting the International Code Council's model codes for application in New York State was done by a group of Technical Committees, coordinated by staff from the DOS. The first Energy Conservation Code of New York State based on the ICC International Energy Conservation Code took effect in 2002.

3.3.1. Enforcement in NYC

As discussed above (Section 3.2.3) although the State Energy Law, Article 11, required state-wide implementation of the NYSECCC by local jurisdictions, since the NYSECCC was only minimally referenced by the NYC Building Code until development of the 2007 Code, it was generally not enforced by the NYC DOB. The State never established its own compliance and enforcement unit for New York City. Thus the NYSECCC was always "in force" in NYC, as in the rest of the State, but was never "enforced" in any systematic way. New York State licensed professionals (Registered Architects and Professional Engineers) bore individual responsibility for applying the NYSECC. A statement of NYSECCC compliance could often be found on plan sets. But full, meaningful compliance with submission of documentation and calculations was not required until an August 2007 DOB memorandum, designed to make on-going practice consistent with the provisions of the 2007 Code which was at that time nearing completion and public release.

3.3.2. General Structure of the NYSECCC

The current NYSECCC is based upon the ICC International Energy Conservation Code. It thus follows the same format and uses the same methodologies as have been previously discussed for the ICC model code and ASHRAE Standards 90.1 and 90.2. (see Section 2.2 above).

Provisions apply to the design of building envelopes for adequate thermal resistance and low air leakage and the design and selection of mechanical (heating, ventilating and air-conditioning), service water-heating and illumination systems and equipment that will enable the effective use of energy.

Like all ICC codes, the NYSECCC is revised on a roughly three year cycle. A 2006 revision became effective January 1, 2008, replacing the previous 2002 edition. Many state energy codes still reference ASHRAE 90.1-1999, as this is what is required by the federal Energy Policy Act (EPACT) of 2005. NYSECCC has been ahead of this game, referencing 90.1-2002 in both its 2002 and 2006 versions. After review and discussion, the 2006 version upgraded its reference to 90.1-2004 as of April 2008. ASHRAE has just recently completed and released its 2007 edition of 90.1.

The main area of change from successive 90.1 editions has been in the area of lighting. It has been possible to consistently push down the lighting power density (watts per square foot). The lighting industry has been able to keep up with such systematic reduction.

3.3.3. Compliance and "Leakage"

As with building code generally, the NYSECCC applies to new construction and alterations and not to existing buildings that remain unaltered. However, the NYSECCC provision regarding "substantial alteration" includes particular language that is open to interpretation. Section 101.4.2.4 (2002) reads:

> Substantial alteration to existing buildings. This Code shall apply only to that portion of a building subsystem that is replaced, provided that 50 percent or more, measured in units appropriate to that subsystem, of such building subsystem is replaced within any consecutive 12-month period.

Strictly interpreted this "50% rule" means that the NYSECCC does not apply, even to new and altered work, if less than 50% of the building or relevant sub-system is affected. Since large amounts of construction activity affect less than 50% of a building or sub-system – for example, and depending upon interpretation, office fit-outs and home improvements – this provision may be a huge loophole. A large amount of construction work that requires a building permit could "leak out" of the energy code process, depending on the interpretation of the term "subsystem."

3.4 Summary Points for Section 3

Important points to take away from this section:

- The 2007 NYC Building Code refers to the NYS Energy Conservation Construction Code (ECCC) for its specific energy efficiency requirements.
- The compliance and enforcement requirement placed on the DOB will be challenging, time-consuming, and will require new skills and understanding
- The Building Code contains requirements for various inspections and periodic reports for specialized systems that have health and safety implications. This mechanism could be extended to buildings' energy using systems and overall energy use.
- Certain technologies and materials with strong energy consequences – ventilation systems, concrete, and others – should be studied in detail so that recommendations can be brought into the three-year revision cycle.
- **The so-called "50% Rule"**, Section 101.4.2.4 (2002) of the NYSECCC needs to be clarified, interpreted and tightened so that the large amounts of construction done in relatively small partial renovations and office fit-outs will be captured by the energy code. This may require legislative change to Article 11 of the State Energy Law.

4. Code Potential To Impact NYC Energy

The goal of this section is to outline a quantitative approach and reach some preliminary quantitative assessment of the potential of the Building Code for achieving PlaNYC2030's energy/carbon reduction objectives.

4.1 A Thought Experiment

> *A physicist is asked to determine how much greenhouse gas is associated with milk production. He starts by saying "let us assume that a cow is a sphere…"*

A simple thought experiment, even if an over-simplification, can often help in understanding the dimensions of a quantitative problem. If 30% below 2005 level is the energy/carbon reduction goal for the building sector and if we assume 30% as the achievable reduction by the requirements of new building code on buildings built to earlier or no energy standards, *then* we can see that for building code alone to achieve the goal, by 2030 we would have to build anew or alter every square foot in NYC buildings. If our timeframe is 22 years (from 2008 to 2030) and NYC's floor area in buildings is 5.2 billion square feet [31 p.135], then the average annual amount of floor area that would have to go through building and energy code regulated construction would be 236 million square feet per year. Data from the NYC Building Congress suggests annual construction on the order of 40-50 million square feet per year [Appendix 2, Reference 3].

We recognize this as an over-simplification. The energy target must actually be higher than the carbon reduction target (because only about half of our electricity is carbon-based). We have seen that energy code may not immediately require 30% lower than previous standards and that energy code in its current form does not address energy consumption beyond control of the design, ie – "plug loads" are not captured. We have seen that certain kinds of construction, while regulated by the building code, may escape requirements of the energy code.[14] So our thought experiment produces a conservative estimate – the amount of construction required to meet the target would actually be considerably higher.

Of course, our thought experiment also assumes that the Building Code is to be the only policy instrument at work in the buildings sector and this is patently not the case. Nevertheless, it does give us an idea of what kind of quantification is necessary.

4.2 Establishing the Target: PlaNYC2030

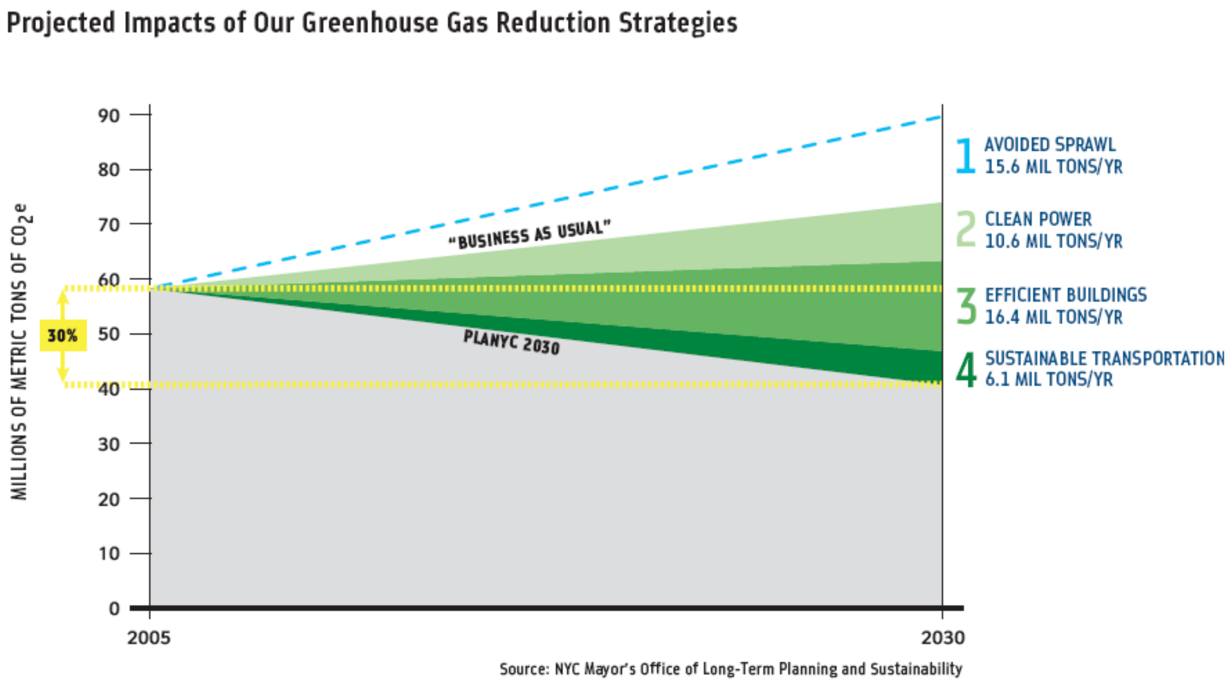
PlaNYC2030 sets forth a municipal goal for energy/carbon reduction. It is quantitatively expressed, which is extremely important, as it can provide the basis for planning and monitoring progress.

[14] Referring, in particular to the NYSECCC "50% Rule" discussed above. However, even without considering the potential effects of this rule, there are still examples of "energy code leakage" during renovations. For example, in a tenant renovation ("fit-out") within a large building, lighting would be subject to code and, conceivably new air distribution within the space. But it would not be reasonable or feasible to expect that this work would bring its portion of the thermal envelope up to code.

This is the first time such a goal has been set for energy use in New York City. It follows in broad outline goals that have been established by other cities.[15] The ability to meet such goals and the relative effectiveness of different policies and approaches is yet to be demonstrated. We are in a period of policy experimentation with results and conclusions still pending.

PlaNYC2030 calls for a 30% reduction in greenhouse gas (GHG) emissions from our 2005 level. As shown in Figure 5, the citywide goal is actually much greater than the stated 30% when (populating and economic) growth is taken into account. The contribution expected from improvements in the building sector is equivalent to the full 30% reduction target. Figure 5 shows these quantities graphically, using the convention of "Socolow-Pacala wedges:"[16]

FIGURE 5. PlaNYC2030 CARBON STABILIZATION WEDGES



For purposes of this study, we take GHG emission or "carbon" reductions as equivalent to energy use reductions; see the discussion of this in Section 1.4 above. In Appendix 1 we use data from PlaNYC2030 to calculate the 2005 energy usage and to derive the 30% target energy savings. This target value is carried forward into the spreadsheet-based calculations as shown below in Figures 7 and 8.

[15] Municipal planning in this vein has been led by the International Council for Local Environmental Initiatives, ICLEI, a Toronto-based NGO. Their model "Greenhouse Gas Inventory" and "action-oriented commitment process" has been used in cities globally, including, in the US, Seattle, Portland, Boston and many others.

[16] This is a reference to the recent work by two Princeton physicists who developed a graphical representation method for examining technology potentials and combinations in relation to needs for stabilizing atmospheric carbon dioxide by mid-century.

4.3 A Provisional Quantification

With this target in mind, we would like to answer the question, what can be expected from the normal workings of the Building Code?"

Answering this question requires knowledge of how much construction will be done over time, how much of that construction will be subject to energy code requirements, and, for construction that is so subject, how much energy impact code will mandate. Since definitive knowledge of these questions is not available, they represent uncertainties.

To understand possible and likely outcomes in the face of uncertainties, we provide a spreadsheet model that treats areas of uncertainty as variables. By being able to readily see and vary these variables, we are able to understand the range of outcome possibilities. The spreadsheet model helps us to examine:

- How much construction can be expected annually in NYC within distinct market segments and by type of construction
- What we can say about energy use in the different building market segments
- How building code differentially impacts different kinds of construction, in particular with respect to energy
- Based on the above, what we might reasonably expect to be the aggregate results of the Building Code in moving NYC's building stock towards energy/carbon reduction

Using the spreadsheet, we are able to estimate an energy reduction in the range of 15-30% of the goal from "normal" workings of the Building Code. This is to say that of PlaNYC2030's 30% reduction goal, not more than a third can be expected from the impact of the Building Code alone. This is equivalent to a 5% - 9% reduction in the City's energy consumption. This provisional finding is derived from what we consider reasonable values for our model's input variables. The values are shown below in Figure 7.

4.4 Managing Uncertainties by Spreadsheet-based Scenario Modeling

The estimate provided is considered provisional because of the uncertainties involved. Further construction industry research and data is possible to reduce the uncertainties, but they cannot be completely eliminated. When faced with uncertainties, a useful modeling technique is to create a spreadsheet that allows a small number of variables to be changed across the uncertainty range. Seeing the uncertainties as variables with some reasonably bounded ranges helps to understand the possibilities. Being able to easily change variables' values makes it possible to develop an understanding of the range of possible outcomes. This is the approach taken by our quantitative work. The spreadsheet is an important product of our work. It can be used for further research and is available for others to use and refine.

4.4.1. Linear Models and Non-Linear Effects

The spreadsheet model as presently constructed is linear – it assumes that variables will remain constant over time. In fact, this will probably not be the case and non-linear effects represent another kind of uncertainty.

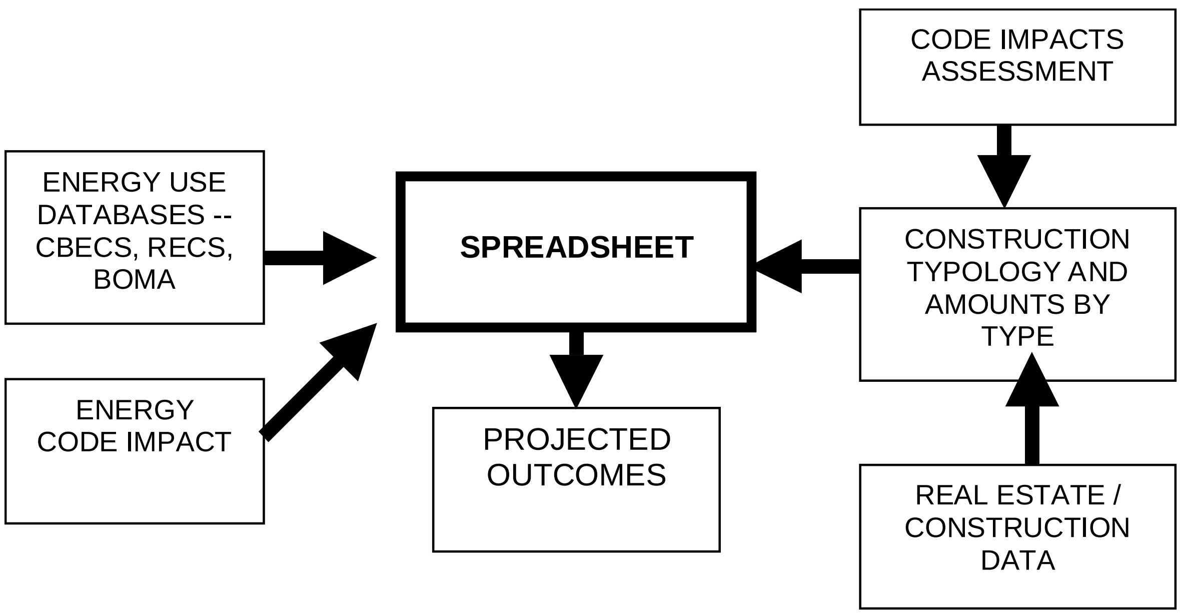
There are many different kinds of non-linearities, such as the oscillations that are common in market cycles and upward-bending curves characteristic of technology learning and adoption processes. The adoption of LEED certifications, and "green" building technologies more generally, has certainly shown an accelerating pace in the past few years. Building code changes that start slowly and with small impacts may gain momentum and realize dramatic changes late in the timeframe.[17]

Programming into the spreadsheet model exponential, curved functions is a challenge for a next generation of tool development. An intermediate step would be to change the value of variables at certain points across the timeframe. This results in "kinked" lines that approximate the smooth transitions of curves.

4.5 Spreadsheet Methodology

As shown schematically in Figure 6, the spreadsheet (actually, two related spreadsheets, Figures 7 and 8) brings together data from various sources with values for impacts and uses these to calculate outcomes.

FIGURE 6. SPREADSHEET SCHEMATIC FLOWCHART



The spreadsheet, shown in Figure 7, solves for the amount of energy reduction that can be predicted, based on the square footage in each building type segment, an estimated amount of annual construction (that would be subject to code), and estimated reduction impacts of code. The annual reduction calculated is then multiplied by the duration of the program (number of years to 2030) and this result can be compared to the 2030 reduction target. This provides a relatively

[17] This valuable discussion was suggested by Christopher Garvin in his review comments.

straightforward answer to the research question "how much contribution can be expected from the normal workings of building code as now written?" Because the input variables are relatively few, they can be varied directly on the spreadsheet to reflect more or less optimistic assumptions – about how much construction and how effective code will be in achieving energy reductions.

FIGURE 7. SPREADSHEET 1 PROJECTED ENERGY REDUCTION

Building Sector	Square Footage	Annual Construction: % of SF	Annual Construction	Avg Energy USE: MBTU / SF (BTUx10(3))	Energy Use REDUCTION (%)	Energy REDUCTION: MBTU / SF	Energy REDUCTION MMBTU (BTUx10(6))
Commercial:	788,600,000	2,50%	19,715,000	80	30%	24	473,160
Office	436,000,000			60.3			
Retail	152,600,000			50.7			
Industrial	200,000,000			NA			
Institutional:	1,111,400,00	0.50%	5,557,000	90	30%	27.00	150,039
K-12 Schools			-	76.6			
Universities			-	76.6			
Hospitals			-	171.9			
Public Assembly			-	TBD			
Municipal Buildings			-	111.1			
Residential:	3,300,000,000	0.75%	24,750,000	105	20%	21.00	519,750
Multifamily	1,650,000,000			110			
"Single Family" homes	1,650,000,000			100			
Total	5,200,000,000		50,022,000		Annual Energy Reduction		1,142,949
					Time period: 2030 - 2008		22
					Reduction over period:		25,144,878
					PlaNYC 2030 Target::		177,810,000
					% of 2030 Target::		14.1%

The second spreadsheet, shown as Figure 8, adds more detail in terms of types of construction and solves ("backsolves") for the amount of construction that would be required to reach a specified target of energy reduction. The question addressed here is: how much construction?

FIGURE 8. SPREADSHEET 2 HOW MUCH CONSTRUCTION TO ACHIEVE ENERGY REDUCTION TARGET

Building Type (Sector)	Sector Energy %	Energy Use BTU/SF	Installed Base (Million SF)	Annual Construction by Sector (% of base)	Construction Type	% of Annual Construction Within Sector	Energy Impact %	Energy Reduction BTU/SF	Annual Energy Reduction MMBTU BTU x $10^{(6)}$	How much Construction per year? SF x $10^{(6)}$
					1	25%	50%	40,000	1,140,916	29
Commercial and Industrial	44%	80,000	789	3,50%	2	25%	50%	40,000	1,140,948	29
					3	25%	25%	20,000	570,474	29
					4	25%	25%	20,000	570,474	29
					1	25%	50%	45,000	466,751	10
Institutional (includ NYC gov't)	18%	90,000	1,111	3,50	2	25%	50%	45,000	466,751	10
					3	25%	25%	22,500	233,376	10
					4	25%	25%	22,500	233,376	10
					1	25%	50%	50,000	407,481	8
Residential Multifamily	22%	100,000	1,650	2,50%	2	25%	50%	50,000	407,481	8
					3	25%	35%	35,000	285,237	8
					4	25%	25%	25,000	203,741	8
					1	25%	50%	55,000	277,828	5
Residential 1-3 Family	15%	110,000	1,650	2,50%	2	25%	50%	55,000	277,828	5
					3	25%	35%	38,500	194,480	5
					4	25%	25%	27,500	138,914	5
Total	99%		5,200					annual	7,016,086	208
								over term of program	154,353,896	4,585
								% of target	87%	

4.5.1. Building Market Segments

The spreadsheet is structured based on market segments. We treat the buildings market under three broad categories that are a common convention when dealing with real estate and energy data: Commercial, Institutional, and Residential. Each of these has sub-categories as shown in the table below. Each segment has its own characteristics with respect to energy usage and amounts and kinds of construction. PlaNYC2030 cites 950,000 buildings in NYC and 5.2 billion square feet of floor area (p.135). Characterizing this aggregate more finely is helpful in thinking through the amounts and kinds of construction and how energy is used.

Figure 9 shows this market segmentation, along with general comment about energy use. Our estimates of floor area by segment are shown on spreadsheet-1, Figure 7, above. Our research on floor areas by segment is still at a relatively early stage. Various data sources have been cross-checked and used as the basis for estimates of values to run the spreadsheet.

FIGURE 9. BUILDING SECTOR SEGMENTS

SEGMENT	SUB-SEGMENT	TYPES
COMMERCIAL		
	OFFICE	Private office buildings, all boroughs but dominated by Manhattan. *Electricity dominates energy use.*
	RETAIL	Includes supermarkets, department stores, shopping complexes, 1st floor and storefront spaces. Also food service establishments. *High energy usage in food service, high electricity in supermarkets and shopping.*
	INDUSTRIAL	Production and associated facilities such as warehousing
INSTITUTIONAL		
	K-12 SCHOOLS	Public and private. *Moderate energy use rates but very large floor area – largest single segment of municipal buildings.*
	UNIVERSITIES	Public and private
	HOSPITALS	Public and private, also nursing homes. Very high energy use rates, all sources.
	PUBLIC ASSEMBLY	Places of worship, theatres, movie houses, *High ventilation rates when occupied drive energy use.*
	MUNICIPAL BUILDINGS	Government buildings not included in categories above
RESIDENTIAL		
	"SINGLE FAMILY" HOMES	1-3 dwelling units. Mix of detached and rowhouse constructions. *Gas and oil dominate for heating and hot water.*
	MULTIFAMILY (APARTMENT BUILDINGS)	4 or more dwelling units, includes public housing. *Gas and oil dominate for heating and hot water. Typically, somewhat smaller per household and more efficient than single family.*

The segments and building types correspond broadly to energy data sources. For example, Con Edison has major data categories for "CI" – Commercial/Industrial customers and Residential customers. National data surveys use similar distinctions: we draw on energy consumption data from the national Commercial Building Energy Consumption Survey (CBECS) and the Residential Energy Consumption Survey (RECS), both conducted and maintained by the US Department of Energy.

The Institutional segment is the most difficult to model as a single category. It includes sub-segments that vary widely in terms of their energy use characteristics. Hospitals, 24-hour facilities with lots of equipment, are very energy intensive, while schools are much less so. For better accuracy it may be desirable to treat this segment in at least two categories. We do want to limit the number of segment categories used because of the complexity that results when we layer the Construction Typology (see next section) on top of the Building Sector Segments.

4.5.2. Spreadsheet Variables

As suggested above by the schematic spreadsheet flowchart, Figure 6, the spreadsheet uses a limited number of variables to characterize how events are unfolding with respect to construction activity, energy code evolution, and energy code application to specific types of construction. In spreadsheet 1 (Figure 7, above), the structure is sufficiently simple that we can enter the variables, as percentage values, directly onto the spreadsheet.

We do have in mind for further development a more complex structure in which we introduce the "construction typology" – different kinds of construction work that will have certain shares of the market and that will also be differentially affected by energy code. At this point, adjusting the variables – for four construction types, across three (or more) building segments, for two different impacts (share of construction activity and impact of energy code) – becomes too complicated to do directly on the spreadsheet. Instead we provide Input Tables on the spreadsheet that allow us to see the variables and assigned values more easily. These are shown as Figures 11 and 12 and further discussed below.

The spreadsheet with easy-to-change values for input variables allows iterative runs to show the range of outcomes with respect to input values. In this way we can establish a likely range of outcomes based on plausible but uncertain input values. The further elaboration to data input tables, structured around the construction typology, suggests the possibility of constructing "scenarios" that would characterize various patterns in the unfolding of events. For example, we might construct a "recession scenario" that has a lower overall level of construction activity and that activity more heavily concentrated in "partial renovations" with limited energy-reduction impact.

4.5.2.1 Construction Typology In this section we describe the breakdown of overall construction activity into four categories that are differentially affected by building code and energy code. With some interpretation, these categories apply across the distinct segments of the building market: commercial, institutional, and residential.

Code affects different types of construction differently. Different scopes of work will call different aspects of the Building Code into play and will impact different building elements. In new construction, obviously, the full provisions of code will be brought to bear on all building elements. A mechanical upgrade, however, such as a chiller replacement, will only affect that mechanical system. The replacement chiller must meet code but that job will not require other building elements, such as lighting, to meet code. We cannot, therefore, assume that issuing a Construction Permit for work at a certain address will bring to bear the full force of code to comprehensively reduce energy use in that property.

To reflect this situation we characterize types of construction into several broad categories that can be applied to any of the market segments (Commercial, Institutional, Residential). Figure 7 presents the Construction Typology as a table with explanatory comments.

Partial Renovation may be the most important category, as it is the most problematic in terms of scope of work, capture by code, and applicability of energy code; this category may "leak" from the regulatory system via the 50% provision of the NYSECCC (see Section 3.2 above). Partial renovations probably represent the greatest number of construction permits and construction jobs across all segments of the building sector. So even if each job is of relatively small square footage, in aggregate they constitute a significant portion of construction.[18]

FIGURE 10. CONSTRUCTION TYPOLOGY

	TYPE	DESCRIPTION	CODE AND ENERGY
1	**New Construction**	New buildings or new wings, additions to buildings	Fully new construction -- all elements subject to Code.
2	**Full Renovation**	An existing building is emptied and substantially re-constructed. Sometimes called "gut rehab". New mechanical and electrical systems throughout. May or may not include replacement of building "shell" (envelope) – more commonly included in Residential, with wall insulation added, than in Commercial.	All elements included in the rehab are subject to Code. Can therefore be expected to achieve energy performance at least close to new construction.
3	**Central System Replacement**	Major mechanical and/or electrical equipment is replaced and controls upgraded – new boilers, chillers, air-handlers, fans, pumps – but not necessarily all together. Distribution systems throughout building may or may not be included.	Replaced elements are subject to Code. Should generally be expected to have significant energy impacts but not on all systems.
4	**Partial Renovation**	Ranging from repairs and cosmetics such as painting, new carpets, not subject to Code, to common renovations such as bathrooms and kitchens or new rooms (Residential) or fully new offices (office "fit-out") on one floor of a large Commercial building.	Repair and cosmetic work, while commonly counted in rehab construction statistics are not subject to Code. Next level up, a very large portion of rehab construction, is subject to Code ***but may not be subject to NYSECCC depending on interpretation of the "50% rule."***

This typology is applied across the building market segments to provide a more granular view of the kinds of construction that might be expected. Figure 11 shows an input table from the spreadsheet model. Percentages are entered to show how construction is weighted in each segment. The types of construction add up to 100% in each segment. A separate column (on the spreadsheet, not in this input table) indicates how much of each segment's floor area is affected by construction in a typical year. In this way, the spreadsheet develops how much floor area is estimated to be affected by different types of construction.

It should be noted that the distribution of construction types is not constant over time and may show a cyclical pattern. During the "boom" cycle of the economy, we might hypothesize a higher proportion of new construction and full renovation. As the cycle declines, the steady "churn" of office fit-outs and home improvements becomes a larger portion of the smaller construction "pie." The spreadsheet model is currently not able to reflect this kind of dynamic over time.

[18] Further research is required to identify just how much Alteration work actually falls into this category in a typical year.

FIGURE 11. SPREADSHEET INPUT TABLE FOR PERCENTAGE OF CONSTRUCTION ACTIVITY BY TYPE OF CONSTRUCTION

CONSTRUCTION BY TYPE					
		commercial	institutional	multifamily	homes
1	New Construction	10%	10%	10%	10%
2	Full Rehab	20%	20%	20%	20%
3	New Central Systems	30%	30%	30%	30%
4	Partial Renovations	40%	40%	40%	40%
		100%	100%	100%	100%

We do not as yet have good data for how much construction of specific types is performed annually in New York City. Pending better data, we can better understand what outcomes may be likely by examining scenarios. In having the ability to easily alter inputs, we can see the sensitivity of outcomes to various inputs. Someday, with better data, we may be able to know and say specifically just how far building code improvements will be able to take us towards PlaNYC2030 goals. For now, we are limited to rough projections of what may happen.

4.5.2.2 Energy Reduction by Building Type and Construction Type Similarly to our procedure for amounts of construction by type, we can also examine projected energy reduction by building sector segment and construction type. The US Energy Information Agency (EIA) of the Department of Energy (DOE) maintains databases for energy use in commercial buildings and residential buildings. Data is compiled from a triennial Commercial Building Energy Consumption Survey (CBECS) and Residential Energy Consumption Survey (RECS). The samples are drawn in a statistically valid manner across four climate regions.

The CBECS and RECS data provides an absolute number (in MBTU of energy use per square foot) for energy consumption by building type. By applying an estimated percentage reduction based on energy code impact, we will obtain an estimated energy reduction, in MBTU per square foot.

FIGURE 12. PERCENTAGE ENERGY REDUCTION BY CONSTRUCTION TYPE

ENERGY REDUCTION BY TYPE					
		commercial	institutional	multifamily	homes
1	New Construction	35%	40%	40%	50%
2	Full Rehab	35%	40%	40%	35%
3	New Central Systems	15%	15%	15%	15%
4	Partial Renovations	20%	5%	5%	5%

The CBECS and RECS values are on the spreadsheet by building segment (and in some cases, sub-segment), ie – commercial, institutional, residential. The percentage factors entered as an input to the "Energy Reduction by Construction Type" table represents an estimate of how building and energy codes will apply. If overall we assume that energy standards and codes will produce a 30% improvement from earlier construction practice, then, as shown in the sample table, 40% indicates that code will be exceeded. For example, a high acceptance of LEED objectives might be thought to provide a "better-than-code" result for new construction and full rehabs. At the other extreme, a 5% entry suggests that energy code may not be well applied and/or that when it is, it affects only a portion of the building's overall energy consumption. Thus, in the sample input table, the value entered for "Partial Renovation of homes" reflects a view that the NYSECCC "50% Rule" may be in effect or that when, say, a bathroom is renovated it does not require the home's thermal envelope to be upgraded.

4.6 A Final Note: On Quantification and Monitoring

There is lots of work still to do in refining the quantifications discussed. This work is not simply to answer an academic question or even a policy question. Quantification provides an essential element for tracking and monitoring progress over the extended period of time implied by a 2030 goal. To know how we are doing in moving towards a distant, long-term goal requires near-term measurement against a reasonably calculated progress benchmark. This is just basic project management.

At an early phase of this study, we investigated the public database maintained by the DOB to see if the data might provide some basis for our calculations and estimates. We found public access to monthly spreadsheets that provided extensive information on each individual building permit application. We are aware that the DOB reports on the number of building permits processed monthly. This, of course, is a measure of productivity in the agency's core mission. For other purposes the wealth of data is tantalizing. Could this data be used to track the amount and types of construction activity? Theoretically, yes but the "flat-file" spreadsheet format requires programming to aggregate data across the monthly reports. There are other data issues that would also have to be resolved, such as multiple entries for the different permits required for the same job. But if the city is serious about managing its 2030 goals, it will need to develop its data-tracking resources. Our quantification suggests that square footage of various types of construction would provide a useful metric in tracking progress from the workings of the building code towards the energy/carbon reduction goal.

A "square footage of construction" metric is, of course, just a proxy for energy reduction. It assumes that a certain energy reduction impact is being obtained by the code requirements. That energy reduction is not measured in the code process, at least not as it is currently written. Ultimately, the proof, as they say, must be in the pudding. And the facts about the pudding reside in the actual metered data that is resident with our utility companies.

This data is accessible. In California a pending law would require that as part of any real estate transaction the utility would provide an energy-use benchmark report to the parties. At an aggregate level for the city as a whole, it is even more readily accessible. This is how we will really know if we are making the intended progress. Are we here slipping away from our strict focus on building code? Perhaps. But keep in mind that the building code provides for the DOB's governance of existing building operations when public health and safety are involved. There is precedent in the regular inspections and reports for elevators, boilers, and façades.

We cannot simply be comfortable that compliance with code at some point of construction (new or alteration) will achieve for us our energy/carbon reduction objectives. To reduce energy consumption by 30% in 2010 but to have it creep back up to its original level by 2020 does not achieve our purposes….and does little good for the atmosphere and climate change drivers. That initial 30% reduction must be maintained for the life of the building or until it too can be improved upon. To do so requires information and attention. To use building code truly effectively for sustainability requires that we understand this long-term dynamic.

4.7 Summary Points from Section 4

- Estimation of contribution from the "normal workings" of the Building Code is possible, within a range of uncertainty. We estimate this contribution to be 15-30% of the PlaNYC "30-by-30" carbon reduction target. This is an initial and highly provisional estimate.
- The amount of this contribution is sensitive to how much construction is performed, what types of construction, how energy code requirements evolve and how effective they are at impacting different types of construction.
- There is more work that can be done, using the initial spreadsheet tools created for this study, to improve the modeling and better establish sensitivities to the various uncertainties.
- Quantified projection is an important basis for progress tracking and management of the "30-by-30" goal. The DOB database may be useful in such a management system, although utility company data gives a more direct picture of energy use and trends.
- Maintaining the carbon reductions achieved from building performance is a long-term requirement that needs to be addressed.

5. Conclusion: Findings and Recommendations

Building energy standards and codes are certainly a key tool in the regulatory toolkit for reducing energy and carbon. There is a well established and relatively complex set of institutions that create and deploy the technical knowledge that underpins code requirements and related programs. It is important that the 2007 NYC Building Code more directly than in the past incorporates energy conservation requirements and enables the flexibility for adopting the most advanced standards and technologies as they are developed.

We have however, seen that the 2007 NYC Building Code, in and of itself, cannot guarantee achievement of a specific level of energy/carbon reduction. It depends on reference to other documents for its provisions directly related to energy, most specifically to the New York State Energy Conservation Construction Code. The minimum required levels of energy efficiency are established through the standard-making process that extends from the NYSECCC back through the International Code Council and the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE).

We have seen that this standards-setting process is technically pain-staking and somewhat ungainly. Improvements made at the technical level of ASHRAE committees can take several years to be passed through and adopted at the enforceable level of State code. While goals based on technical feasibility suggest standards requiring energy use 30-40% below current levels, actual standards improvements in successive revisions of ASHRAE 90.1 have generally been on the order of 5-10% from previous standard/code requirements.

There are important exceptions to this general pattern. California's Energy Code, Part 6 of Title 24, has pushed well beyond the level of requirements found in other states, the International Energy Conservation Code, and ASHRAE 90.1/90.2 guidance. So, while NYC's Building Code remains dependent upon others for its minimum requirements with respect to energy, it can choose to exceed those minimums and might look to California for a model of how to do so within the code framework. Aside from a code-based process, there are programmatic policy tools, such as incentives, voluntary commitments, and labeling, that can be used to encourage projects to exceed code.

Building code comes into effect and impacts energy use primarily when projects are designed for construction, new buildings and additions to or alterations of existing buildings. But code cannot determine the amount and kinds of work that goes into construction. In a period of slowing construction, code will have less impact. There will be less new construction and less major alteration of existing buildings. In a relatively slower economy, programs, rather than code impacts on construction, may assume greater importance in driving energy conservation.

Also in a slower economy it will be all the more important to capture code-based energy efficiency potential in the smaller kind of construction projects that continue through the inevitable "churn" of the marketplace – individual office fit-outs as business open, close and re-locate and home improvements in the residential sector. We have noted that this kind of work, while subject to the Building Code through the work permitting process, might not be subject to the NYSECCC, based on the "50% rule" for applicability of NYSECCC. If this is allowed to remain the case, then a significant portion of commercial and residential alteration volume would not be captured by energy code; such work will "leak" out of the system.

We thus conclude that while the potential from application of the State Energy Code through the 2007 NYC Building Code is promising and important, there are major uncertainties affecting the quantitative outcomes that can be expected:

- What construction requirements and associated levels of energy reduction will ultimately be expressed in energy technical standards
- When will mandated energy reductions actually find their way through the standards process and into force in codes
- How much construction will occur, bringing code requirements into play
- How much of smaller alteration work will fall under the purview of the NYSECCC

Given such uncertainties, we can only provide a preliminary and provisional estimate of the 2007 NYC Building Code's potential impact.

Under what we consider to be one plausible set of values, we find that the workings of the code process can be expected to contribute 15-30% of the PlaNYC2030 goal of 30% energy/carbon reduction. In other words, less than a third of the goal sought from the building sector can be anticipated from routine workings of the 2007 Code.

The spreadsheet-based tool that we developed for this work can be made available for researchers who might wish to further explore the range of scenarios and possible outcomes.

Recommendations

From our investigation these recommendations have emerged, many of which are consistent with recommendations in PlaNYC2030:

1. The City should work with the State to clarify the "50% rule" (NYSECCC section 101.4.2.4 [2002] and its originating legislation, Article 11) to be sure of capturing more of the many alteration projects that, under a strict interpretation of this rule's language, may not be subject to the State's Energy Code. The City should vigorously encourage an interpretation or revision that clarifies the intent as applying to all alteration work undertaken.

2. The City should plan how it will assure the persistence of energy/carbon reductions over time. This is a critical issue. Meeting a code-based standard at the point of construction does not assure that performance over the building's full life cycle. Under the Building Code the NYC DOB already has the authority to govern ongoing building operations, by establishing requirements for inspections and reporting. As suggested by ASHRAE Standard 180-2008, improved monitoring of building operations holds important potential for energy savings.

3. The City should consider creating incentives to encourage more extensive alterations at points of partial renovation, to deepen the reach and energy impact of Code provisions.

4. The City should create smart and effective incentives for construction and alteration projects to exceed Code by a demonstrated percentage; for example, by showing compliance with a more aggressive standard such as ASHRAE 189, following an approved design guide or meeting a LEED Certification level. The Building Code already provides for discounted permit fees for incorporating high-performance elements. Expedited permit processing is more highly sought and other forms of incentive may be feasible.

5. The Department of Buildings should foster the accelerated identification, verification, and adoption of new, high-energy-value technologies – such as ventilation designs (heat recovery), air and duct sealing, and low-energy cement – by establishing a formal working body to address this ongoing task, including any issues related to the Building Code. This body should assess which advanced technologies show the greatest promise of delivering the greatest savings at the lowest cost, and it should determine how their adoption can be accelerated. Funded studies would provide the kind of quantification and cost-benefit analysis that would be needed to add specific technology requirements in future Code revisions.

6. The Department of Buildings is undoubtedly already exploring strategies for significantly expanding its capabilities to meet the added requirements of enforcing the NYSECCC, with or without increasing its staffing. Intensive training should be planned for both DOB staff and the professional design community that must prepare and submit documents.

7. A twenty-two year process (ie – 2030 goals) obviously requires a management and monitoring system based in quantitative data. The Department of Buildings should convert the wealth of data contained in its monthly spreadsheets into a rich, online, public-access database that all parties concerned with progress toward the City's carbon goal can use to track and monitor progress. This could be done by the Department or by an outside party to whom the monthly data were exported.

8. The Mayor should create a formal working body to identify issues related to "greening the Codes" and assign oversight responsibility to a Deputy Mayor. We understand that the kernel for such a group is already in development.

A Closing Word

While our study finds that what the 2007 NYC Building Code, in its present form, will contribute to the carbon goal is likely to be more modest than what some parties hope for, this finding should not obscure the more important point. The Building Code has become a dynamic living document committed to a triennial revision process so that it will change over time. In concert with PlaNYC2030, it provides a doorway to great change in our built environment. It is up to us to open it.

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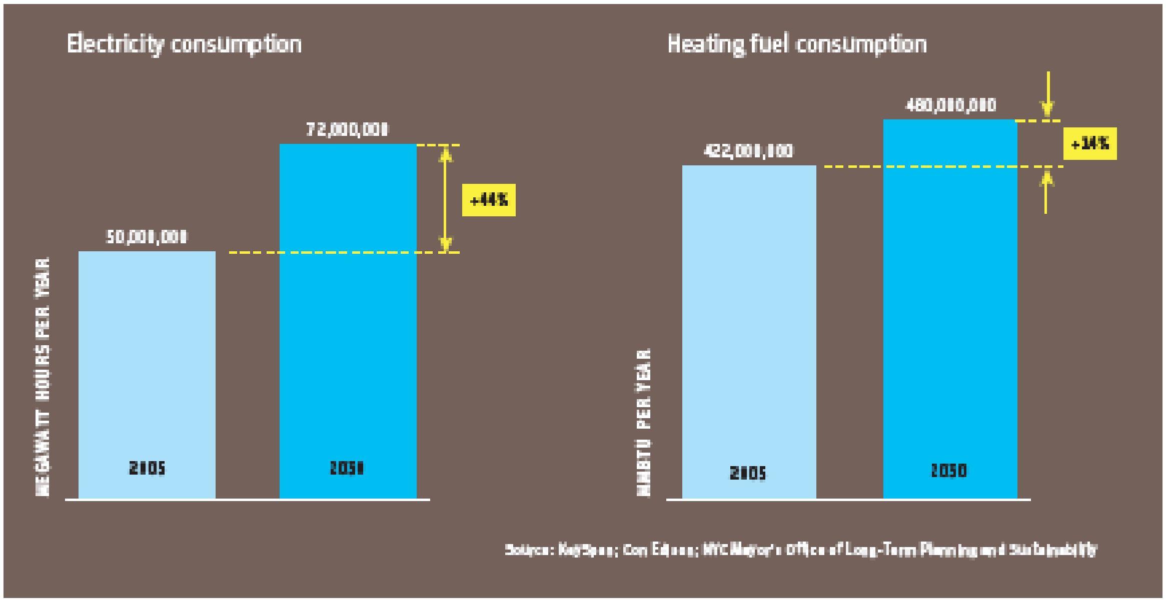
APPENDIX 1: Establishing the Energy Reduction Target

From PlaNYC2030's table, shown below, we are able to derive NYC's energy usage, as the sum of electricity and heating fuels. Heating fuel is expressed in BTU's ("MMBTU" or million BTU). Electricity expressed in MWH (megawatt hours) is converted into BTU's, first as the "site value" (3,414,000 BTU/MWH), then as the "source value", showing the fuel requirement to produce the consumed electricity, based on a composite "heat rate" for New York State power plants and import sources (10,000 BTU/MWH).



2005 ENERGY		BTU CONVERSION		2005 ENERGY in BTU	2030 SAVINGS TARGET, BTU
					30%
HEATING FUELS	422,000,000 MMBTU	1,000,000 btu/MMBTU	4.2E+14		
ELECTRICITY	50,000,000 MWH	site value	1.7E+14	5.9E+14	1.8E+14
		3,414,000 btu/mwh			
		source value	5.0E+14	9.2E+14	2.8E+14
		10,000,000 btu/mwh			
PROJECTED GROWTH TO 2030				2030 AVOIDED ENERGY, BTU	
HEATING FUELS	58,000,000 MMBTU	1,000,000 btu/MMBTU	5.8E+13		
ELECTRICITY	22,000,000 MWH	site value	1.5E+13	1.3E+14	
		3,414,000 btu/mwh			
		source value	2.2E+14	2.8E+14	
		10,000,000 btu/mwh			

Having computed the combined (heating fuels + electricity) energy use for 2005, we can then compute the 2030 target energy reduction.

APPENDIX 2: NYC Real Estate Market Data and Derivations

The following describe sources and derivations for real estate data that is used in the spreadsheet calculation tool.

Office market square footage is derived from multiple data sources. For Manhattan, which dominates the offices sector, value used is based on a range of reported data [1], [2], [8] ranging from 357 million square feet (sf) to 436 million sf. Data for outer boroughs from [1], totaling 36 million sf

Retail space, square footage Data not available, estimated value used subject to further investigation.

Industrial space: Data not available. Calculated based on data from [4] as follows: 500,000 industrial jobs with about 80 percent of the employing firms having fewer than 20 employees. Most firms occupy less than 10,000 SF. Therefore, .80 x 500,000 (employees) = 400,000 industrial jobs / 20 average workers = 20,000 firms x 10,000 sf = 200,000,000 SF as an estimated value for the industrial sector.

Residential: Square footage for the residential sector is derived by multiplying 3.3 million housing units by an average housing unit size in NYC of 1,000 sf [5] = 3.3 billion sf of residential floor area. Pending further data, this is divided equally between "single-family homes" and multifamily buildings (defined as having 4 or more apartments.)

Institutional: Value derived as the difference between reported NYC total floor area of 5.2 billion square feet [7, p 137] and other known and estimated values.

5.2 billion sf - 3.3 billion residential sf – .788 commercial sf = 1.1 billion sf as the estimated value for institutions, including NYC government.

Energy Use Rates by sector, building type: Offices and institutional facilities as shown from [10], using northeast regional data. Because of the varied nature of this sector, an overall default value is estimated and used for calculation purposes. Residential buildings from [11] for single family homes. No data is available for multi-family buildings. They are assumed to be marginally more efficient to estimate a value for current purposes.

Rate of Growth for Housing: City population is projected to increase by 900,000 residents (2010-2030) [7]. 900,000 residents divided by the average family size of 2.5 [9] = 360,000 housing units. 360,000 housing units / 20 years = 18,000 housing units per year. 18,000/3.3 billion total housing units = 0.5% annual growth rate of housing units.

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