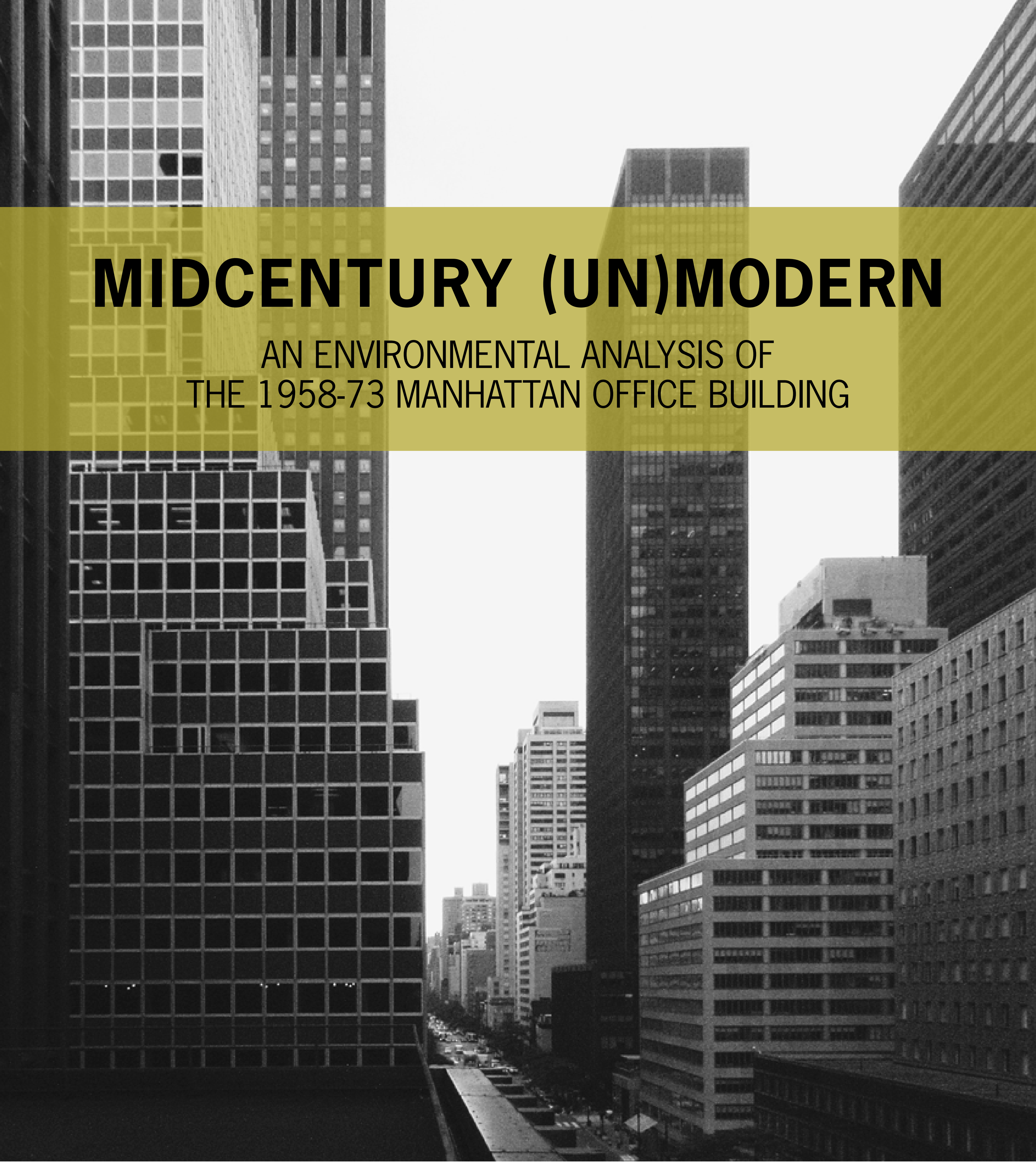
MIDCENTURY (UN)MODERN

AN ENVIRONMENTAL ANALYSIS OF THE 1958-73 MANHATTAN OFFICE BUILDING



TERRAPIN
BRIGHT GREEN

Cover photo credit: Bill Browning, Terrapin Bright Green

ACKNOWLEDGEMENTS

Primary authors for this report are William Browning, Alice Hartley, Travis Knop and Curtis B. Wayne. Special thanks to Brandon Specketer, Scott Corey, Catie Ryan, and Namita Kallianpurkar for production assistance; Integral Group for energy modeling; and Maurya McClintock for façade expertise. In addition, Terrapin Bright Green would like to thank the following experts, whose input helped make this possible. The opinions of and conclusions in this report are solely those of the authors and do not necessarily reflect the views of NYSERDA or the participating experts.

Serge Appel, COOKFOX Architects
Rick Cook, COOKFOX Architects
Todd Coulard, Trane
Fiona Cousins, ARUP
Michael Deane, Turner Construction
Alberto DeGobbi, Permasteelisa Group
Liz Dunn, Preservation Green Lab
Wendy Fok, Natural Resources Defense Council
Bob Fox, COOKFOX Architects
Scott Frank, Jaros Baum & Bolles
Patrice Frey, Preservation Green Lab
Ashok Gupta, Natural Resources Defense Council
Elizabeth Heider, Skanska
Michael Hsueh, Integral Group
Mark Huppert, Preservation Green Lab
Barry Langer, Vornado
Valentine Lehr, Lehr Consultants International
Richard Leigh, Urban Green Council
Ken Lewis, SOM
Maurya McClintock, McClintock Façade Consulting
Chris Mills, Plaza Construction
Steve Mosto, Mosto Technologies, Inc.
Dan Nall, Flack & Kurtz WSP
John Rice, AKF Group
Mead Rusert, UTC Climate/Controls/Security
Cecil Scheib, Urban Green Council
Bill Sisson, UTC Research
Russell Unger, Urban Green Council
John Weale, Integral Group
Don Winston, The Durst Organization
Richard Yancey, Green Light New York

An estimated 85% of New York City's building stock in 2030 will be buildings that exist today (PlaNYC 2030, p. 135). Understanding how these buildings perform, and what improvements can be made to them, will help New Yorkers shape their future more sustainably.

EXECUTIVE SUMMARY

MIDCENTURY (UN)MODERN
AN ENVIRONMENTAL ANALYSIS OF THE 1958-73 MANHATTAN OFFICE BUILDING

Tens of millions of square feet of commercial office buildings were built in Manhattan from the 1950s through 1970s, much of it located near significant public transportation. Most of these buildings were built with single-glazed curtain wall exteriors, a then-modern technology that promised better and more valuable office space. Designed in an era when energy resources were cheap and plentiful, these first-generation glass buildings were optimized to the standards and ideals of their day. Times have changed, however, and we are now acutely aware of the demands buildings place on energy and water infrastructure, as well as their impacts on global climate change.

For other reasons, many of the early curtain wall buildings in Manhattan are no longer desirable as modern class A office space. They tend to have low floor-to-floor heights and tight column spacing that obstruct daylight and views. Many still have their original, highly inefficient mechanical systems that provide sub-par regulation of temperature and outside air. Even basic code requirements for handicap accessibility, life safety measures and wind loads are frequently impossible to remedy.

This segment of New York City's building stock needs to be overhauled; the question is how best to approach the task, and at what speed. Certainly, the strategy of retrofitting existing buildings with more efficient lighting, mechanical systems, and even façade upgrades will play a central role in meeting the sustainability challenges facing 21st century American cities. However, some buildings are better candidates for retrofit than others, for a range of structural, technical, and financial reasons. For the target group of early curtain wall buildings, Terrapin Bright Green decided to compare the relative opportunities of retrofit vs. redevelop strategies.

Based on in-depth analysis of a representative early curtain wall building, this study draws three main conclusions:

1) Maintain. Older buildings, if well-maintained, can achieve better than average energy efficiency. Energy use per square foot in a constantly well-maintained prototype building was 10% less than the national average derived from CBECS data. Measures such as retrofit window films, caulking the façade, variable speed drives on mechanical systems, and attentive building management help the study building, 675 Third Avenue, outperform its cohort. This approach offers an intermediate stage of energy savings for older properties.

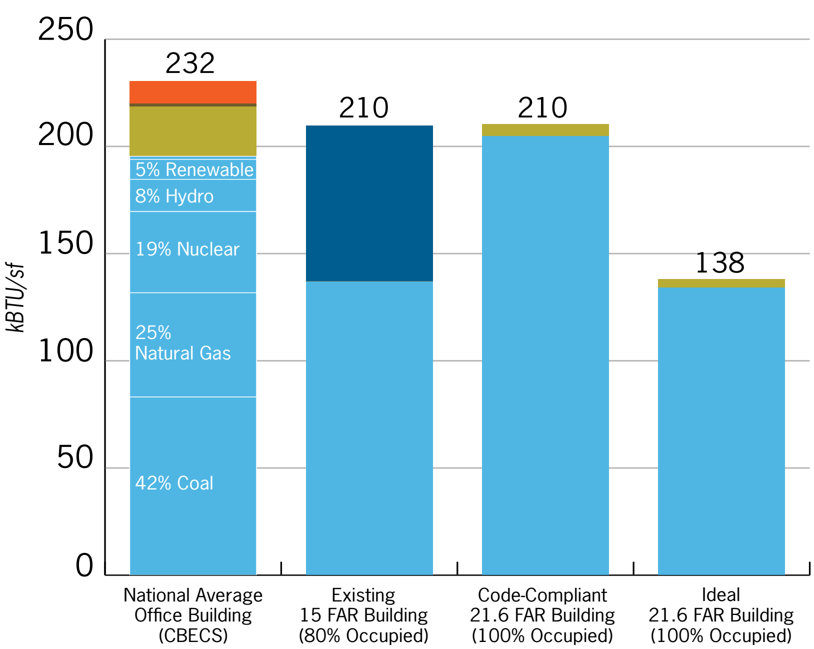
2) Retrofit. Deep retrofitting of early curtain wall office buildings could theoretically lower their energy use by more than 40%, but is unlikely to happen for a number of structural and financial reasons. While the theoretical savings are significant, the basic problems of low ceilings, poor layout and limitations on vertical transportation mean that this building type would not achieve the Class A rents necessary to undertake a major retrofit.

3) Replace. With a high performance replacement building, it is possible to increase occupancy while actually reducing absolute energy use. Even with 44% more square footage, a conceptual replacement building for the site would have a 5% lower total source energy use. On a same square footage basis, the embodied energy required to dismantle the existing building and construct a new one would be offset in 15.8 to 28 years.

Existing and Replacement Building Energy Performance	Site EUI (kBTU/sf)	Source EUI (kBTU/sf)	Total Source Energy (kBTU)
Existing 15 FAR Building (at 80% occupancy)	101	209.7	58,538,084
New, 21.6 FAR High Performance Building (at 100% occupancy)	43.8	138	55,471,623
Savings	57%	34%	5%

The replacement solution modeled adds 44% to the zoning floor area of the existing building, a key strategy for both accommodating a growing population and creating a market-based incentive for building owners. There is ample precedent in New York City for using zoning bonuses, such as incentives for open space or public amenities, to support development priorities.

If the owners of first-generation curtain wall buildings could replace them with more rentable floor area, New York City could simultaneously prepare for population growth and a more resource-constrained future. Accelerating the transition to better building performance will actively further the city's sustainability goals for 2030.



COMPARISON OF SOURCE ENERGY USE

In terms of total energy use per square foot, the case study building outperforms the average office building in America, and performs very closely to a new, code-compliant office building. With the proper measures, an ideal replacement building could be 44% larger, but still use less total energy.

MIDCENTURY (UN)MODERN
AN ENVIRONMENTAL ANALYSIS OF THE 1958-73 MANHATTAN OFFICE BUILDING

INTRODUCTION

PlaNYC, New York City's ambitious sustainability agenda, addresses the fundamental question of how to accommodate an estimated one million additional inhabitants in the city by the year 2030. First released in 2007 with an update in 2011, PlaNYC sets its sights on what New York City needs to accomplish by 2030 to reduce greenhouse gas emissions, protect the quality of drinking water, and reduce wastewater outflows while improving the quality of life for 9.1 million inhabitants in 2030.

The 2011 PlaNYC[1] update underscores both the urgency of the city's sustainability issues and the opportunities these efforts represent:

> "Climate change poses acute risks to our city. By 2030, average temperatures could rise by as many as three degrees Fahrenheit in New York City." (PlaNYC, p. 10)
>
> "Our once-innovative energy infrastructure needs to be modernized and our buildings are full of outdated equipment." (PlaNYC, p. 104)
>
> "The most cost-effective options are when stormwater controls can be designed as part of planned construction, such as new buildings, sidewalk replacements, and road reconstructions." (Sustainable Stormwater Management 2008 report, p. 8)[2]

A core question posed by PlaNYC is: can we support more people without placing additional burdens on the already stressed water and energy infrastructure? The purpose of this study is to investigate the role of 1950s-1970s era office buildings in meeting this challenge.

BACKGROUND

New York City's building stock is exceptionally diverse. In the city that gave the world many of its first modern skyscrapers, there exists a rich lineage of architectural and historic landmarks; indeed, the fight to save many of these buildings in the 1960's helped launch the modern preservation movement. Today, members of New York's architectural community are vocal participants in the effort to unite the "sister ethics" of historic preservation and environmental sustainability – a movement that is growing around the country thanks to a lively coalition of planners, advocates, architects, researchers and building owners.

Among building types commonly found in New York City, there is considerable potential to re-purpose existing structures while adapting to the demands of the 21st century. In particular, buildings with high ceilings and the potential for effective daylighting, and even natural ventilation, make excellent candidates for repositioning through retrofitting efforts. Recent work on the Empire State Building is a good example.[3] Much can be learned from the "mass wall" buildings – with smaller but higher windows, and good opportunities for natural ventilation – that have survived in New York City from previous centuries, and whose energy performance may be better than that of postwar buildings.

However, alongside classic prewar towers, New York's building stock also includes its fair share of mediocre-quality buildings – sometimes located on the same block as more noteworthy properties. The focus of this study is a subset of Manhattan office buildings representing the first generation of glass curtain wall buildings in New York City.

For this specific target group of commercial buildings constructed during the roughly 20-year period between the late 1950s through the mid-1970s, a more drastic transformation is needed. Prior to this period, curtain wall construction was very rare, and double-glazed buildings did not become prevalent until after 1974, as a response to the 1973 Energy Crisis. Some early curtain wall buildings are spectacular architectural and historic assets, such as the 1952 Lever House and the 1958 Seagram Building. This study does not aim to determine the architectural significance of any particular building.

While some of the office buildings from this era should be preserved purely for their architectural merit, there are many that have been rendered obsolete by changes in the marketplace. Modern Class A office space requires an adaptability of space, safety, and longevity that these buildings cannot provide.

While single-glazed curtain walls were considered innovative at the time, these enclosures generally do not meet current wind code requirements and are at high risk from failure in a serious hurricane. The code at the time required meeting wind loads of 30 lbs per square foot, whereas today it is understood that façades may experience loads above 70 lbs per square foot. Curtain walls from this era were intended to be as thin as possible; they utilized non-load-bearing systems hung on the exterior of a building's structural frame. As a result, most of these buildings make poor candidates for straightforward façade retrofits, as their structures cannot bear the weight of a modern, double-glazed curtain wall, let alone a triple-glazed or a double-wall system.

Floor structures in these buildings tend to be a composite of concrete encased steel girders, beams, and filler beams, between which are thin, reinforced, low strength, concrete slabs, commonly known as "goulash" slabs. Incapable of any concentrated point loading, they are generally limited to the barest of code-minimum distributed loadings. These buildings also feature tight column spacing, typically 20' by 20' bays versus the 40'-45' bays used today. This column spacing is problematic for Class A-type tenants' space planning. They have low floor-to-finished ceiling heights of 8 feet or less, a strategy to squeeze as many floors as possible into then-regulated height and setback limitations. Most do not offer adequate handicap accessibility, and in some cases do not meet current life safety codes.

All of these buildings have heating, cooling and ventilation systems optimized for an era in which natural resources were cheap and plentiful. For example, the preferred system for cooling was the Constant Volume Reheat (CVR) system: a constant volume of air is cooled and distributed throughout the building, and in areas where thermostats sense a need for less cooling, the air-conditioned supply air is reheated with electrical resistance coils or steam/hot water coils. While such systems generally have a low first cost, they are doubly inefficient, analogous to driving a car with the accelerator pushed to the floor and controlling one's speed with the brakes. These buildings also consume significant quantities of potable water that is evaporated through their cooling towers.

As these buildings have aged and architectural standards have changed, many of them are considered no longer suitable for Class A tenancy. In particular, ceiling heights of 8 feet or less seriously limit daylight and views in interior spaces. Also, a desirable density of workspaces is difficult to achieve with 20' column bay spacing. While control strategies can help increase vertical transportation, adding elevators is almost impossible. A study by Permasteelisa, a world class exterior wall contractor, of buildings in Midtown Manhattan identified 107 single-glazed office buildings constructed in the era between 1958 and 1974, many of which have become Class B or C properties.[4]

Forty-Second Street in midtown Manhattan is home to several hundred thousand square feet of the type of overbuilt high-rise buildings that this study addresses.

If many of these buildings are of such poor quality, why have they not been replaced? The reason in many cases is that they are "overbuilt," containing more floor area than current zoning code permits. Many were built with Floor Area Ratios (FAR) of 15 or greater[5]; current zoning allows only 15 FAR in C5-3 commercial zones—the type generally found along major avenues in Midtown. To demolish these buildings and replace them with less rentable square footage is something that no real estate professionals would be able to finance.

Given these barriers, what must happen for New York City to realize major energy savings from obsolete, inefficient office buildings? Terrapin Bright Green seeks to address this challenge by asking two main questions:

1) For the target group of early curtain wall buildings, how much energy can be theoretically saved through retrofitting the envelope and mechanical systems?

2) How does a deep retrofit program compare to replacement with a new, high performance green building?

METHODOLOGY

Terrapin Bright Green (Terrapin) identified a specific building as representative of the 1950s-1970s single glazed Manhattan office building. The target building was chosen based on several factors, including having design elements typical of the period and access to reliable energy and water data. Drawings and operational data were gathered and analyzed, and a façade expert undertook site investigation to explore possibilities for retrofitting the building.

675 Third Avenue, a 1966 Emory Roth office building, is used as a case study building within this paper. It has been continuously owned by its original owner and well-maintained since its construction.

THE BASELINE BUILDING: 675 THIRD AVENUE

To establish a baseline for comparing energy performance at 675 Third Avenue to alternative scenarios, Integral Group, an engineering firm with in-depth experience in advanced energy efficiency was hired to develop a computer simulation. Integral first modeled the building's existing condition and occupancy, coming within 6% of the actual source energy records of the building. This is considered highly accurate for energy modeling.

For another point of comparison, the baseline model was used to model the existing building as if it were filled with Class A tenants. The baseline model was modified to simulate the building's performance at 100% occupancy (its actual occupancy rate is about 80%), and the use density that would be expected with Class A office tenants. As expected, the existing building uses considerably less energy than it would if filled with Class A tenants. However, for purposes of this study, all comparisons are done on a more conservative basis, using the existing building at 80% occupancy and its current density of use.

Terrapin then hosted a design charrette to explore:

1. Retrofitting the building with advanced energy efficiency measures
2. Designing a replacement building on the site

The charrette team included architects, engineers, contractors, building experts, equipment manufacturers and building owners, all with deep experience in high performance building in the Manhattan market. The teams made recommendations on qualitative aspects of state-of-the-art office buildings, including specifics related to the façade, mechanical systems and quality of the indoor environment.

675 Third Avenue includes perimeter induction units, single-glazed curtain wall, and overhead ductwork that limits floor-to-ceiling height.

DEEP RETROFIT

The modeling and engineering team investigated the best theoretically possible energy retrofit of the building, without considering the cost of implementing the measures. The team used energy-use simulation software based on the US Department of Energy's DOE 2.2 program. The energy models were generated based on a three-dimensional Computer-Aided Design (CAD) model of the building specifying volume and architectural features, entered into the eQUEST™ program. The outputs of the model estimate energy use required for cooling, heating, general area lighting, mechanical equipment and occupant plug load.

This was an important exercise to understand the theoretical limits of retrofitting. However, this approach intentionally ignores financial constraints; while the existing building is a very well-run property, with its small floor plates and 8' ceilings, it would never be rentable as a Class A property. Therefore, the owners would find it very difficult to justify the increased rents necessary to cover the expense of the theoretical energy upgrades.

NEW HIGH PERFORMANCE BUILDING

Finally, the Terrapin-led team conducted a design study for a hypothetical new building on the site, which included an expert charrette. To address the inherent economic challenges of creating a qualitatively and quantitatively better-performing building through advanced energy efficiency measures, the team modeled a building with more zoning floor area than the existing structure, increasing its size from a 15 FAR to a 21.6 FAR building.[6]

The new building would occupy the same footprint as the existing building and reflect current best practices in high performance design, as determined by the charrette participants and additional consultants. These parameters include:

- Floor-to-ceiling height: 9'-6"
- 40' clear bay spans
- Concrete core, steel structure
- Building-integrated green spaces
- Daylighting and lighting efficiency strategies
- Advanced water and stormwater systems
- Plug load: 1.4 watts per square foot

Based on a conceptual design, the modeling team first simulated various façade and glazing options, to determine an optimal combination of enclosure, light transmittance, daylighting and thermal performance.

Using the optimal façade configuration, the team then modeled four different mechanical strategies:

1. Advanced Variable Air Volume (VAV)
2. Under Floor Air Delivery (UFAD)
3. Passive Chilled Beam with UFAD
4. Overhead Active Chilled Beam

The energy modeling exercise helped the team create an optimal design scenario for a replacement building, based on both qualitative criteria and annual energy use. In addition, the team studied measures to reduce the new building's peak load on the energy infrastructure, as well as the time required for energy savings to surpass the energy involved in constructing a new building and the energy required to deconstruct the existing building.

RESULTS

BASELINE PERFORMANCE OF 675 THIRD AVENUE

Based on 2011 billing data, a mild year with fluctuating tenancy, the source energy use derived from the split billing between 675 Third Avenue and the adjoining building was 55,353,629 kBTU. These factors partially account for the building's relatively low Energy Use Intensity (EUI).[7] The corresponding source EUI would be 198.3 kBTU. At the time of the study, the building was 80% occupied, at a density of use that is less than typical Class A space. This 80% occupancy rate was used as the assumption for modelling the building.

Rather than study the worst of the cohort of potential candidates, the team intentionally chose a building that has been well cared-for, and for which good operating data could be obtained. The selected building, 675 Third Avenue, is owned by the Durst Organization, which has a history of implementing energy efficiency and other high performance building measures.

TABLE 1.
675 THIRD AVENUE

Year Completed	1966
Architect	Emery Roth & Sons
Area	279,159 Conditioned sf
Floor Area Ratio	15
Floors	32
Envelope	Single-Glazed Curtain Wall with Operable Windows
Mechanical	CVR Constant Volume Reheat, Steam Chiller, Roof Top Cooling Towers
Construction	Steel Columns & Beams Encased in Lightweight Concrete Slabs

Where possible, enhancements have been installed, such as variable frequency drive fans for the central fan rooms, giving the building an approximation of a Variable Air Volume (VAV) distribution, but at a more manageable cost than that of a total replacement. The air distribution still works through induction units, which require significant fan power. Induction units use high-pressure air flow to mix air from within the room and blow it across a heating coil. Additionally, bronze tint film was applied to the original green-tinted single glazing to reduce heat gain, which also reduces daylight to the interior.

Outside air is provided by the central air distribution system. Although the building's curtain wall contains operable window sections, these are solely for the purpose of allowing window washing, and have become a constant source of air balancing problems, as leaks around the aluminum awning increasingly occur, adding to ventilation imbalance. Tenants occasionally open windows for more outside air when cooling is insufficient in a space.

The building has a minimal amount of exterior insulation: 1" of rigid insulation in the form of mineral wool board, mounted inboard of the anodized aluminum spandrels. V-shaped column covers that run the height of the tower are somewhat insulated by honeycomb aluminum backing, which also serves to defeat "oil-canning" of the surfaces.

It is worth noting that through measures taken, including retrofit window films, caulking the façade, installing variable speed drives on mechanical systems and rigorous maintenance standards, this building consumes significantly less energy than its cohort.

The modeling team was able to simulate the existing building's source energy usage to within 6% of billing data. For the existing building, the model identified a site EUI of 101 kBTU/sf, a total site energy use of 28,221,013 kBTU, a source EUI of 209.7 kBTU/sf, and a total source energy use of 58,538,084 kBTU. This weather-normalized result was almost identical to the data reported to the City's energy benchmarking.[8] This set of numbers was used as the baseline for comparing options for retrofit and replacement.

THEORETICAL DEEP RETROFIT OF 675 THIRD AVENUE

To investigate the maximum potential energy savings at 675 Third Avenue, the team modeled alternatives for improving major building systems. The team focused first on feasible retrofits to the building façade, with the aim of improving daylight penetration and thermal performance. This was followed by improvements to energy efficiency in lighting and air-conditioning.

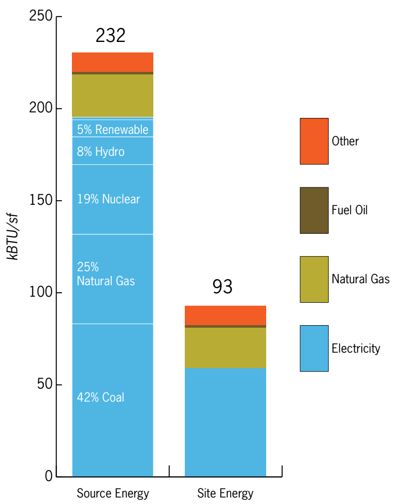
Glazing Upgrades

To understand the theoretical potential for retrofitting the existing structure, the façade expert made a series of recommendations for new glazing and façade upgrades. It was determined that the existing structural spandrel beam system could not bear the weight of a modern, thermally-broken, double-glazed curtain wall.[9] Therefore, replacement of all vision glass was recommended, with two different high performance single glazing options studied. The team also looked at upgrading lighting and installing perimeter daylighting controls.

The glazing study focused on the best combination of visible light transmittance, shading coefficient and thermal performance. The two low-e glass options studied were Pilkington and Viracon:

TABLE 2. GLASS PROPERTIES	SHGC	Ucog winter	Ucog summer	VLT
Pilkington "Solar-E" Clear Monolithic (pyrolitic "hard coat" low-e coating)	0.53	0.65	0.5	60%
Viracon VE13-85 Ultra-Clear (laminated glass with "soft-coat" low-e coating)	0.65	0.97	0.8	87%

SITE VS. SOURCE ENERGY



National Average Energy Use Intensity (EUI) for Office Buildings (Site and Source Energy). Data collected from U.S. Department of Energy Commercial Building Energy Consumption Survey (2003).

This study compares *site EUI*, the energy consumed on site, with *source EUI*. Site energy use is the most commonly understood method of expressing a building's energy use, and is easily understood by looking at the building's utility bills. The study also expresses energy use as source EUI. Source energy accounts for the fuel used to generate and transmit electricity, deliver natural gas, or produce and pipe steam. Source EUI is important for comparing carbon and other environmental impacts.

With less Visual Light Transmittance (VLT), the Pilkington glass has the more favorable Solar Heat Gain Coefficient (SHGC). Predictably, since the Viracon glass admits more visible daylight, it also results in more heat gain and greater energy use.

TABLE 3.
MODELED GLAZING RETROFITS

Glazing Retrofit	Electricity (MkBTU)	Heating (MkBTU)	Total Energy (MkBTU)	Square feet	Site EUI (kBTU/sf)
Pilkington Solar-E	9.18	18.78	27.96	279,159	**98.3**
Viracon VE13-85	9.30	19.55	28.85	279,159	**101.5**

HVAC Upgrades

The next step was to study the replacement of the 46-year-old steam-driven turbine chillers with high-efficiency, electrically-driven chillers. Energy use was modeled for replacement chillers in combination with each of the above-referenced glass types, still in single-glazed configuration but without additional insulation of the spandrel or column covers. With the adoption of these additional energy efficiency measures, the resulting source EUI is 116.9 and the total projected source energy use is 32,634,844 kBTU.

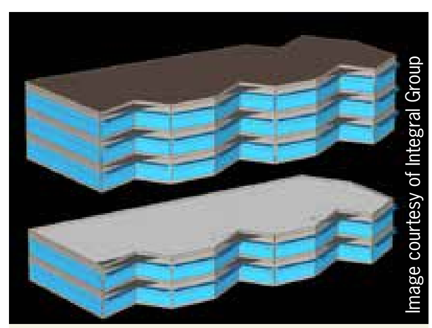
Conclusion

While reducing energy use by 44% would be a tremendous achievement, it should be noted that there are significant practical and financial barriers to doing so. Certain improvements, such as replacing glazing units and adding insulation to the perimeter, could be implemented while the building is occupied, although others would require significant disruption to tenancy in the building. As with many buildings of this era, the chillers are essentially entombed in the building, so that replacing them would require opening up the structure of the building. Installing new chillers would involve vacating the bottom two floors of the building for an extended period, which would prove expensive in terms of lost rent.

On energy savings alone, a deep retrofit would have a payback period of 44 years.[10] Paying for these upgrades would require higher rents, which would be difficult to justify for offices with low ceiling heights and few of the characteristics of a high-quality commercial space. It is really unfortunate that this building is not as adaptable as the high-ceilinged, daylit, naturally ventilated buildings of other eras.

NEW HIGH PERFORMANCE BUILDING

If building owners had the incentive of increasing rental income from their properties – while still decreasing annual energy usage in absolute terms – the economics could be shifted in favor of energy efficiency improvements. The Terrapin team therefore studied alternatives for a



Sections of replacement building as modeled.

new, 44% larger replacement building at 675 Third Avenue, constructed to Class A standards with state-of-the-art systems.

Considerations for the design case included:

- Biophilic design/connection to nature
- Building envelope/façade
- Lighting and daylighting
- Plug loads
- Indoor environmental quality

After establishing a combination of qualitative improvements, the Terrapin team quantified the energy use and EUI of four alternative mechanical systems to identify the optimal scenario.

BIOPHILIA AS A CONCEPT

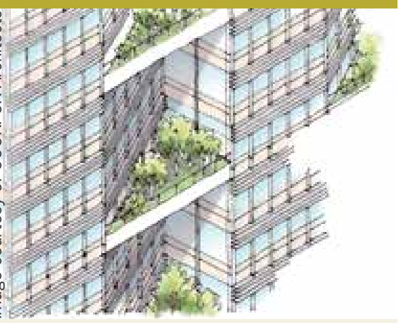


Image courtesy of COOKFOX Architects

Salaries and benefits for employees account for about 86% of the annual cost a company's occupancy in a building.[12] Rent is about 9% of the cost, and energy less than 1%. Focusing on improving the wellbeing of the occupants is an important way to boost the economic performance of a company, and one of the best ways to do that is through a field of research know as biophilia. Biophilia is the innate connection of people to nature, and research has shown that reconnecting people with experiences of nature can lead to significant financial gains through increases in productivity, as well as drops in absenteeism and health care costs. Biophilic design incorporates measures that connect occupants to experiences of nature through the use of high ceilings, deep natural daylight penetration, sky gardens, occupied green roofs, representations of nature, and spatial configurations that emulate the conditions of preferred landscapes.

Biophilic Design

As discussed in Terrapin's 2012 white paper *The Economics of Biophilia*, workers who can see greenery directly outside their windows enjoy significant health and welfare benefits. The conceptual re-design therefore incorporates significant, building-integrated green spaces. These green spaces serve multiple purposes, including improving occupants' connection to the natural world, providing passive solar shading to floors below, and reducing stormwater discharge to city sewers.

Intensively-planted terraces are an integral element of the building's form, improving daylight penetration into the building, as well as occupants' access to outdoor space. The building's structural systems are designed to support the loadings imposed by deep plantings, such as full-height trees, as well as deep beds for planting and grasses.[11]

Building Envelope/Façade

The façade system, based on the energy modeling case studies conducted for this report, consists of Viracon-insulated glazing units comprised of two layers of low-iron glass, separated by a suspended low-e film layer, with both resulting cavities filled with argon gas. This assembly offers similar thermal qualities to triple-glazed units, but with significantly less weight. As is already typical of high performance curtain wall construction, the framing systems of the exterior walls are thermally broken.

Two sill heights (18" and 30" above the finished floor height) were studied, but a constant feature of all permutations is that fully unobstructed vision glass extends to 7' above finished floor level. From 7' to a constant ceiling height of 9'6", clear glazing is shielded from direct sun exposure by horizontal fixed, 8" deep louvers mounted at 8" intervals vertically, set 8" outboard of the glazing to facilitate window washing.

Lighting and Solar Shading

The horizontal louvers outlined above not only shield direct solar radiation, but also serve as a series of mini-light shelves, reflecting daylight onto the ceiling of perimeter space through the area of glass above head height – this increases the depth at which daylight penetrates the building to at least 15'. Direct sunlight into the interior is mitigated by providing interior fabric shades with an opacity of 50%.

The building's standard lighting system is direct/indirect suspended pendant fixtures at 8' above the floor. The total connected lighting load is 0.8 watts per square foot. A perimeter lighting dimming system, used to control lighting within 15' of the exterior, would result in an overall electrical load reduction of 0.45 watts per square foot.

Plug Loads

As with the model for the existing building, a plug load of 1.4 watts per square foot was assumed, which is reflective of actual measured use in dense Class A buildings. The charrette participants recommended consideration of a green lease clause that would state the systems in the building were designed to provide comfort for tenants with plug loads up to 2 watts per square foot, and that additional loads could be met at the tenant's expense.[13]

HVAC Options

After establishing a set of conceptual design criteria, the team compared a series of four different mechanical strategies with the Viracon glazing and either an 18" or 30" sill. These four strategies were: advanced Variable-Air-Volume (VAV), Under Floor Air Delivery (UFAD), Passive Chilled Beam with UFAD, and overhead Active Chilled Beam with Dedicated Outdoor Air Supply (DOAS).

The baseline for the modeling was an advanced VAV system. These systems came into use in the 1980s and deliver 55° F conditioned air through overhead ducts. Return ducts in the ceiling bring the warm air back to air-handling units, typically on a floor-by-floor basis. VAV systems are ubiquitous in commercial office buildings.

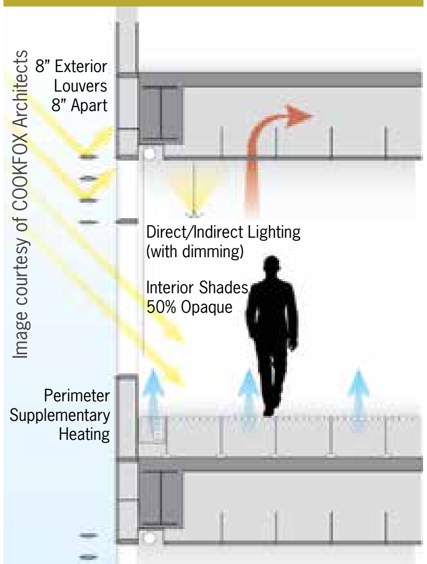
In UFAD systems, the space under raised floor is treated as a pressurized plenum. Conditioned air at 65° F is delivered through small tenant operable vents at each workstation. The heat of bodies, lights and equipment causes the air to rise, and the warm air is returned through the ceiling. UFAD systems require about 1/3 of the fan power of VAV systems, and air quality is improved as the air displaces vertically and is not blended throughout a space.

A Passive Chilled Beam with a UFAD system uses overhead fixtures to radiantly heat or cool a space. Dehumidified and conditioned air is distributed through the vents in a raised floor. This combination of

GREEN AREA RATIO

Singapore has an initiative to transform their urban model from Garden City to City in a Garden.[14] As part of this effort, new buildings are required to include green roofs, sky gardens and other planting areas equivalent to the site area, this is called the Green Area Ratio. The 33-story 21.6 FAR model building works out as having a Green Area Ratio of 105%. It would be interesting if the City of New York considered a zoning floor area bonus for buildings that achieve a high Green Area Ratio.

FACADE CROSS-SECTION IDEAL 21.6 FAR BUILDING



14'0" Floor to Floor
1'6" Raised Floor
Sill 1'6" A.F.F.
Vision Glass Sill to Ceiling
9'6" Clear Ceiling

technologies has been used in Europe, but is currently relatively rare in the United States.

Active Chilled Beams with Dedicated Outdoor Air Supply (DOAS) systems are in some ways similar to the induction units found in Constant Volume Reheat systems. Typically, dehumidified and conditioned outdoor air is blown through overhead fixtures with radiant elements for chilled water and hot water. There are also now ceiling-mounted induction modules that can handle both room sensible and latent loads, allowing them to handle buildings with mixed-mode ventilation and high density zones. A typical system was modeled here. The thermal regulation is a combination of the air temperature and radiant heating/cooling from the chilled beam.

The most energy-efficient combination is the Passive Chilled Beam with UFAD and a 30" sill height. It would result in a site EUI of 43.0 kBTU/sf, a source EUI of 137.1 and total source energy use of 55,120,757 kBTU. Total variation between the different mechanical options is not huge, which is a result of having focused on an optimized envelope performance first.

However, the team decided to choose the UFAD solution with an 18" sill height as the ideal replacement, as it would be less costly to build and maintain than a building with the Passive Chilled Beam. A 18" sill better meets market expectations and has an energy performance close to that of the Passive Chilled Beam with UFAD. The UFAD solution would result in a site EUI of 43.8, a source EUI of 138, and a total source energy use of 55,471,623 kBTU. This is a substantial improvement over the performance of the existing building at 80% occupancy, with a site EUI of 101, a source EUI of 209.7, and a total source energy use of 58,538,084 kBTU. Even with 44% more square footage and a higher density and occupancy, the proposed replacement building would have a 5% lower total source energy use.

TABLE 4. REPLACEMENT BUILDING ENERGY COMPARISON

MODEL	Site EUI (kBTU/sf)	Source EUI (kBTU/sf)	Total Source Energy (kBTU)
Existing Building	101.0	209.7	58,538,084
New 21.6 FAR Building, Code Compliant	66.6	210.4	84,574,801
New 21.6 FAR Building with VAV, 18" sill	44.9	143.3	57,610,942
New 21.6 FAR Building with Active Chilled Beam, DOAS, 18" sill	44.9	143.5	57,680,002
New 21.6 FAR Building with Passive Chilled Beam, UFAD, 30" sill	43.0	137.1	55,120,757
Idealized Building: New 21.6 FAR Building with UFAD, 18" sill	43.8	138.0	55,471,623

Reducing Peak Loads

Total annual energy use is a critical measure of a building's performance, but its peak demand profile also impacts the city's energy infrastructure. Peak energy demand is tracked in utility bills for 675 Third Avenue and is estimated in the energy model for the 21.6 FAR replacement building.

Reduced peak loads can be achieved using three methods. The first is load shedding, where temperatures are allowed to drift outside of normal comfort parameters, and systems or parts of systems are shut down by signals from the utility company during times of peak load. The second is thermal storage, which uses stored chilled water or ice to carry a portion of the peak cooling load of the building. The third is the use of cogeneration systems to produce electricity on site, using waste heat for space heating or to power absorption chillers for cooling.

The peak electrical use of 675 Third Avenue currently occurs in the month of August and is 845 kW. If the steam driven chillers were instead electric chillers, the peak electrical use would be in the month of July and would be 1421 kW. In the optimal model for the 21.6 FAR replacement building, the peak electrical use would occur in the month of July and would be 1728 kW.

To investigate the opportunities to reduce peak demands, the modelers ran three additional simulations. Load shedding was not modeled as a peak load reduction strategy, because load shedding depends on operational control instead of capital investments, making it very difficult to model.

TABLE 5.
PEAK LOAD REDUCTION OPTIONS

MODEL	Peak Load (kW)	Site EUI (kBTU/sf)	Source EUI (kBTU/sf)	Total Source Energy (kBTU)
Existing Building with Electric Chillers	1421	56.9	162.9	45,467,484
New 21.6 FAR Building with Thermal Ice Storage	1139	44.0	138.6	55,722,336
New 21.6 FAR Building with Cogeneration	1159	102.9	125.9	50,559,506
New 21.6 FAR Building with Thermal Ice Storage and Cogeneration	1161	100.7	130.1	52,290,627

First, the 21.6 FAR design was modeled with the addition of a thermal ice storage system. This system would use a series of ice tanks which are melted during the day to offset the use of chillers in peak demand periods. The tanks are refrozen at night by running electric chillers that use less expensive nighttime electricity. This strategy may actually increase the total energy use of a building, but lower the overall carbon impact by shifting away from peak electricity, which tends to be more carbon intensive. The modeled ice system has a capacity of 100 kBTU; this resulted in a maximum peak of 1139 kW, a site EUI of 44.0 kBTU/sf, a total source EUI of 138.6 kBTU/sf, and a total site energy use of 17,696,648 kBTU.

Second, the 21.6 FAR design was modeled with the addition of a cogeneration system. Cogeneration is typically done with natural gas in either a reciprocating engine, a large turbine, a cluster of micro-turbines, or fuel cells. The modeled 580 kW cogen system results in a maximum peak of 1159 kW, a site EUI of 102.9 kBTU/sf, and a total site energy use of 41,366,892 kBTU. This site number appears very high, because it includes the on-site burning of natural gas for electricity.

Third, the 21.6 FAR design was modeled with both thermal ice storage and cogeneration. This results in a maximum peak of 1161 kW, a site EUI of 71.6, and a total site energy use of 40,481,396 kBTU. The source EUI is not calculated here, as the conventional method of calculation double counts some of the source items without offsetting the replacement on-site impacts of the cogen system. The total source energy as normally calculated is higher than it should be as a result of the double counting.

The peak electric demand of the existing building (which has steam driven chillers) is modeled at 845 kW and would occur in the month of July. The 21.6 FAR building's peak without these strategies would be 1673 kW and would occur in the month of July. This peak would be reduced to 1139 kW with thermal ice storage and to 1159 kW with cogeneration. With a combination of thermal ice storage and cogeneration, the peak would be reduced to 1161 kW.

TABLE 6.
SUMMARY OF IDEAL 21.6 FAR REPLACEMENT BUILDING

- 21.6 FAR
- 401,979 square feet conditioned (422,078 gross sf)
- Concrete shear wall core, steel super structure surrounding core with 40' clear span, column free space, 14' floor-to-floor height
- Triple-glazed thermal-break aluminum curtain wall framing
- Low-iron glass IGU with low-e suspended film and dense gas (argon) fill
- 9'6" clear ceiling height to optimize daylight, 18" sill height above floor
- Exterior passive shading (horizontal fins) on east, south and west facades
- Interior fabric 50% shading
- Suspended pendant direct/indirect lighting fixtures for 0.8 W/sf lighting, plus perimeter dimming to lower as used load
- 18" Raised floor, with Under Floor Air Distribution (UFAD)
- HEPA air filtration, 95% particulate filtration
- High-efficiency electric chillers and high-efficiency cooling towers
- 100% rainwater and graywater capture to serve cooling towers, toilet flushing and sky garden irrigation
- Green roof and sky garden terraces provide 105% Green Area Ratio
- 2-micron potable water filtration
- Low-flow/dual-flush water closets and lavatories, waterless urinals
- Destination-dispatch elevator controls
- Variable voltage, variable frequency drive elevator motors with regenerative cycle
- Limit tenant power to 2 W/sf for plug loads as used, modeled at 1.4 W/sf

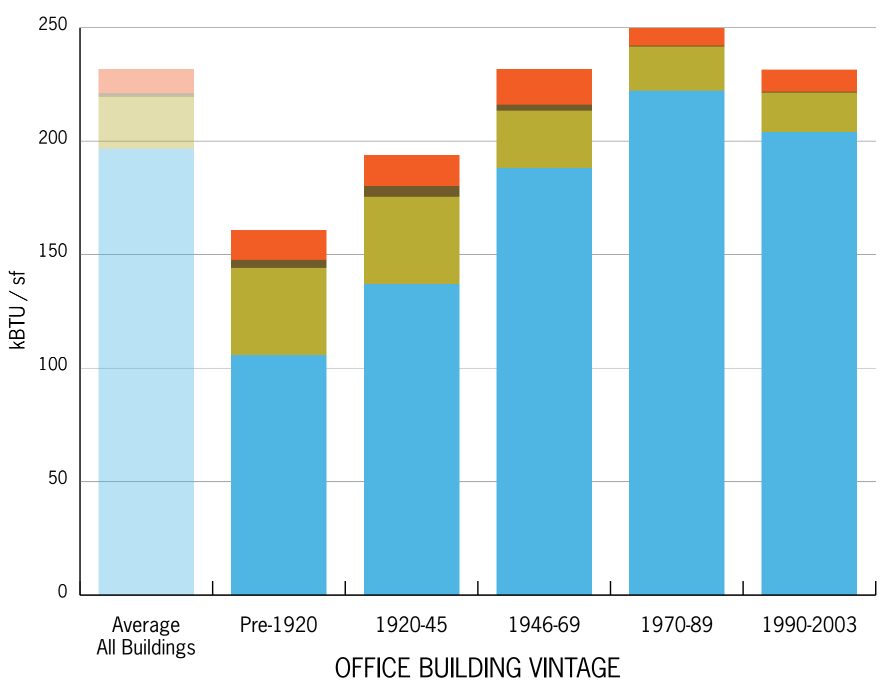
DISCUSSION

In concept, we have shown that a hypothetical deep retrofit of an inefficient 1960s office building could significantly reduce its energy use. Starting with a relatively well-maintained building means this improvement is a conservative estimate; the savings would be even greater for a more inefficient, single-glazed curtain wall building. In practice however, as noted above, the technical and financial barriers to achieving these savings are so great as to make them normally unattainable.

To put the analysis of 675 Third Avenue into context, we can compare the results to two sources of commercial office building performance data. Both databases allow for comparison of source energy use intensity (kBTU/sf).

The Commercial Buildings Energy Consumption Survey (CBECS), published by the DOE Energy Information Administration, is the main national source for comparing energy performance by building type and age. The last year that this data was compiled was 2003, but the summary is still very informative. There are noticeable differences in source energy use per square foot by age of buildings.

It should be noted that the older, pre-war buildings are more likely to have thicker walls constructed of masonry and stone, as well as high windows, and were designed to be daylit and naturally ventilated. This partly accounts for their lower energy use, although it can also be attributed to the fact that these buildings are less likely to be densely occupied or to have intensive users like financial trading floors and data centers. The cohort of buildings we focus on here, dating from 1958 to 1974, span the two highest periods of energy use per square foot.



NATIONAL AVERAGE EUI BY BUILDING VINTAGE (SOURCE ENERGY)

Other

Fuel Oil

Natural Gas

Electricity

Data Collected from U.S. Department of Energy Commercial Buildings Energy Consumption Survey (2003)

TABLE 7. ENERGY PERFORMANCE BY QUARTILE

Performance Quartile	Source EUI (kBTU/sf)
0%	95.1
25%	169.6
50%	212.8
75%	268.5
100%	424.9
Case Study Building: 675 Third Ave	209.7

Data excerpted from D. Hsu (2012).

Office buildings in New York were ranked according to their source EUI. The sample included 811 buildings' energy use as reported under New York City Benchmarking laws, and 155 buildings as reported in the U.S. Department of Energy's CBECS database.

The second data set is compiled by the City of New York, which now requires building owners to submit energy use data as part of a city-wide benchmarking system, as an outgrowth of the PlaNYC effort and city local law. The building data is recorded in the Environmental Protection Agency's EnergyStar Portfolio Manager system. In the first round of submittals there were 811 office buildings, representing 283.3 million square feet of space.

David Hsu, PhD, of the University of Pennsylvania, undertook a data cleaning and compilation exercise to understand the range of source energy use. He divided the buildings into source energy quartiles, with the 0% quartile registering at 95.1 EUI, the 25% quartile registering at 169.6 EUI, the 50% quartile registering at 212.8 EUI, the 75% quartile registering at 268.5 EUI and the 100% quartile registering at 424.9 EUI.[15] As with the CBECS data, there is no compensation for the density of occupancy, and the intensity of plug loads are not expressed in the EUI. So for example, despite being very efficient, a building with trading floors or a data center would have a high EUI. The building as it exists today has a source EUI of 209.7, which would put it into the 50% quartile for benchmarked buildings in New York City, and below the national average source EUI of 232 for office buildings constructed from 1946-1969. The 21.6 FAR building with a source EUI of 131.6 would be in between the 0% and 25% quartile for benchmarked buildings in New York City, and is significantly below the national average source EUI of 232 for recently built office buildings.

OPERATIONAL ENERGY VS. EMBODIED ENERGY

The analysis of energy use presented up to this point focuses on annual operating energy. Looking at a building's total energy impacts from a lifecycle perspective, however, leads to the question of how to properly account for the initial investment of energy expended during construction. Since much of this energy is "embodied" in the materials used to construct a building, the concept of embodied energy (EE) is key to the evolving discussion on how to improve existing buildings.

How might we estimate the embodied energy of 675 Third Avenue, and how does it affect our findings? While scant data exists for 60s-era buildings, a 1979 study authored by Richard G. Stein and Dr. Bruce Hannon[16] offers a relevant source for EE data. This data was recompiled and illustrated in *Handbook of Energy Use for Building Construction* published by the US Department of Energy in 1981.[17] *New Energy from Old Buildings*, published by the National Trust for Historic Preservation in 1981, contains a compilation of EE calculations by building type that extracts data from the Stein-Hannon study.[18] The embodied energy for offices is estimated at 1,642 kBTU per square foot.

However, this number was not calculated from an inventory of actual materials and assemblies in a representative building. Instead, using the "input/output" method, Stein took the total direct and indirect energy flows in the office building construction sector and divided by total number of square feet of office space built in that year. The result is a rough approximation of national average energy use that treats all office buildings equally.

It is important to note that the energy embodied in 675 Third Avenue is a sunk cost: while significant, it has already been expended. However, one should be careful in just using that as an argument for retaining an existing building. The study building 675 Third Avenue has had some improvements made to the existing systems that have brought annual source energy use down to 209.7 kBTU per square foot. Using the original Stein calculation of 1,642 kBTU per square foot as the total embodied energy, the building consumes an equivalent amount of energy every 8 years. Over its 46-year operating life, the amount of energy consumed is already equivalent to it having rebuilt it 5.8 times. So while the amount of energy represented in the construction of the building is important, it would be very difficult to justify preserving these buildings purely on that basis.

It is argued that since embodied energy of an existing building is a sunk cost, it should not be included when analyzing alternatives for future action. It is critical, however, to consider the embodied energy of a new building on the site, and to compare this cost to the savings that would be realized over time from new construction.

In the 30+ years since the Stein study, Life Cycle Analysis (LCA) methods for buildings are starting to gain greater awareness in the building community (see Appendix G online). At this point the best strategy for thinking about embodied energy is to use a range between the Stein data (particularly for older buildings) and the more current data for newer buildings. This is a sensible approach, given the number of assumptions and standard practices that have changed. For example, architectural steel and other metals are now largely fabricated from recycled metals. Industrial processes have become much more energy efficient. Office buildings have become more complex, with more parts. Using a newer figure of 927 kBTU/sf and the older 1,642 kBTU/sf as bounds, we estimate the new 21.6 FAR building will have a one-time energy cost of 391-693 MkBTU embodied energy. Deconstruction of the existing building would also have an energy cost. Using the same methodology, that is 64-113 MkBTU. The total embodied energy for deconstruction and new construction would be 455-806 MkBTU.

How many years of more efficient operations would it take to "pay back" the first cost of the new building? The 5% source operational energy savings amount to 3.1 million kBTU per year (58.5 vs. 55.5 MkBTU source energy). At that rate, it would take 148 to 263 years to make up the initial energy cost.

However, the new building will accommodate 44% more space than the baseline. Compared to an equivalent amount of office space, the effective operational savings are actually larger than 3.1 MkBTU/year. Adding the energy usage of 44% more space to the baseline, we calculate: 1.44 x 58,538,084 = 84,294,841 kBTU. This is a more accurate estimate

EMBODIED ENERGY

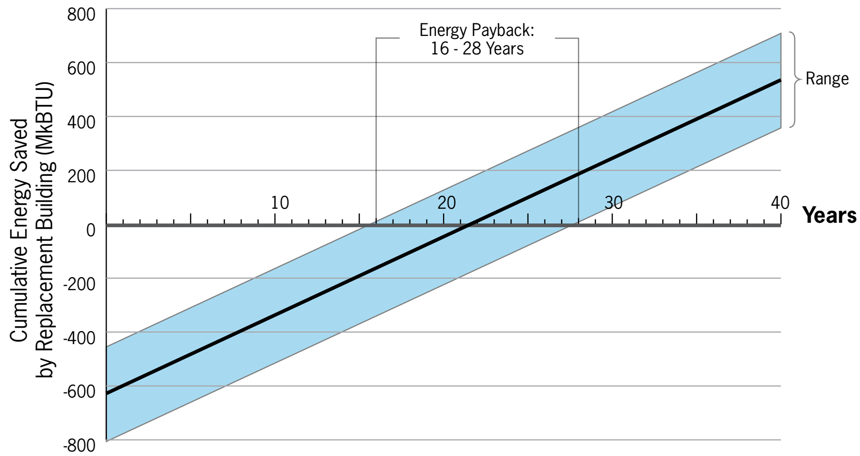
Embodied energy is the amount of energy required to produce a product. More specifically it is the term for the total amount of energy expended in mining and harvesting raw materials, transportation, processing and manufacturing, delivery to the jobsite, construction and erection energy, and removal of waste materials at the end of construction – to produce a completed structure. This represents an investment in resource use that has a definite life cycle for the structure's intended use, as well as potential adaptive reuse after its initially conceived function is no longer satisfactory or required. An extensive discussion on embodied energy can be found in Appendix G (available at www.terrapinbrightgreen.com).

TABLE 8. COMPARISON OF ENERGY USE (MKBTU)

Existing Building	58.5
Replacement Building	55.5
Existing Building with Equivalent Space to Replacement Building	84.3
High Performance Building Annual Savings	28.8

CUMULATIVE ENERGY SAVINGS

A 21.6 FAR Building at the current site would accommodate 44% more of New York City's office space than the current building. This building would use 3.1 million kBTU/year less than the current building, but the energy savings to the City would be 28.8 million kBTU/year. Depending on the estimate used for the embodied energy of the new building, the energy used to deconstruct the existing building and construct a new one would be repaid in 16-28 years.



of actual energy impact, resulting in energy savings of 28.8 MkBTU/yr. Dividing the new building's first cost by this number results in a payback period of 15.8-28 years. This is a conservative calculation, based on only 80% occupancy for the existing building and lower density of use.

WATER AND STORM WATER

The existing building consumes 10,385,640 gallons of water annually. This water is used for handwashing, drinking fountains, toilet/urinal flushing and maintenance, as well as recharging the cooling towers. For the purposes of this study the team recommended a package of water measures used first on the Bank of America Tower at One Bryant Park. These include efficient water fixtures (faucet aerators, dual flush toilets, waterless urinals), and efficient cooling towers coupled with rainwater capture cisterns and filtering of graywater captured from gound water infiltration and other sources. All toilet flushing and a portion of the mechanical system water requirements would be met by this system.

Stormwater management is a significant issue for New York City, as even small rainfalls can overwhelm existing infrastructure and result in raw sewage flowing into the Hudson and East Rivers. Present-day city regulations require that all new structures detain – through capture and storage, or through delayed outflow "blue" roofs – the outflow of rainwater from a building site. Based on data provided by NOAA, 578,350 US gallons[19] of precipitation fall on the site per annum. On an average year there are 25" of snowfall, which is the equivalent of 2.5" of rain, representing only 5% of total precipitation. A significant portion of snowfall on a roof returns to the atmosphere by evaporation. Neglecting snow precipitation, approximately 549,000 gallons of rainwater can be captured for use in the building. Currently, all of that water goes down the sewer.

Use of potable water from the New York City Water Board – approximately 93,000 gallons a year needed for toilet and urinal flushing – can be completely eliminated, leaving a remainder of approximately 455,000 gallons for irrigation of the green elements and cooling tower makeup water.

Cooling tower makeup water, based on a nominal 100-ton tower, will average less than 250 gallons per hour. Based on 260 operating days a year and 14 hours of cooling tower operation a day, approximately 900,000 gallons of cooling tower water will be required.

Thus, the demand on potable supplies can be lowered by approximately 53% through the capture and use of rainwater falling on the site. Potable water will be required for hand washing and drinking fountains, pursuant to code regulations.

CONCLUSION

This study began by asking whether it is possible to support more New Yorkers with the city's existing infrastructure. Ideally, doing so would require increasing either the density or the supply of our building stock while actually decreasing the demands on energy, water, transportation and other infrastructure systems.

Using a representative building as a case study, we have demonstrated that it is possible to increase commercial occupancy in Manhattan while using less energy on an absolute basis. The example analyzed here suggests that significant energy savings are locked up in a segment of obsolete office buildings, which are not only inefficient but also have lost commercial value in the last fifty years.

The barriers to realizing these savings are not primarily theoretical; the high performance building modeled for the site utilizes commercially available systems and standard construction practices. The bigger barriers are financial and regulatory, which suggests that effective solutions will need to consider such issues. While replacing an older building is not always the answer – certainly factors such as historic significance and full lifecycle costs need to be taken into account – neither should we dismiss new construction as an alternative strategy for early curtain wall office towers.

New York City is growing, putting pressure on its building stock to evolve. Solutions that add square footage need to be part of the solution, as do incentives for accelerating the spread of high performance building practices. In addition to energy and water savings, the benefits include green job creation and better quality, healthier workplaces for New Yorkers, present and future.

ENDNOTES

1. Office of Long Term Planning, City of New York, *PlaNYC 2011 report*.

2. Office of Long Term Planning, City of New York, *PlaNYC Stormwater Management 2008 report.*

3. "Empire State Building Retrofit," *Whole Building Design Guide*, available at http://www.wbdg.org/references/cs_esb.php. Accessed 10/15/2012. In older masonry skinned buildings with high windows, a raised floor and underfloor air distribution (UFAD) can be used as a retrofit strategy. For the Skanska space in the Empire State Building, a 10-foot ceiling height with increased daylight distribution was achieved by removing the suspended ceiling and overhead ductwork that was blocking the top foot of the windows. The combination of UFAD, the addition of insulation behind radiators, new high performance glazing in the existing frames, daylight dimming, suspended pendent direct/indirect lighting, and attention to plug loads led to an energy savings of more than 50%. The effective floor-to-ceiling height went from 8 feet to 10 feet. Unfortunately that strategy would not work in 675 3rd Avenue and other buildings with similar curtain wall constructions. The floor to underside of slab height is frequently lower than that of the Empire State Building, and without rebuilding the leaky exterior façades, it would be extremely difficult to seal the edges of the plenum created by the raised floor UFAD system.

4. From a survey of single-glazed office buildings in Midtown Manhattan, Permasteelisa USA, unpublished.

5. How big is it? This is one of the most common questions about a building, and the answer is always, it depends on what definition you use. According to the NYC Zoning department, **zoning floor area** (also called floor area ratio or FAR) is the ratio of total building floor area to the area of its zoning lot. So a 15 FAR building is 15 times the size of the lot it occupies. The building may actually be physically bigger, as some unoccupied spaces, like mechanical rooms, are not counted. So the **gross area** includes these spaces and is about 5% larger than the FAR square footage.

   The Real Estate Board of New York (REBNY) defines **REBNY-useable** area as the total area of building measured from the outside of the exterior walls less elevator shafts, public stairs, mechanical spaces and shafts, fire towers and electrical/telecommunications spaces as well as the nominal 4" of wall surrounding elevator shafts, public stairs, and mechanical spaces. In multi-tenant buildings, public corridors and bathrooms are also subtracted from the total area. In New York, the leasing community defines **rentable area** as including the tenant's portion of common areas and other space, although sometimes the rentable square footage exceeds the gross area. A **loss factor** is the difference between these areas, and can range from 20-40%, depending on the building and the owner's measurement of rentable area.

   Another term is **carpetable area**, which refers to area that a tenant would carpet for their own use. This square footage would probably be the closest to what most people would define as the physical size of their space. **Conditioned** or **modeled area** is used for determining the energy use of building, and is typically pretty close to the FAR.

6. Increases in zoning density in the City of New York are frequently granted in 20% increments. This happens through the use of bonuses for the inclusion of features such as plazas, arcades, or even new Broadway theatres. A 20% increase on 15 FAR results in 18 FAR, and a 20% increase on 18 FAR results in a 21.6 FAR. This cumulative increase means that 21.6 FAR is 44% bigger than 15 FAR.

7. One common benchmark of a building's efficiency is the EUI, which stands

for Energy Utilization Index. According to the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) and the U.S. Department of Energy, EUI is a number that is the result of dividing the amount of energy (which includes electrical energy, which can be expressed in units of heat) in thousands of BTUs (British Thermal Units – the measure of heat energy used in the United States, based on the legacy Imperial system originating in Britain) by the conditioned floor area of the building expressed in square feet.

8. The data recorded for this building as part of the City of New York Local Law 84-2009 on energy benchmarking is a site EUI of 99.8, a weather normalized source EUI of 209.2, and an ENERGY STAR score of 62.

9. Some single-glazed curtain wall buildings of this era, particularly ones built to different structural codes, can bear the weight of additional glazing. If the original exterior glazing was individual, sealed, non-operable units, there are some interesting opportunities:

   The Moorhead office building in Pittsburgh was retrofitted with magnetically-attached interior storm windows and increased insulation (See Charles Enos "Curtain Wall Retrofit – William S. Moorhead Building, Pittsburgh, PA," *Environmental Design and Construction,* Oct. 3, 2011).

   In the 1990s, a 1957 St. Louis fixed, single glazed façade at Monsanto's headquarters was retrofitted by removing a dark film on the clear original glass; insulation was added to the inside of the outer wall; and a new interior wall was built with operable clear glass to create a thin profile double wall. Interior air was pulled through the slots under the window and exhausted in the return plenum in the suspended ceiling. The ceiling was then sloped on the perimeter to help with light distribution. Unlike the buildings that discussed in the paper, this was a low-rise midcentury building with a beefy structure and substantial room above the suspended ceiling.

   A proposal was made to retrofit the 1965 Byron Rogers Federal Office Building in Denver with a high performance reglazing in the original frames, interior insulation and passive chilled beams. It has a precast concrete panel skin, and structure would have no problem bearing the weight of additional glazing. The ductwork could be downsized because the air was for ventilation, and not for space conditioning.

   Unfortunately, it would not be possible to use the strategies of the Moorhead Building, Byron Rogers or Monsanto buildings on the study building. The exterior glazing in this case presents a life safety issue because they were designed for maximum wind loads of 30 pounds per square foot.

   Even if it could bear the weight of an interior storm window, with the operable center units for window cleaning (because buildings of this cohort did not have exterior window-washing rigs) one would wind up with condensation between the layers of glass, while being unable to clean the exterior of the building.

10. Without accounting for the displacing tenants, we estimate that a deep retrofit would cost \$11,200,000, or \$38 per gross square foot. This includes: \$8.8 M for reglazing (conservatively, \$100 per square foot, at 88,000 sf of glazing), \$1.8 M for new electric chillers (again conservatively, \$2,000 per ton, and downsizing the existing system from 1,200 to 900 tons), and \$0.5 M in construction costs to remove the steam-driven chillers and replace them.

    The energy savings from this retrofit (outlined in Appendix C) would include slightly higher electricity costs and lower steam costs. These savings would be approximately \$250,000 per year or \$0.88 per sf per year, resulting in a payback period of 44 years.

11. German Federal office construction standards mandate that workers desks be

no further than 23 feet (7 meters) from an exterior window; while this is not instituted in any North American code requirement, it stands as an indication of a desirable distance from exterior to face of interior core. Thus, the green element “indentations” in the form of the schematic tower design serve to lessen the distance from a glazed exterior wall to a dimension approaching the German standard.

12. Terrapin Bright Green, *The Economics of Biophilia*, New York, 2012.

13. Leasing brokers typically request the capability of plug loads to be as high as 6 watts a square foot. This is based on what are called “name-plate” plug loads, which is the number calculated by looking at the wattage number on the name-plate of all the equipment in an office and dividing by the square footage. The problem with this methodology is that the name-plate wattage is related to the third wave harmonic spike that the device may be caused the instant it is turned on, the actual energy use of the device is typically 1/4-1/3 of the name-plate. Wires must be sized to name-plate capacity, but mechanical systems can and should be sized to the actual energy use over time. For this study, the actual plug load assumption of 1.4 watts per square foot was determined based on the actual loads reported by independent experts in Class A Manhattan office space.

14. Ministry of National Development, Singapore, From Garden City to City in a Garden, Singapore, 2011.

15. D. Hsu, “Characterizing Energy Use in New York City Commercial and Multifamily Buildings”, *2012 ACEEE Summer Study on Energy Efficiency in Buildings*, American Council for an Energy Efficiency Economy, Washington DC, 2012, pp. 3-130.

16. Assessing the Energy Conservation Benefits of Historic Preservation: Methods and Examples, Advisory Council on Historic Preservation, 1979. Online at: http://www.achp.gov/1979%20-%20Energy%20Conserv%20and%20Hist%20Pres.pdf. Prepared in support of of Section 106 of the National Historic Preservation Act and Title I of the Public Buildings Cooperative Use Act.

17. R.G. Stein, C. Stein, M. Buckley and M. Green, *Handbook of Energy Use for Building Construction,* The Stein Partnership, New York, NY, 1981 prepared under contract to the U.S. Department of Energy – DOE / CE / 20220-1

18. *New Energy from Old Buildings* National Trust for Historic Preservation, Washington DC, 1981, ISBN-13: 9780891330950

19. Rainfall source: http://www.erh.noaa.gov/okx/climate/records/nycnormals.htm

APPENDIX: SUPPORTING MODELS AND CALCULATIONS

COMPLETE LIST OF APPENDICES

675 Third Avenue

also known as 201 East 42nd Street

Completed: 1966

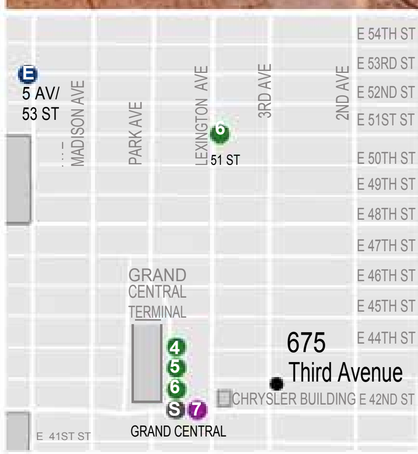
Architect: Emery Roth & Sons

Stories: 32

Building Area: 342,000

Major Tenants: Siller Wilk LLP, Prudential Douglas Elliman, SS & C Technologies, Inc.

On the northeast corner of Third Avenue and East 42nd Street, 675 Third Avenue is one block from Grand Central Terminal and just a short walk to the United Nations. In addition to this advantageous location, 675 Third Avenue affords a full-service corporate venue. Built of steel and reinforced concrete with an aluminum-and-glass curtain-wall façade, this boutique building has a varied tenant roster of law firms, hedge funds, governmental consulates, nonprofit organizations, and accounting firms. Bank of America currently occupies the retail space.



Durst.org
One Bryant Park
New York, NY 10036
212.257.6600
info@durst.org

675 Third Avenue

also known as 201 East 42nd Street

SPECIFICATIONS

Design and Construction

Architect: Emery Roth & Sons (1966)

Lobby: In 1996, the building entrance and lobby were fully renovated to include a new concierge desk and a security system connected to a central alarm reporting station.

Building Height: 365

feet **Stories:** 32

Slab Height: 11 feet, 4 inches

Floor Plates:
Low: approx. 18,300 sf
Mid: approx. 10,500 sf
High: approx. 8,500 sf

Heating, Ventilation and Air Conditioning

Heating is provided by Con Edison steam. Heat exchangers convert the steam to hot water, which is supplied to the coils in the central fan rooms and the perimeter induction units. The air conditioning system is a central-fan constant-volume type consisting of two refrigeration machines with capacities of 600 tons each. The central fan rooms are located on the eighth and thirtieth floors. The cooling tower has a total capacity of 1,700 tons. Conditioned air is distributed to the perimeter and interior spaces through overhead ductwork. Temperatures for the perimeter and interior zones are controlled by thermostats. Perimeter fan coil units have individually controlled fan-speed selection.

Base Building and Life Safety

Since 2006, The Durst Organization has had the only First-Responder In-Building Communications System that enables first responders (FDNY, EMS, and NYPD) to communicate within the building. Under the control of the respective responder agency (FDNY controls FDNY, etc.), the system is tested regularly by both building personnel and an outside testing service to ensure uninterrupted operation.

Telecommunications

The property has a complete state-of-the-art telecommunications system for communication between and among building management, building services, engineers, and security. Wireless services are provided by one or more carriers, depending on the tenant requirements and carrier participation. Telecommunications are being constantly updated and modernized. Time Warner Cable provides cable TV, Cogent provides wired high-speed Internet, and Rainbow Broadband provides wireless high-speed Internet and telphone; the building has T-3 capacity.

Electrical System

Con Edison delivers electrical power to the building via a second contingent, 120/208V, spot network located in the sidewalk vault. The service is made up of the three 4,000-amp service take-offs, which feed the building's service switchgear and is shared with the adjacent building, 205 E. 42nd Street; also owned and operated by The Durst Organization. Power is then distributed via pipe and wire risers throughout the building. 10% of the total energy utilized by the building consists of wind power, which is purchased from a third-party energy supplier. The building's electrical distribution system is continuously maintained in accordance with national testing standards and applicable codes to provide the highest level of reliability. It is equipped with a sophisticated, web-enabled electrical metering system, which is used for tenant billing as well as allowing our in-house experts to monitor system performance in real-time. Our in-house electrical engineers analyze new tenant designs and requirements to ensure that sufficient electrical distribution is provided in accordance with lease terms and building rules and regulations.

Security

Electronic Security Systems provide security for the building, proximity key cards for all tenants, and CCTV cameras. The lobby is staffed by licensed security personnel 24/7. All buildings are centrally monitored from our security control command center.

Cleaning

High-caliber green cleaning is provided, which helps tenants achieve and maintain optimal efficiency and professionalism. Our recycling program ensures an environmentally responsible workplace in keeping with The Durst Organization's corporate philosophy.

Messenger Center

The building has a separate messenger center, which directs daily packages, food deliveries, and delivery personnel to a secure location separate from the building lobby.

Area Amenities

Several high-end restaurants, including Sparks Steak House, Capital Grille, Cipriani Dolci, Osteria Laguna, and Sushi Yasuda

A number of hotels, including The Alex Hotel, The UN Plaza Hotel, Waldorf Astoria, and Grand Hyatt

A variety of other destinations, including the United Nations, Grand Central Marketplace and the Ford Foundation

Transportation:
Subways: 4, 5, 6, 7, E, S
Grand Central Terminal

Corporate Neighbors: Pfizer, Mitsubishi International Corporation, TIAA-CREF, Neuberger & Berman, Avon

ENERGY STAR

The Durst Organization

Durst.org
One Bryant Park
New York, NY 10036

212.257.6600
info@durst.org

675 Third Avenue Utility Summary

Conditioned Area: 279,159 sf (~80% occupied)

Total Energy Use			
Steam	12,873,348	kBTU/yr	(12,326 Mlb)
Electricity	11,909,739	kBTU/yr	(3,490,400 kWh)
Peak Demand	844.8	kW	
	24,783,087	kBTU/yr	
Energy Utilization Index			
Steam	46.11	kBTU/sf/yr	
Electricity	42.66	kBTU/sf/yr	(12.44 kWh/sf/yr)
All Energy	88.78	kBTU/sf/yr	

Total Water Use		
Basic Water & Sewer	10,385,640	gallons
Water Towers	2,987,981	gallons
Steam Condensate	5,412,773	gallons
Stormwater on Site	555,845	gallons

	Electricity					
Billing Date	Peak Demand (kW)	Average kWh/Day	Total kWh	Electric Generation charges	Electric Transmission Charges	Total Electric Charge
June '12	729.6	9,561	277,280	$ 36,494.42	$ 26,091.48	$ 62,585.90
May '12	720.0	9,163	274,880	$ 21,552.53	$ 22,477.80	$ 44,030.33
April '12	678.4	8,501	263,520	$ 23,161.26	$ 14,141.16	$ 37,302.42
March '12	652.8	9,153	265,440	$ 22,393.37	$ 13,892.53	$ 36,285.90
February '12	588.8	8,800	264,000	$ 20,337.24	$ 14,543.21	$ 34,880.45
January '12	588.8	8,572	282,880	$ 22,162.09	$ 19,750.62	$ 41,912.71
December '11	614.4	8,623	250,080	$ 19,306.05	$ 15,425.67	$ 34,731.72
November '11	665.6	8,701	295,840	$ 23,347.50	$ 20,363.45	$ 43,710.95
October '11	729.6	9,517	276,000	$ 18,888.28	$ 25,591.92	$ 44,480.20
September '11	806.4	10,693	320,800	$ 39,676.31	$ 31,680.57	$ 71,356.88
August '11	844.8	11,479	355,840	$ 43,282.36	$ 37,998.36	$ 81,280.72
July '11	819.2	12,128	363,840	$ 39,844.46	$ 45,464.54	$ 85,309.00
Annual Total	summer: 844.8 winter: 588.8	9,574 kWh/Day	3,490,400 kWh (11,909,739 kBTU)	$ 330,445.87	$ 287,421.31	$ 617,867.18

Billing Date	Days in Cycle	Cooling Degree Days	Heating Degree Days	Total Steam Charge	Total Steam Use (Mlb)	Average Daily Steam Use (Mlb)
	Steam					
July '12	32	487	0	$ 27,731.06	1,789	55.90
June '12	30	265	18	$ 17,653.22	1,132	37.73
May '12	32	54	212	$ 15,574.29	744	23.24
April '12	29	28	330	$ 29,296.00	781	26.92
March '12	29	15	459	$ 47,898.08	1,009	34.81
February '12	30	0	726	$ 17,586.30	387	12.92
January '12	33	0	908	$ 88,702.66	1,976	59.88
December '11	33	5	596	$ 67,738.15	1,282	38.84
November '11	29	2	411	$ 31,048.03	680	23.45
October '11	29	153	96	N/A	N/A	N/A
September '11	30	291	24	$ 16,482.66	928	30.92
August '11	32	506	0	$ 27,695.39	1,619	50.60
Annual Total	336	1319	3780	$ 359,674.78	1,788.67	33.93
Estimated 365 Day Total	365	1319	3780	$ 387,260.46	1,925.86	33.93
					(1,868,079 kBTU)	

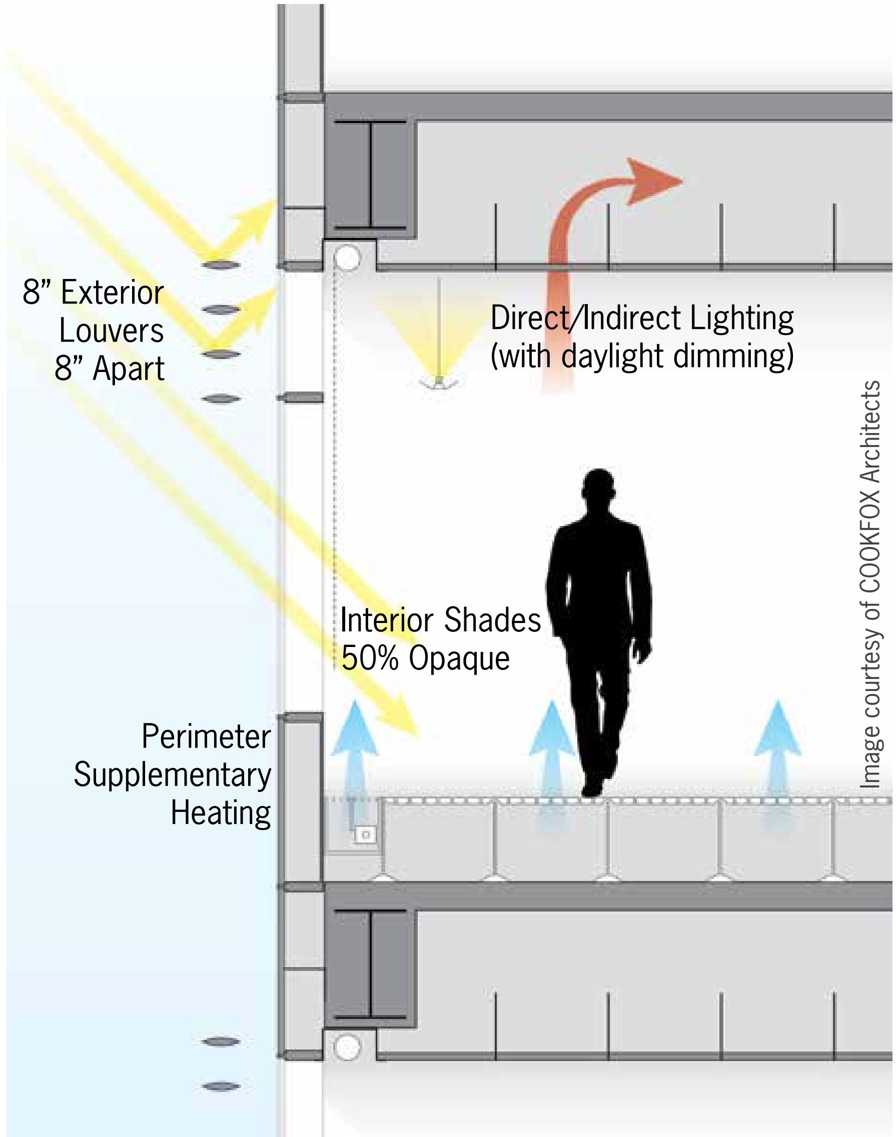
Billing Date	Daily Average Use (gal)	Average daily water charge	Average daily sewer charge	Daily Average Use (gal)	Daily Average Sewer (gal)
	Water				
	Basic Water and Sewer			**Cooling Tower**	**Steam Condensate**
June '12	35,906.50	$ 152.16	$ 241.93	10,099	N/A
May '12	N/A	N/A	N/A	N/A	N/A
April '12	19,217.04	$ 81.44	$ 129.48	2,859	N/A
March '12	15,684.16	$ 66.46	$ 105.68	1,770	N/A
February '12	16,924.03	$ 71.72	$ 114.03	1,445	N/A
January '12	16,527.55	$ 70.04	$ 111.36	1,188	N/A
December '11	N/A	N/A	N/A	N/A	11,328
November '11	22,132.02	$ 93.79	$ 149.12	2,837	11,328
October '11	28,236.15	$ 119.66	$ 190.25	7,505	11,328
September '11	34,221.27	$ 145.02	$ 230.58	12,037	18,331
August '11	49,584.44	$ 210.12	$ 334.10	21,800	18,331
July '11	46,104.94	$ 188.99	$ 300.50	20,322	18,331
Annual Daily Average	28,453.81	$ 119.94	$ 190.70	8,186	14,830
Estimated Annual Total	10,385,640 gal	$ 43,777.86	$ 69,606.79	2,987,981	5,412,773

APPENDIX C: ENERGY MODEL RESULTS - SUMMARY

		Building	Modelled Area (sf)	Peak Electric (kW)
Existing 15 FAR Building	Existing	Existing Building, Modelled	279,159	-
		Existing Building, by Utility Data	279,159	844.8
		Existing Building at Full Occupancy, Class A	279,159	-
		Existing Building w/ Pilkington Glazing Upgrade	279,159	-
		Existing Building w/ Electric Chiller	279,159	-
Replacement 21.6 FAR Building	Ideal	21.6 FAR Tower, UFAD, 18" sill	401,979	1728
	Peak Control Options	21.6 FAR Tower, UFAD, 18" sill + 100 MBTU Ice Storage	401,979	1139
		21.6 FAR Tower, UFAD, 18" sill + 580 kW Cogen	401,979	1159
		21.6 FAR Tower, UFAD, 18" sill + 100 MBTU Ice Storage + 385 kW Cogen	401,979	1161
		21.6 FAR Tower, UFAD, 30" sill	401,979	1721
		21.6 FAR Tower, Passive Chilled Beam, 18" sill	401,979	1593
		21.6 FAR Tower, Passive Chilled Beam, 30" sill	401,979	1565
		21.6 FAR Tower, VAV PPG SB72XL (Double Paned), 18" sill	401,979	2061
		21.6 FAR Tower, VAV VNE 13-63 (Triple Paned), 18" sill	401,979	2037
		21.6 FAR Tower, VAV VNE 13-63 (Triple Paned), 30" sill	401,979	2001
		21.6 FAR Tower, VAV VNE 13-63 (Triple Paned), 18" sill, No Daylight Dimming	401,979	2140
		21.6 FAR Tower, Active Chilled Beam, 18" sill	401,979	1658
		21.6 FAR Tower, Active Chilled Beam, 30" sill	401,979	1626
		21.6 FAR Tower, at 90.1 ASHRAE baseline	401,979	2154
24 FAR Tower		24 FAR Tower, based on Ideal 21.6 Tower	455,110	-
		24 FAR Tower, based on Ideal 21.6 Tower, with Ice Storage	455,110	-
		24 FAR Tower, based on Ideal 21.6 Tower, with Cogen	455,110	-
		24 FAR Tower, based on Ideal 21.6 Tower, with Cogen + Ice Storage	455,110	-

Source Energy Use				Site Energy Usage				
Electricity (MBtu)	Gas / Steam (MBtu)	Total (MBtu)	Source EUI (kBTU/sf)	Electricity (MWh)	Electricity (MBtu)	Gas / Steam (MBtu)	Total (MBtu)	Site EUI (kBTU/sf)
38,246	20,292	58,538	209.69	3,356	11,451	16,770	28,221	101.09
39,777	15,577	55,354	198.29	3,490	11,909	12,873	24,783	88.78
46,119	22,409	68,528	245.48	4,047	13,808	18,520	32,328	115.81
30,675	22,724	53,399	191.28	2,692	9,184	18,780	27,964	100.17
41,139	4,329	45,467	162.87	3,610	12,317	3,578	15,894	56.94
53,926	1,545	55,472	138.00	4,732	16,146	1,476	17,622	43.84
54,177	1,545	55,722	138.62	4,754	16,221	1,476	17,697	44.02
24,404	26,196	50,600	125.88	4,791	16,347	25,020	41,367	102.91
27,529	24,762	52,291	130.08	4,933	16,831	23,650	40,481	100.71
53,801	1,466	55,267	137.49	4,721	16,108	1,400	17,508	43.55
54,496	1,257	55,754	138.70	4,782	16,316	1,201	17,517	43.58
53,938	1,183	55,121	137.12	4,733	16,149	1,130	17,279	42.98
56,787	1,522	58,309	145.05	4,983	17,002	1,454	18,456	45.91
56,365	1,246	57,611	143.32	4,946	16,876	1,190	18,066	44.94
55,921	1,193	57,113	142.08	4,907	16,743	1,139	17,882	44.48
58,747	1,146	59,893	149.00	5,155	17,589	1,095	18,684	46.48
56,468	1,212	57,680	143.49	4,955	16,906	1,158	18,064	44.94
55,818	1,129	56,947	141.67	4,898	16,712	1,078	17,790	44.26
82,371	2,204	84,575	210.40	7,228	24,662	2,105	26,767	66.59
59,155	1,759	60,914	133.84	5,191	17,711	1,680	19,391	42.61
-	-	-	-	5,282	18,024	1,593	19,617	43.10
-	-	-	-	5,255	17,930	29,130	47,060	103.40
-	-	-	-	5,387	18,381	15,250	33,631	73.90

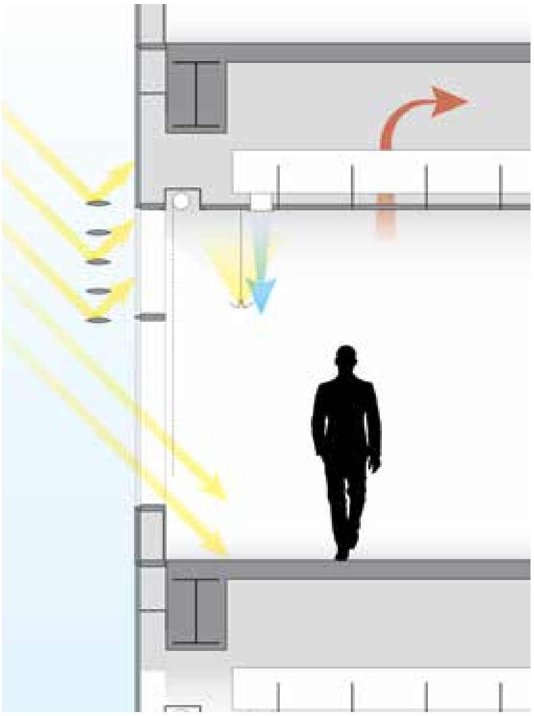
DESIGN FEATURES OF IDEAL 21.6 FAR BUILDING (UNDERFLOOR AIR DISTRIBUTION)



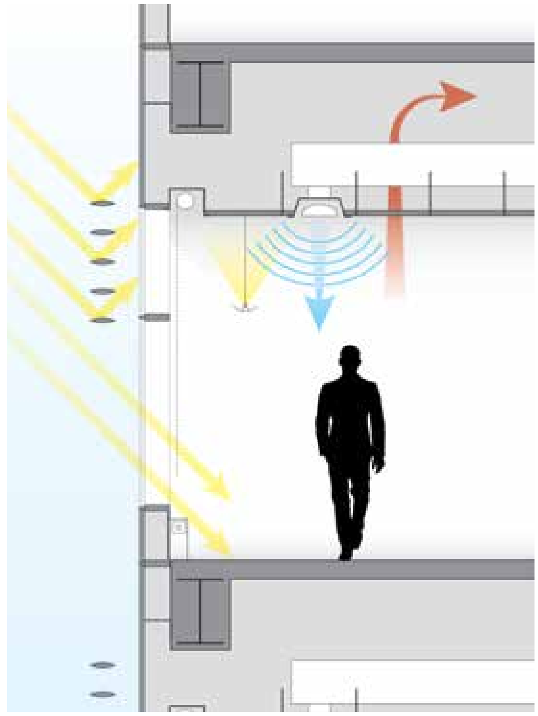
14'0" Floor to Floor
1'6" Raised Floor
Sill 1'6" A.F.F.
Vision Glass Sill to Ceiling
9'6" Clear Ceiling

CONCEPTUAL ILLUSTRATIONS OF HVAC SYSTEMS

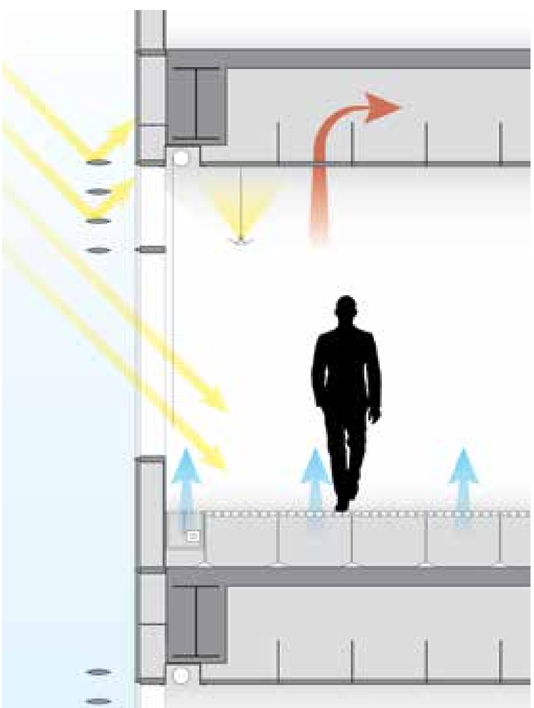
All images courtesy of COOKFOX Architects



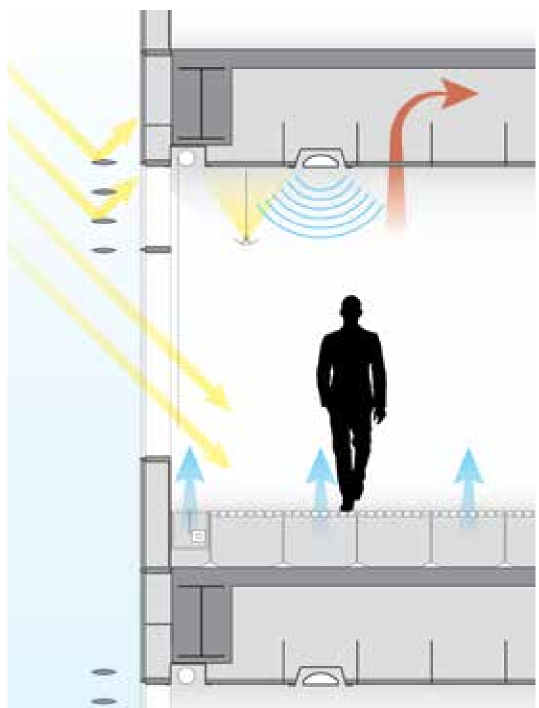
ADVANCED VAV



ACTIVE CHILLED BEAM

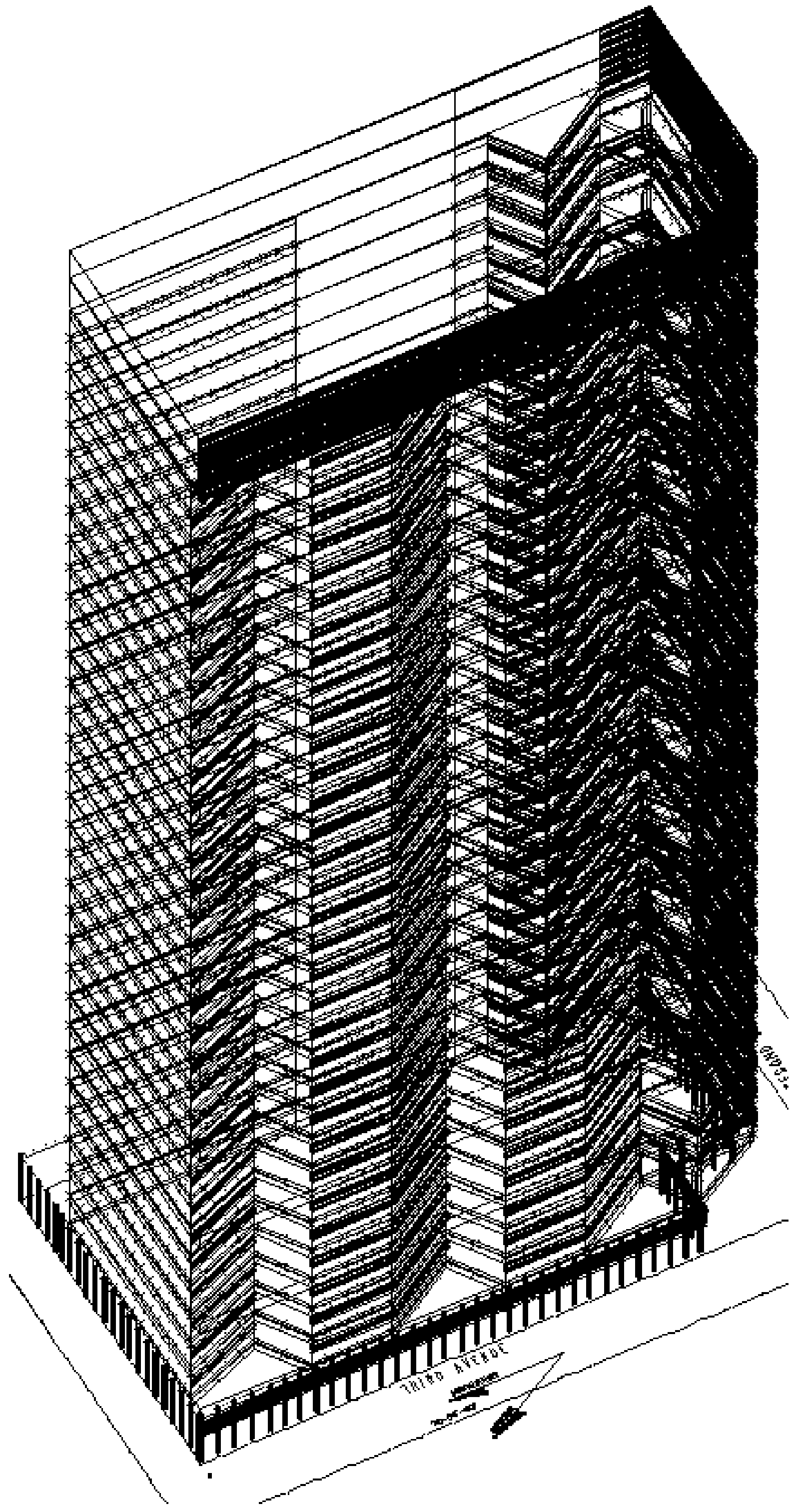


UNDERFLOOR AIR



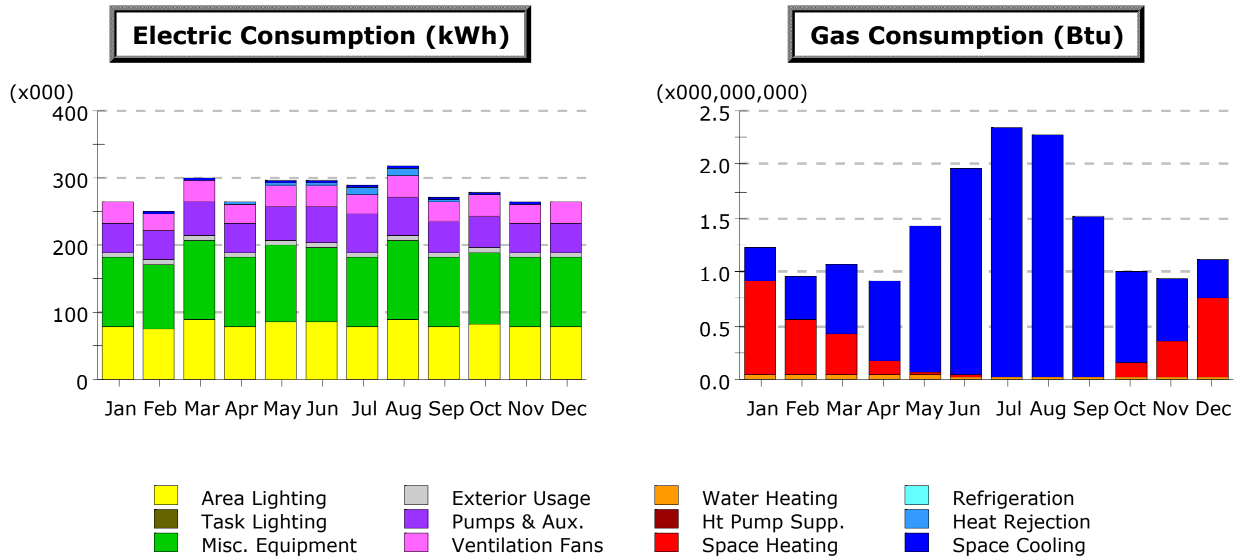
UNDERFLOOR AIR WITH PASSIVE CHILLED BEAM

WIREFRAME ILLUSTRATION OF
21.6 FAR REPLACEMENT BUILDING



APPENDIX E: ENERGY MODEL RESULTS - EXISTING BUILDING

Project/Run: Midtown-Modelv9-Base - Baseline Design | Run Date/Time: 10/04/12 @ 14:52



Electric Consumption (kWh x000)

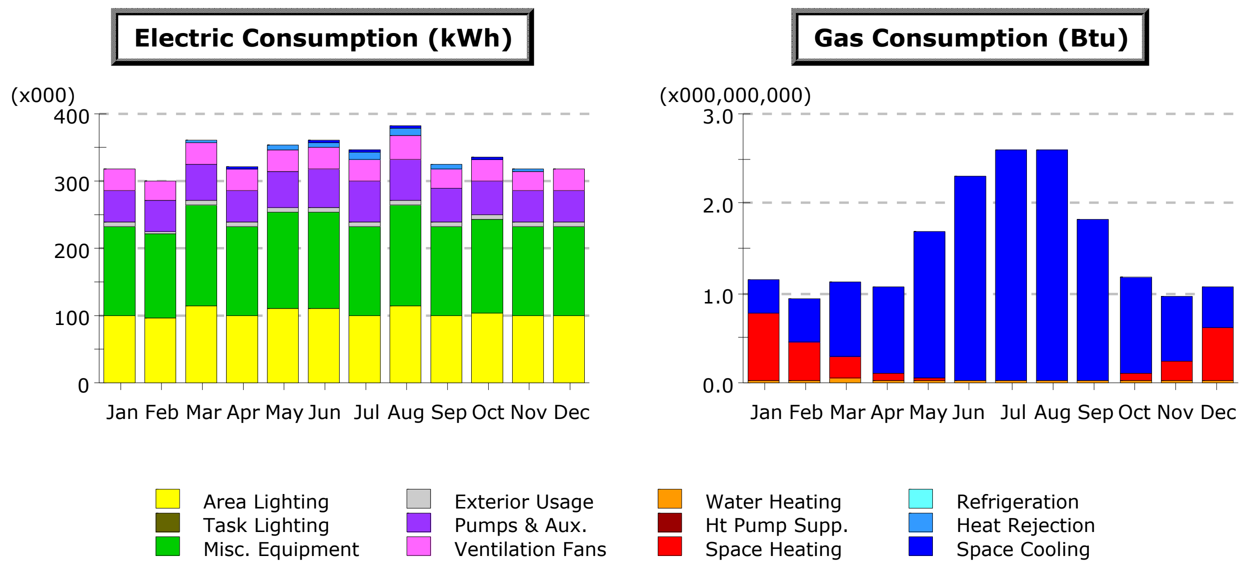
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	2.2	2.1	2.6	2.2	2.7	2.8	3.6	3.5	2.4	2.3	2.2	2.2	30.9
Heat Reject.	0.0	0.1	0.6	1.0	4.1	5.0	10.6	8.6	4.1	1.5	0.5	0.0	36.1
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	29.5	28.0	33.9	29.5	32.4	32.4	29.5	33.9	29.5	30.9	29.5	29.5	368.3
Pumps & Aux.	44.9	41.9	49.5	44.7	50.3	51.3	56.2	57.4	46.5	46.7	44.6	44.9	578.9
Ext. Usage	6.4	6.1	7.3	6.4	7.0	7.0	6.4	7.3	6.4	6.7	6.4	6.4	79.6
Misc. Equip.	103.4	97.5	116.7	103.0	112.3	111.7	103.5	116.7	102.9	107.9	102.9	103.4	1,281.9
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	78.6	74.5	89.9	78.5	86.2	86.1	78.6	89.9	78.5	82.4	78.5	78.6	980.4
Total	265.0	250.3	300.5	265.3	294.9	296.3	288.4	317.4	270.1	278.5	264.4	265.0	3,356.1

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.32	0.39	0.65	0.73	1.34	1.94	2.31	2.24	1.49	0.84	0.57	0.35	13.19
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.88	0.54	0.38	0.15	0.04	0.00	0.00	0.00	0.01	0.13	0.33	0.73	3.19
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.03	0.03	0.04	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.38
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	1.24	0.96	1.07	0.92	1.42	1.97	2.34	2.27	1.53	1.00	0.93	1.12	16.77

eQUEST 3.64.7130 | Monthly Energy Consumption by Enduse | Page 1

Project/Run: Midtown-Modelv9-Base - Baseline Design   Run Date/Time: 10/04/12 @ 15:05



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	2.3	2.2	2.7	2.4	2.9	3.3	4.1	4.0	2.7	2.5	2.3	2.3	33.8
Heat Reject.	0.0	0.2	0.8	1.4	4.9	5.8	12.1	10.0	4.8	2.0	0.7	0.1	42.8
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	30.7	29.2	35.3	30.7	33.8	33.8	30.7	35.3	30.7	32.3	30.7	30.7	384.2
Pumps & Aux.	47.1	44.1	52.1	47.6	53.4	56.7	61.1	62.4	50.2	49.2	46.8	47.2	618.0
Ext. Usage	6.4	6.1	7.3	6.4	7.0	7.0	6.4	7.3	6.4	6.7	6.4	6.4	79.6
Misc. Equip.	132.0	124.5	149.0	131.5	143.4	142.7	132.1	149.0	131.3	137.8	131.3	132.0	1,636.7
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	100.4	95.2	114.8	100.3	110.0	109.9	100.4	114.8	100.2	105.2	100.2	100.4	1,251.8
Total	319.0	301.5	362.1	320.3	355.3	359.2	347.0	382.8	326.4	335.6	318.6	319.1	4,046.9

Gas Consumption (Btu x000,000,000)

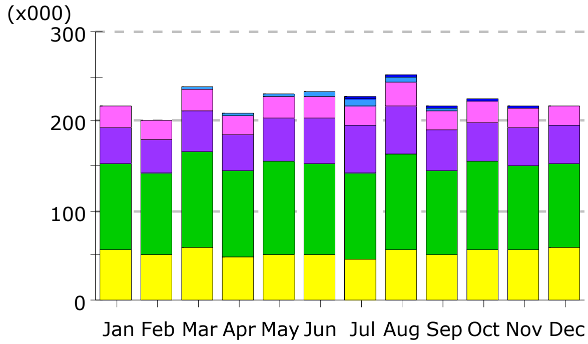
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.39	0.49	0.83	0.94	1.65	2.26	2.58	2.57	1.79	1.07	0.72	0.45	15.75
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.74	0.41	0.26	0.09	0.02	0.00	0.00	0.00	0.00	0.07	0.22	0.59	2.39
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.03	0.03	0.04	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.38
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	1.16	0.94	1.13	1.06	1.70	2.29	2.61	2.60	1.82	1.17	0.97	1.07	18.52

eQUEST 3.64.7130   Monthly Energy Consumption by Enduse   Page 1

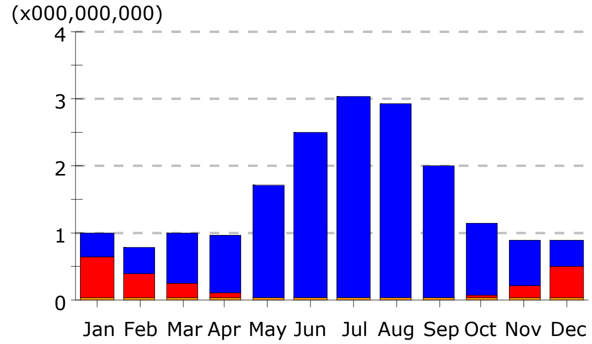
EXISTING BUILDING - WITH PILKINGTON GLAZING

Project/Run: Midtown-Modelv12-Existing Building with Pilkington Solar E - Baseline Design   Run Date/Time: 10/03/12 @ 10:38

Electric Consumption (kWh)



Gas Consumption (Btu)



Area Lighting | Exterior Usage | Water Heating | Refrigeration
Task Lighting | Pumps & Aux. | Ht Pump Supp. | Heat Rejection
Misc. Equipment | Ventilation Fans | Space Heating | Space Cooling

Electric Consumption (kWh x000)

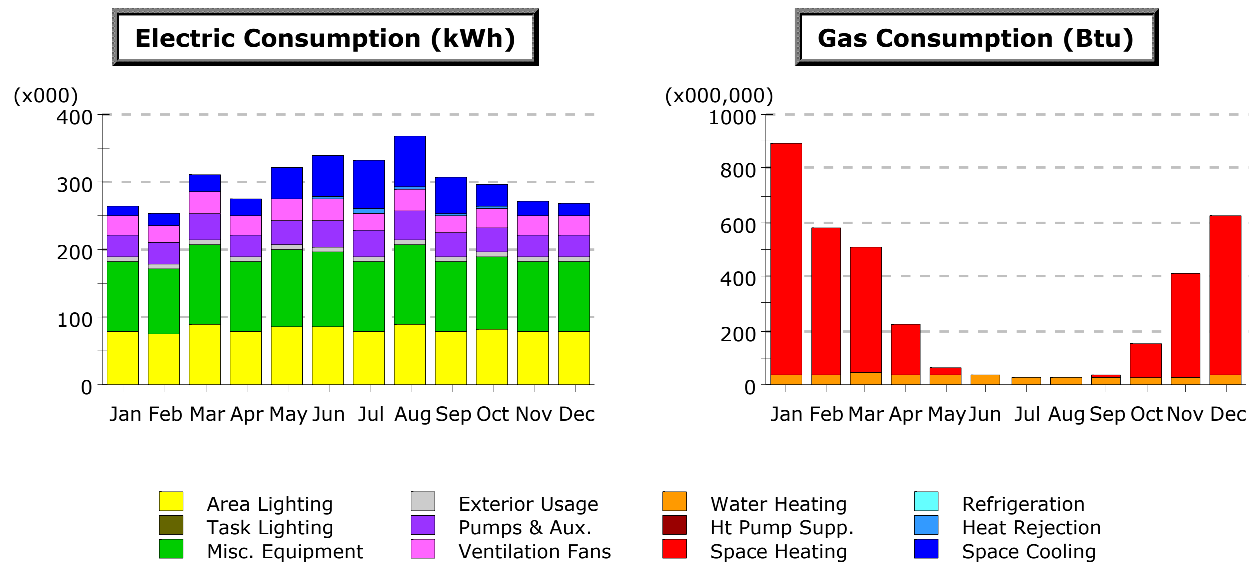
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	1.6	1.5	1.8	1.6	1.9	2.1	2.7	2.7	1.7	1.6	1.6	1.6	22.2
Heat Reject.	0.0	0.1	0.5	0.9	3.3	4.9	8.3	7.3	4.0	1.5	0.4	0.0	31.3
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	21.8	20.7	25.1	21.8	24.0	24.0	21.8	25.1	21.8	22.9	21.8	21.8	272.5
Pumps & Aux.	41.4	38.8	45.8	41.6	46.9	49.0	53.4	55.3	44.3	43.5	41.3	41.4	542.7
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	95.7	90.1	107.7	95.2	103.7	103.1	95.7	107.7	95.1	99.7	95.1	95.7	1,184.4
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	56.9	51.0	58.4	49.0	51.8	50.8	46.8	54.9	50.2	55.2	55.6	57.8	638.5
Total	217.4	202.1	239.3	210.0	231.6	233.9	228.6	253.0	217.1	224.5	215.9	218.3	2,691.7

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.34	0.42	0.73	0.84	1.66	2.45	2.99	2.89	1.97	1.06	0.66	0.37	16.39
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.61	0.35	0.22	0.08	0.02	0.00	0.00	0.00	0.00	0.06	0.19	0.48	2.01
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.03	0.03	0.04	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.38
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	0.99	0.80	1.00	0.96	1.71	2.48	3.02	2.92	2.00	1.14	0.88	0.88	18.78

eQUEST 3.64.7130   Monthly Energy Consumption by Enduse   Page 1

Project/Run: Midtown-Modelv9-Base-electric chillers - Baseline Design   Run Date/Time: 09/20/12 @ 02:05



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	13.8	17.3	25.1	26.0	45.2	63.1	73.4	75.8	53.9	32.7	22.6	18.7	467.8
Heat Reject.	0.0	0.0	0.1	0.2	1.4	2.7	4.4	3.8	2.6	0.7	0.1	0.1	16.1
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	27.7	26.3	31.8	27.7	30.4	30.4	27.7	31.8	27.7	29.0	27.7	27.7	345.7
Pumps & Aux.	34.6	32.4	38.3	34.2	37.7	39.1	39.2	42.2	36.1	35.9	34.2	34.5	438.3
Ext. Usage	6.4	6.1	7.3	6.4	7.0	7.0	6.4	7.3	6.4	6.7	6.4	6.4	79.6
Misc. Equip.	103.4	97.5	116.7	103.0	112.3	111.7	103.5	116.7	102.9	107.9	102.9	103.4	1,281.9
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	78.6	74.5	89.9	78.5	86.2	86.1	78.6	89.9	78.5	82.4	78.5	78.6	980.4
Total	264.5	254.2	309.4	275.9	320.2	340.2	333.0	367.6	308.0	295.3	272.3	269.3	3,609.9

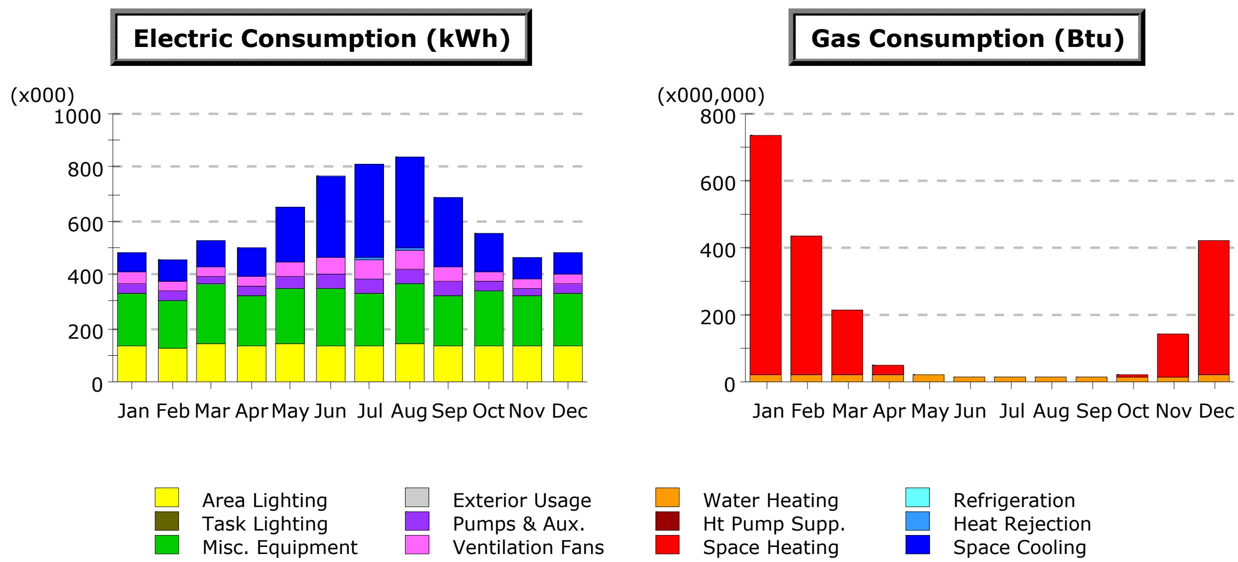
Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	859.0	550.0	464.9	186.9	23.1	-	-	-	8.4	124.1	377.4	597.1	3,190.9
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	34.4	33.7	40.6	35.0	35.5	32.5	27.8	30.0	26.3	28.8	29.7	32.2	386.6
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	893.4	583.8	505.5	221.9	58.5	32.5	27.8	30.0	34.7	152.9	407.1	629.3	3,577.5

eQUEST 3.64.7130   Monthly Energy Consumption by Enduse   Page 1

21.6 FAR BUILDING - BUILT TO CODE

Project/Run: FAR 21.6 90.1 Baseline v4 - Baseline Design Run Date/Time: 11/27/12 @ 21:04



Electric Consumption (kWh x000)

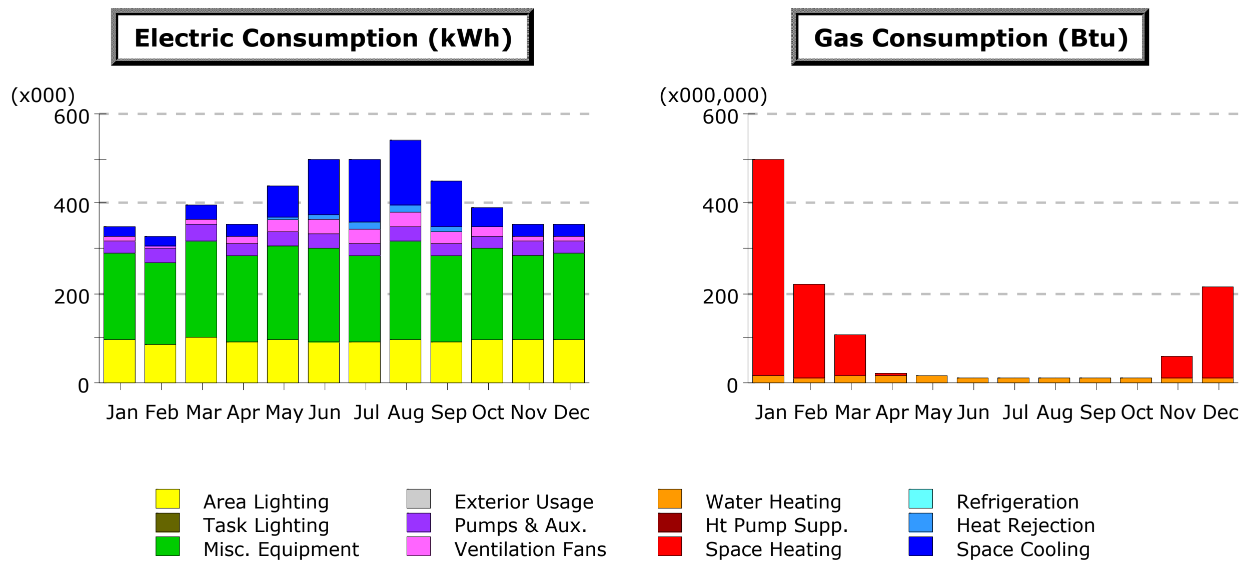
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	73.6	76.3	96.2	108.7	206.4	295.9	348.1	341.7	257.8	140.9	86.0	82.5	2,114.2
Heat Reject.	-	-	0.0	0.0	1.2	2.9	4.9	4.4	2.8	0.3	0.0	0.0	16.5
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	42.5	36.5	38.3	37.9	53.1	66.0	71.9	70.3	55.8	41.9	32.9	38.8	586.0
Pumps & Aux.	43.4	36.6	31.7	29.1	40.6	52.2	61.1	59.5	47.6	32.3	26.2	35.9	496.0
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	193.3	182.4	218.3	192.6	210.0	208.9	193.5	218.3	192.3	201.8	192.3	193.3	2,397.0
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	133.0	123.5	143.8	131.0	140.2	138.3	133.0	143.8	131.0	136.6	131.0	133.0	1,618.2
Total	485.8	455.3	528.3	499.4	651.4	764.2	812.6	838.0	687.3	553.8	468.4	483.5	7,227.9

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	715.0	417.0	189.0	28.1	-	-	-	-	-	9.0	127.7	406.5	1,892.3
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	19.8	19.2	22.7	19.5	19.3	17.3	14.7	15.6	13.9	15.6	16.4	18.2	212.2
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	734.8	436.2	211.6	47.6	19.3	17.3	14.7	15.6	13.9	24.6	144.2	424.7	2,104.6

21.6 FAR BUILDING - WITH VAV, VIRACON TRIPLE-GLAZING

Project/Run: VAV v6 14 ft f-f - 1 | Run Date/Time: 11/28/12 @ 11:19



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	23.1	21.8	28.2	24.6	71.2	123.2	137.7	144.4	105.0	39.3	24.2	23.1	765.8
Heat Reject.	0.0	-	0.1	0.1	5.0	11.2	14.9	15.3	10.0	1.3	0.1	-	58.0
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.4	0.2	0.1	0.0	-	-	-	-	-	0.0	0.1	0.3	1.2
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	9.1	9.1	14.1	16.2	26.7	30.9	30.3	30.6	24.3	19.6	11.5	10.1	232.4
Pumps & Aux.	29.2	27.7	33.6	29.2	32.1	32.1	29.2	33.6	29.2	30.6	29.2	29.2	364.7
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	193.3	182.4	218.3	192.6	210.0	208.9	193.5	218.3	192.3	201.8	192.3	193.3	2,397.0
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	95.7	87.5	100.1	90.2	95.2	93.2	90.1	97.9	90.8	96.2	93.8	96.1	1,126.9
Total	350.9	328.8	394.5	352.8	440.1	499.5	495.7	540.0	451.6	388.9	351.1	352.0	4,945.9

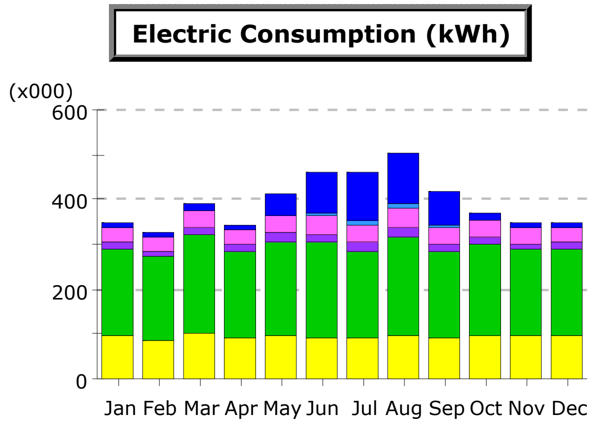
Gas Consumption (Btu x000,000)

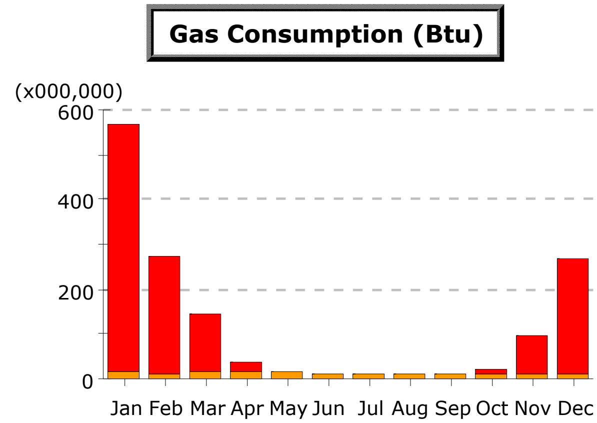
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	486.9	204.3	90.7	6.3	-	-	-	-	-	1.2	49.1	199.2	1,037.8
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	13.6	13.3	16.0	13.8	14.0	12.9	11.0	11.8	10.3	11.3	11.7	12.7	152.5
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	500.5	217.7	106.8	20.1	14.0	12.9	11.0	11.8	10.3	12.5	60.8	211.9	1,190.3

eQUEST 3.64.7130 | Monthly Energy Consumption by Enduse | Page 1

21.6 FAR BUILDING - WITH UFAD, VIRACON TRIPLE-GLAZING

Project/Run: UFAD v10 - 1.5 | Run Date/Time: 11/27/12 @ 21:40





Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	10.7	10.1	13.3	11.6	45.2	87.0	105.9	108.3	73.7	17.9	10.7	10.7	505.2
Heat Reject.	0.0	-	0.1	0.1	3.5	7.8	10.3	10.6	6.9	0.7	-	-	39.9
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.8	0.5	0.3	0.1	-	-	-	-	0.0	0.0	0.2	0.5	2.4
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	33.7	32.1	38.9	33.9	38.3	41.4	42.3	44.0	36.6	35.8	33.8	33.8	444.7
Pumps & Aux.	14.3	13.6	16.5	14.3	17.0	18.6	17.5	19.8	16.4	15.2	14.3	14.3	191.8
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	195.3	184.2	220.4	194.6	212.0	211.0	195.5	220.4	194.2	203.8	194.2	195.3	2,420.9
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	95.7	87.5	100.1	90.2	95.2	93.2	90.1	97.9	90.8	96.2	93.8	96.1	1,126.9
Total	350.6	328.0	389.6	344.8	411.2	459.0	461.6	501.1	418.6	369.8	347.0	350.6	4,731.9

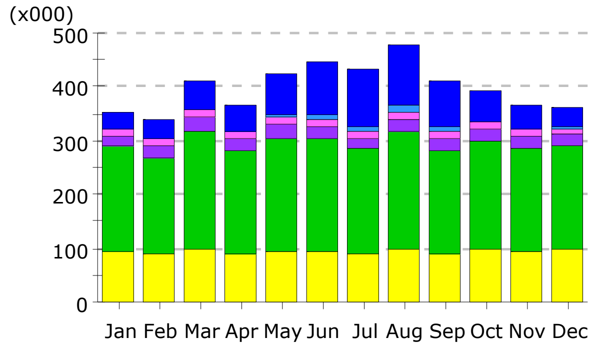
Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	554.4	261.5	127.9	23.8	-	-	-	-	0.8	12.0	85.7	257.6	1,323.8
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	13.6	13.3	16.0	13.8	14.0	12.9	11.0	11.8	10.4	11.3	11.7	12.7	152.5
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	568.0	274.8	143.9	37.7	14.0	12.9	11.0	11.8	11.2	23.3	97.4	270.3	1,476.3

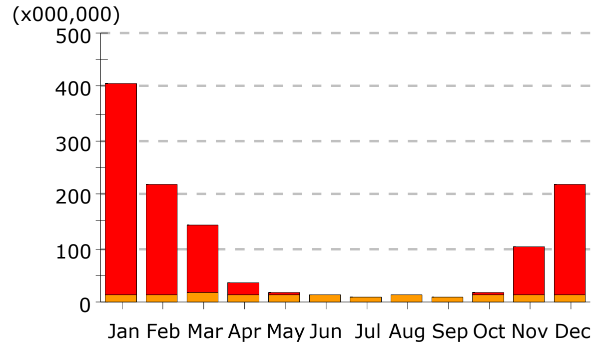
21.6 FAR BUILDING - WITH PASSIVE CHILLED BEAM

Project/Run: Passive chilled beam v5 14' floor-floor - 1.5 Run Date/Time: 11/28/12 @ 10:52

Electric Consumption (kWh)



Gas Consumption (Btu)



Area Lighting
Task Lighting
Misc. Equipment
Exterior Usage
Pumps & Aux.
Ventilation Fans
Water Heating
Ht Pump Supp.
Space Heating
Refrigeration
Heat Rejection
Space Cooling

Electric Consumption (kWh x000)

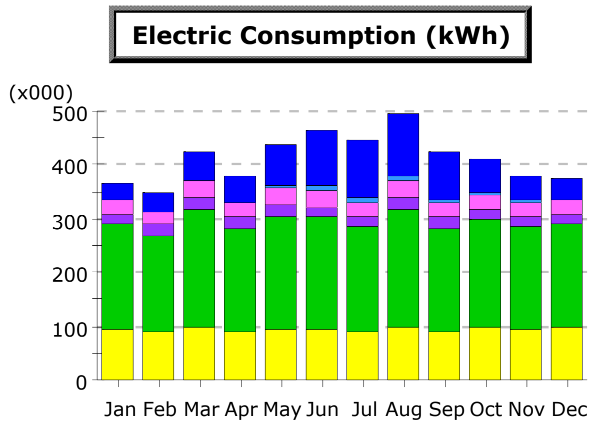
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	28.0	34.8	51.2	50.4	76.0	97.4	104.7	112.6	85.7	58.9	46.2	39.3	785.2
Heat Reject.	0.1	0.4	0.9	1.4	5.6	9.0	10.9	11.6	8.1	2.9	1.0	0.5	52.5
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.7	0.5	0.3	0.1	0.0	-	-	-	-	0.0	0.3	0.5	2.4
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	12.3	11.7	14.1	12.3	13.5	13.5	12.3	14.1	12.3	12.9	12.3	12.3	153.8
Pumps & Aux.	21.1	20.1	24.3	21.1	23.2	23.2	21.1	24.3	21.1	22.2	21.1	21.1	263.8
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	193.3	182.4	218.3	192.6	210.0	208.9	193.5	218.3	192.3	201.8	192.3	193.3	2,397.0
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	95.7	87.5	100.1	90.2	95.2	93.2	90.1	97.9	90.8	96.2	93.8	96.1	1,126.9
Total	351.3	337.3	409.3	368.2	423.5	445.3	432.6	478.8	410.4	394.9	366.9	363.2	4,781.5

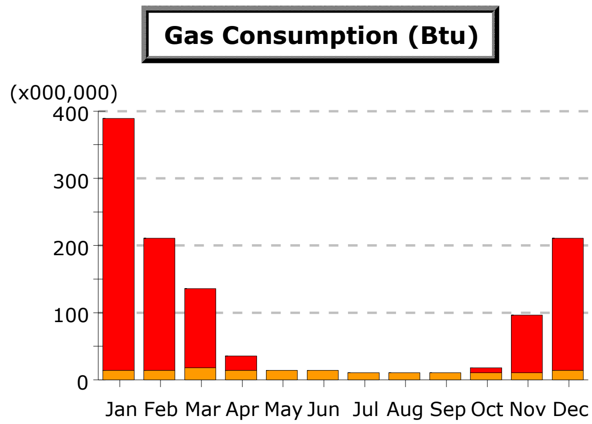
Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	392.4	203.1	125.1	24.1	1.7	-	-	-	-	7.9	89.1	204.3	1,047.8
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	13.7	13.4	16.1	13.9	14.0	12.9	10.9	11.8	10.3	11.3	11.7	12.8	152.9
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	406.1	216.5	141.2	37.9	15.8	12.9	10.9	11.8	10.3	19.3	100.8	217.1	1,200.7

21.6 FAR BUILDING - WITH ACTIVE CHILLED BEAM

Project/Run: Chilled beam v5 14 ft f-f - 1.5 Run Date/Time: 11/28/12 @ 12:08





Area Lighting
Task Lighting
Misc. Equipment
Exterior Usage
Pumps & Aux.
Ventilation Fans
Water Heating
Ht Pump Supp.
Space Heating
Refrigeration
Heat Rejection
Space Cooling

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	29.0	35.1	51.6	51.0	78.0	100.6	107.9	116.2	88.6	60.4	46.4	39.7	804.7
Heat Reject.	0.1	0.3	0.9	1.4	5.7	9.3	11.2	11.9	8.4	3.0	1.0	0.5	53.8
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.7	0.5	0.3	0.1	0.0	-	-	-	-	0.0	0.3	0.5	2.3
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	26.1	24.8	30.0	26.1	28.7	28.7	26.1	30.0	26.1	27.4	26.1	26.1	326.5
Pumps & Aux.	19.4	18.4	22.3	19.4	21.3	21.3	19.4	22.3	19.4	20.3	19.4	19.4	242.2
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	193.3	182.4	218.3	192.6	210.0	208.9	193.5	218.3	192.3	201.8	192.3	193.3	2,397.0
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	95.9	87.6	100.2	90.3	95.3	93.3	90.2	98.0	90.9	96.3	93.9	96.2	1,128.1
Total	364.5	349.1	423.7	380.9	439.1	462.2	448.3	496.7	425.7	409.2	379.4	375.7	4,954.5

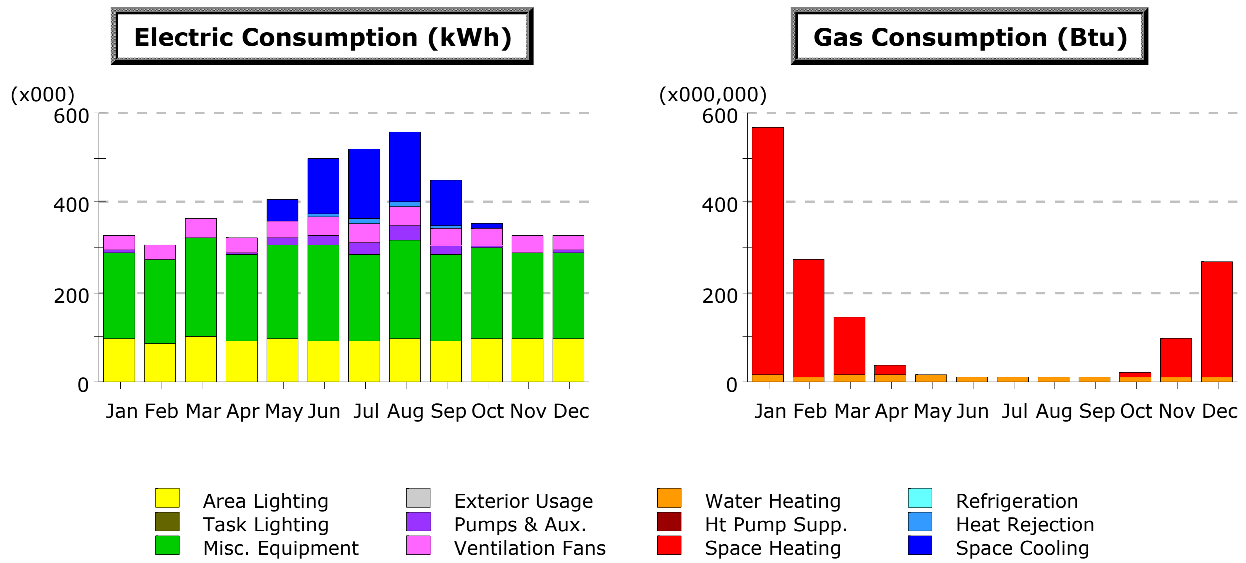
Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	375.0	195.9	120.6	22.8	1.0	-	-	-	-	7.0	86.2	196.7	1,005.1
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	13.7	13.4	16.1	13.9	14.0	12.9	10.9	11.8	10.3	11.3	11.7	12.8	152.9
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	388.7	209.3	136.7	36.7	15.0	12.9	10.9	11.8	10.3	18.3	97.9	209.4	1,158.0

eQUEST 3.64.7130 Monthly Energy Consumption by Enduse Page 1

21.6 FAR OPTIMAL BUILDING - WITH THERMAL STORAGE

Project/Run: UFAD full size TES v5 - Baseline Design | Run Date/Time: 11/28/12 @ 12:46



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	1.0	0.2	45.4	119.9	152.7	153.7	99.3	10.0	-	-	582.1
Heat Reject.	0.1	-	0.1	0.1	3.7	8.6	11.9	12.5	7.6	0.6	-	-	45.2
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.8	0.5	0.3	0.1	-	-	-	-	0.0	0.0	0.2	0.5	2.4
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	33.7	32.1	38.9	33.9	38.3	41.4	42.3	44.0	36.6	35.8	33.8	33.8	444.7
Pumps & Aux.	2.9	2.5	3.2	2.9	12.1	23.3	27.0	28.6	19.6	4.5	2.6	2.6	131.9
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	195.3	184.2	220.4	194.6	212.0	211.0	195.5	220.4	194.2	203.8	194.2	195.3	2,420.9
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	95.7	87.5	100.1	90.2	95.2	93.2	90.1	97.9	90.8	96.2	93.8	96.1	1,126.9
Total	328.6	306.8	364.1	321.9	406.8	497.5	519.5	557.1	448.0	351.0	324.6	328.2	4,754.0

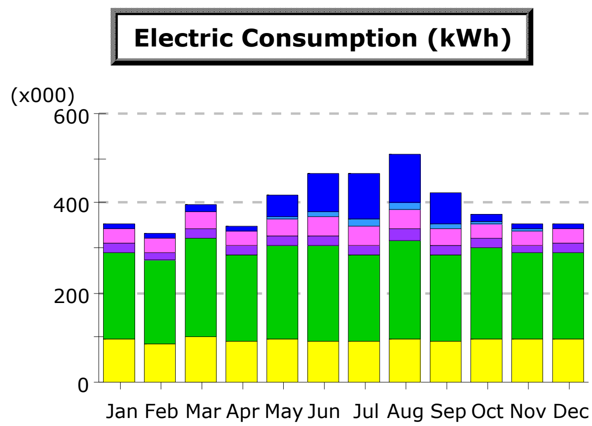
Gas Consumption (Btu x000,000)

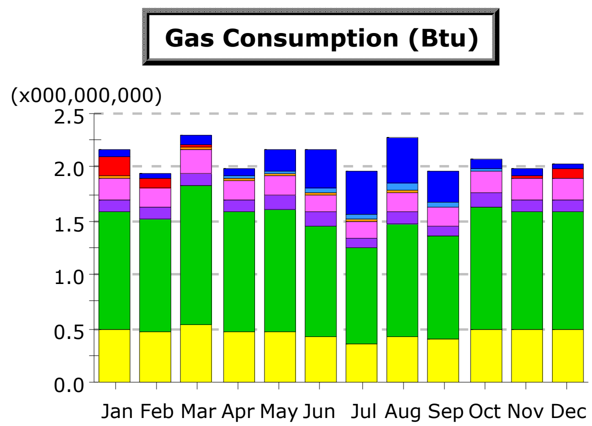
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	554.4	261.5	127.9	23.8	-	-	-	-	0.8	12.0	85.7	257.6	1,323.8
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	13.6	13.3	16.0	13.8	14.0	12.9	11.0	11.8	10.4	11.3	11.7	12.7	152.5
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	568.0	274.8	143.9	37.7	14.0	12.9	11.0	11.8	11.2	23.3	97.4	270.3	1,476.3

eQUEST 3.64.7130 | Monthly Energy Consumption by Enduse | Page 1

21.6 FAR OPTIMAL BUILDING - WITH COGENERATION

Project/Run: UFAD + cogen v2 - Baseline Design — Run Date/Time: 11/28/12 @ 12:58





Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	10.8	10.2	13.5	11.8	45.4	87.0	105.4	108.0	73.7	18.2	10.9	10.8	505.6
Heat Reject.	0.1	0.1	0.4	0.7	5.2	10.0	13.1	13.8	9.2	1.8	0.5	0.2	55.1
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.3	0.1	0.1	0.0	-	-	-	-	0.0	0.0	0.1	0.1	0.7
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	33.7	32.1	38.9	33.9	38.3	41.4	42.3	44.0	36.6	35.8	33.8	33.8	444.7
Pumps & Aux.	17.7	16.9	20.7	18.1	21.1	22.7	21.3	24.1	20.1	19.1	18.0	17.8	237.6
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	195.3	184.2	220.4	194.6	212.0	211.0	195.5	220.4	194.2	203.8	194.2	195.3	2,420.9
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	95.7	87.5	100.1	90.2	95.2	93.2	90.1	97.9	90.8	96.2	93.8	96.1	1,126.9
Total	353.5	331.2	394.1	349.3	417.2	465.4	467.7	508.2	424.7	375.0	351.2	354.0	4,791.4

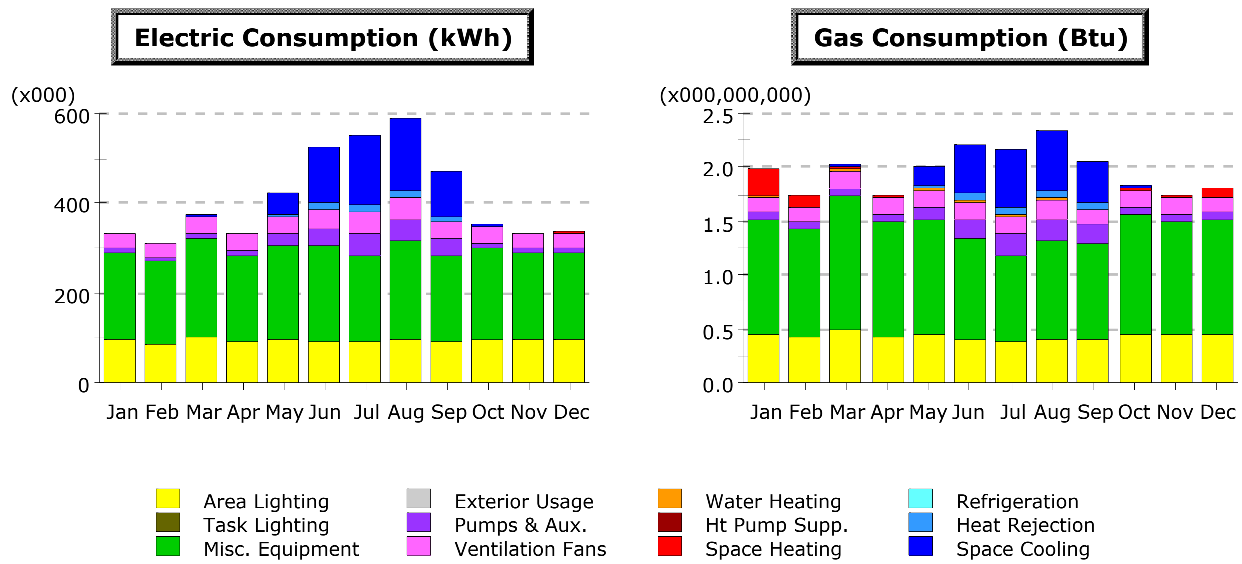
Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.06	0.06	0.08	0.07	0.20	0.35	0.40	0.43	0.30	0.09	0.06	0.06	2.16
Heat Reject.	0.00	0.00	0.00	0.00	0.02	0.05	0.06	0.07	0.04	0.01	0.00	0.00	0.26
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.19	0.07	0.03	0.01	-	-	-	-	0.00	0.01	0.02	0.07	0.40
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.15
Vent. Fans	0.19	0.18	0.22	0.19	0.19	0.18	0.16	0.18	0.16	0.20	0.19	0.19	2.23
Pumps & Aux.	0.11	0.11	0.13	0.11	0.12	0.11	0.10	0.12	0.10	0.12	0.11	0.11	1.36
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	1.10	1.05	1.27	1.11	1.14	1.03	0.88	1.04	0.95	1.14	1.10	1.10	12.92
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.49	0.46	0.55	0.47	0.47	0.43	0.36	0.43	0.41	0.50	0.49	0.49	5.54
Total	2.16	1.95	2.29	1.98	2.16	2.16	1.97	2.27	1.97	2.07	1.99	2.04	25.02

eQUEST 3.64.7130 — Monthly Energy Consumption by Enduse — Page 1

21.6 FAR OPTIMAL BUILDING - WITH COGENERATION & THERMAL STORAGE

Project/Run: UFAD + cogen + TES v2 - Baseline Design | Run Date/Time: 11/28/12 @ 13:06



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	1.0	0.2	46.8	126.5	155.8	157.6	103.2	6.0	-	-	597.0
Heat Reject.	0.1	-	0.1	0.1	4.7	11.7	17.1	16.7	11.1	0.8	-	-	62.5
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.4	0.2	0.1	0.0	-	-	-	-	0.0	0.0	0.1	0.2	0.9
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	33.7	32.1	38.9	33.9	38.7	43.0	47.5	48.6	37.8	35.9	33.8	33.8	457.7
Pumps & Aux.	8.3	8.9	12.1	11.3	23.6	40.6	46.5	46.0	36.2	12.6	10.7	9.7	266.6
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	195.3	184.2	220.4	194.6	212.0	211.0	195.5	220.4	194.2	203.8	194.2	195.3	2,420.9
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	95.7	87.5	100.1	90.2	95.2	93.2	90.1	97.9	90.8	96.2	93.8	96.1	1,126.9
Total	333.5	312.9	372.7	330.3	421.0	526.0	552.4	587.3	473.4	355.4	332.6	335.0	4,932.5

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	0.00	0.00	0.18	0.47	0.53	0.56	0.38	0.02	-	-	2.13
Heat Reject.	0.00	-	0.00	0.00	0.02	0.06	0.08	0.08	0.05	0.00	-	-	0.30
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.26	0.09	0.03	0.01	-	-	-	-	0.00	0.01	0.02	0.09	0.52
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.15
Vent. Fans	0.14	0.13	0.16	0.14	0.15	0.16	0.16	0.17	0.14	0.14	0.14	0.14	1.77
Pumps & Aux.	0.06	0.06	0.08	0.07	0.12	0.19	0.21	0.21	0.18	0.07	0.07	0.06	1.37
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	1.08	1.02	1.24	1.08	1.08	0.92	0.80	0.91	0.88	1.12	1.07	1.07	12.27
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.45	0.41	0.49	0.42	0.44	0.41	0.38	0.41	0.40	0.45	0.44	0.44	5.15
Total	1.99	1.73	2.02	1.73	2.01	2.22	2.16	2.35	2.05	1.82	1.75	1.82	23.65

eQUEST 3.64.7130 | Monthly Energy Consumption by Enduse | Page 1

APPENDIX F: 24 FAR BUILDING

For modeling purposes, an extrusion of the 21.6 FAR scheme was developed, simply adding additional floors to reach an FAR of 24. This is essentially the same building as the 21.6 FAR building, but with more floor area, and a slightly different lighting and mechanical schedule. The 24 FAR building would have a slightly greater Green Area Ratio, owing to inclusion of at least one more level of green space.

EUI calculations

24 FAR Load Reduction Options

UFAD, Triple glazing, 0.8 W/SF light, 18" sill							24 FAR, UFAD
Electric	5,190,800	kWh	Site/Source Factor				
	17,711,010	kBTU		3.34	59,154,772	kBTU	
Heat	1,680,300	kBTU		1.05	1,759,274	kBTU	
	19,391,310	kBTU			60,914,046	kBTU	
Site EUI	48.3		Source EUI		151.8		

UFAD, Triple glazing, 0.8 W/SF light, 18" sill							24 FAR, UFAD + Cogen
Electric	5,254,900	kWh	Site/Source Factor				
	17,929,719	kBTU		3.34	59,885,261	kBTU	
Heat	29,130,000	kBTU		1.05	30,499,110	kBTU	
	47,059,719	kBTU			90,384,371	kBTU	
Site EUI	117.3		Source EUI		225.2		

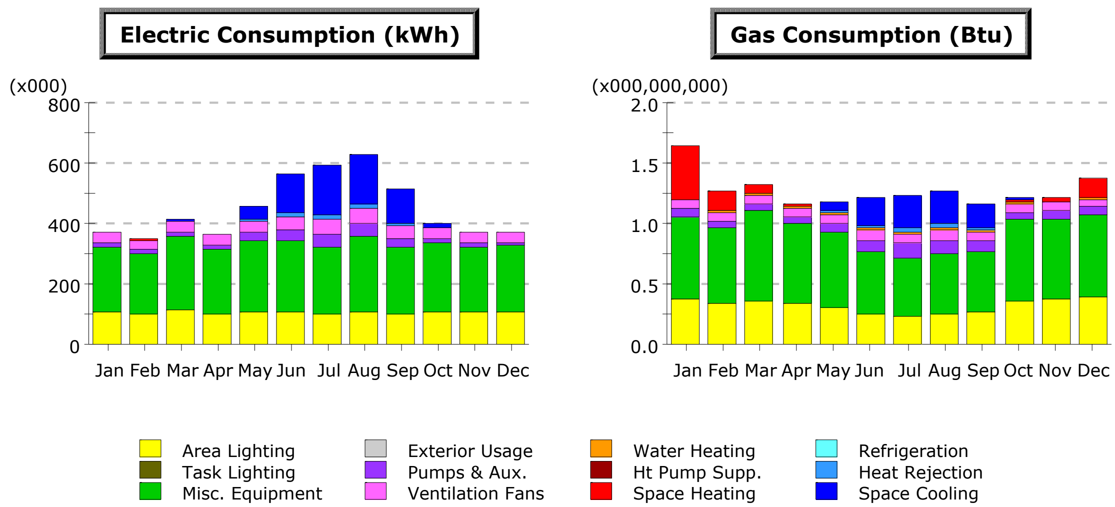
UFAD, Triple glazing, 0.8 W/SF light, 18" sill							24 FAR, UFAD + thermal storage
Electric	5,282,400	kWh	Site/Source Factor				
	17,929,719	kBTU		3.34	59,885,261	kBTU	
Heat	1,593,100	kBTU		1.05	1,667,976	kBTU	
	19,522,819	kBTU			61,553,236	kBTU	
Site EUI	49.1		Source EUI		154.4		

UFAD, Triple glazing, 0.8 W/SF light, 18" sill							24 FAR, UFAD + cogen + thermal storage
Electric	5,387,300	kWh	Site/Source Factor				
	18,381,468	kBTU		3.34	61,394,102	kBTU	
Heat	15,250,000	kBTU		1.05	15,966,750	kBTU	
	33,631,468	kBTU			77,360,852	kBTU	
Site EUI	83.8		Source EUI		192.8		

24 FAR BUILDING - WITH COGENERATION

For modeling purposes, an extrusion of the 21.6 FAR scheme was developed, simply adding additional floors to reach an FAR of 24. This is essentially the same building as the 21.6 FAR building, but with more floor area, and a slightly different lighting and mechanical schedule. The 24 FAR building would have a slightly greater Green Area Ratio, owing to inclusion of at least one more level of green space.

Project/Run: FAR 24 UFAD + cogen + TES - Baseline Design   Run Date/Time: 10/30/12 @ 13:58



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	1.1	0.2	45.6	129.1	160.8	160.9	107.3	11.4	-	-	616.4
Heat Reject.	0.1	-	0.1	-	4.6	10.9	15.8	15.0	10.5	0.8	-	-	57.8
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.6	0.3	0.1	0.0	0.0	-	-	-	0.0	0.0	0.1	0.3	1.4
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	33.7	32.1	38.9	34.0	39.6	46.1	51.5	53.2	39.6	36.0	33.8	33.8	472.4
Pumps & Aux.	11.4	10.8	13.8	13.8	25.6	38.7	44.6	43.7	35.3	16.8	13.5	12.1	280.1
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	217.9	205.6	246.0	217.1	236.7	235.5	218.1	246.0	216.7	227.5	216.7	217.9	2,701.8
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	106.9	97.7	111.7	100.6	106.3	104.0	100.5	109.2	101.3	107.3	104.7	107.3	1,257.5
Total	370.6	346.5	411.8	365.8	458.4	564.3	591.4	628.0	510.8	399.7	368.9	371.3	5,387.3

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	0.00	0.00	0.08	0.23	0.27	0.28	0.19	0.02	-	-	1.07
Heat Reject.	0.00	-	0.00	-	0.01	0.03	0.04	0.03	0.02	0.00	-	-	0.14
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.43	0.16	0.06	0.02	0.00	-	-	-	0.00	0.01	0.04	0.16	0.88
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.15
Vent. Fans	0.07	0.06	0.08	0.07	0.08	0.08	0.08	0.09	0.07	0.07	0.07	0.07	0.87
Pumps & Aux.	0.06	0.06	0.06	0.06	0.08	0.09	0.12	0.10	0.09	0.07	0.07	0.07	0.93
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.68	0.63	0.74	0.66	0.63	0.52	0.47	0.51	0.51	0.67	0.67	0.68	7.37
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.38	0.34	0.36	0.34	0.30	0.25	0.24	0.25	0.26	0.36	0.37	0.39	3.83
Total	1.64	1.26	1.32	1.16	1.19	1.21	1.24	1.27	1.16	1.21	1.22	1.37	15.25

eQUEST 3.64.7130   Monthly Energy Consumption by Enduse   Page 1

APPENDIX G: EMBODIED ENERGY CALCULATIONS

Early studies

Embodied Energy is the term for the total amount of energy expended in mining and harvesting raw materials, transportation, processing and manufacturing, delivery to the jobsite, construction and erection energy, and removal of waste materials at the end of construction – to produce a completed structure. This represents an investment in resource use that has a definite life cycle for the structure's intended use, as well as potential adaptive reuse after its initially conceived function is no longer satisfactory or required.

A 1979 study authored by architect Richard G Stein of New York, and Dr. Bruce Hannon of the Illinois Center for Computational Studies[i] is commonly cited as the definitive North American source for Embodied Energy (EE) data. This data was recompiled and illustrated in "Handbook of Energy Use for Building Construction" published by the US Department of Energy in 1981.[ii] New Energy from Old Buildings, published by the National Trust for Historic Preservation, in 1981 contains a compilation of embodied energy calculations by building type that extracts data from the Stein-Hannon study.[iii] The embodied energy for offices in this book is indicated as being 1,642 MBTU per square foot.

This number was not calculated by adding up the energy content of each material in the building and then multiplying times the amount of each material. Instead Stein took the total direct and indirect energy flows in the office building construction sector and divided by total number of square feet of office space built in that year.[iv]

Recent Studies

Since the 1979 study there has been scant American research into embodied energy. However, the European Union and other British Commonwealth economies have continued their investigations, resulting in useful and more recent data, notably the Inventory of Carbon and Energy (ICE) published by the University of Bath.[v]

Comparing the Stein data with that contained in ICE, which is culled from international sources, we see the EE for rolled structural steel sections varying from 25,000 BTU/lb (Stein et al) to 12,500 BTU/lb (ICE). Carl Stein, son of Richard Stein and one of the authors of the 1981 publication, has clarified the methods and trends in construction noting inefficiencies in American steel production in the 1960s and improvements over the decades in production, notably in the significant increase in recycled steel content.

The enactment of laws requiring tracking of embodied carbon and carbon emissions by the UK have spurred the collection of new data by which to evaluate Embodied Energy in office structures. One early adopter of tracking is Skanska, an international construction and consulting firm.

In one study, undertaken by Skanska US, a mid-rise office building at 733 10th Street NW, Washington DC was evaluated, indicating a total Embodied Energy value of approximately 228,500 Btu/sf.[vi]

SKANSKA EMBODIED ENERGY ESTIMATES FOR NEW CONSTRUCTION*			
Energy Contribution	**tonnes CO_2**	**Energy (GJ)**	**Energy (BTU)**
Electric	13	132.65	
Personnel Travel	507	5,173.47	
Demolition	118	1,203.08	
Waste Removal	13	132.62	
Brick	35	357.14	
Curtainwall	232	2,367.35	
Concrete	3,964	40,448.97	
Metals	995	10,153.06	
Material Deliveries	26	265.31	
Other	369	3,765.31	
Finishes	32	326.53	
Fuel	2	20.41	
Total Embodied Energy:	**6,306**	**64,346.93**	**60,989,120,954**
Embodied Energy (per gross square foot at 266,896 gsf)			**228,513**

**Assumption: 1.00 GJ = 0.098 tonnes CO_2*

An example of a Japanese study cited by the 1996 Canadian report by Cole and Kiernan[vii] indicated an EE value of approximately 927,200 BTU/sf. While this more closely resembles the Stein data, especially when taking into consideration improvements in industrial efficiency, it is significantly at variance with the Skanska data, which may be result of the scope Skanska's accounting methodology.

31-STORY, STEEL SUPERSTRUCTURE OFFICE BUILDING IN JAPAN		
Energy Contribution	**Energy (GJ/m^2)**	**Energy (BTU/sf)**
Structural Embodied Energy	3.60	
Non-structural Embodied Energy	6.93	
Total Embodied Energy:	**10.53**	**927,221**

Limitations of available data and tools

There are real limitations with existing available data. While the Athena EcoCalculator[viii] appears to be definitive, an examination of its choices of materials types, for example including only open-web steel joists as a steel option for office building construction, reveals its limitations and unsuitability for the purposes of this study. Using the EcoCalculator™ for the candidate building, 675 Third Avenue (which is exactly contemporaneous with the data supporting the Stein reports).

EcoCalculator provided an assessment nearly one-third of the Stein figures per square foot.

ECOCALCULATOR RESULTS		
Energy Contribution	**Energy (GJ)**	**Energy (BTU)**
Columns & Beams	11,861	
Intermediate Floors	21,482	
Exterior Walls	28,388	
Windows	29,837	
Foundations	24,535	
Interior Walls (no option for typical commercial partitions)	0	
Roof	1,509	
Total Embodied Energy:	**117,610**	**111,473,082,066**
Embodied Energy (per gross square foot at 293,117 gsf)		**380,302**

What is clear in most of these examples is that the underlying source data are obscure, the assumptions not clearly stated, and the methods of accounting not explained. With the exception of the Stein reports of 1979 and 1981 and the Skanska analysis of 2012, very little can be known that would confirm or refute the validity of the resulting data.

Thus, as data appear to vary significantly among sources, it seems reasonable to conclude that arguments in favor of preservation based on embodied energy are limited in their usefulness, as approximate benchmarks against which operating energy over the lifecycle of a structure might be evaluated.

At this point the best strategy for thinking about embodied energy is to use a range of between the Stein data (particularly for older buildings) and the Japanese data for newer buildings. This would make sense in that a number of things have changed in the last 30+ years. Several trends play into this thinking Architectural steel, and other metals are now largely fabricated from recycled metals. Industrial processes have become much more energy efficient. Office buildings have become more complex, with more parts, but in a typical building the materials still only account for around 15% of the total volume, the rest is air.

Recycling, down-cycling and salvaging of materials

In the case of the candidate building, nearly all materials comprising the structure have a recycling or down-cycling value. For example, all the door hardware in place has significant remaining useful life and can be re-used for new or renovation construction if carefully salvaged and distributed for reuse in lesser-value marketplaces.

All the window glass can be salvaged and is suitable for conversion to Possotive concrete additive;[x] the aluminum column covers can be returned to the production cycle as reclaimed content; the concrete in slabs and cast-in-place structural steel fireproofing can be crushed and reused as aggregate in new construction of buildings and roadways; the steel structural elements will be returned to the production cycle of new steel products; all copper wiring and duct sheet metal, similarly, will find uses as recycled content in the production of new construction materials.

Deconstruction

As the trend away from destructive demolition towards salvage deconstruction of buildings develops accurate data will be available; presently there is no data on the energy or financial cost of deconstruction. Only two examples of deconstruction or demolition of high-rise structures (the 2001 attacks on the World Trade Center notwithstanding) arise from recent history: the slow deconstruction of the Deutsche Bank Building, on Barclay Street in Lower Manhattan, and the demolition of the 1908 Singer Building replaced by One Liberty Plaza (formerly the US Steel Building). To date, the 612-foot tall Singer Building is the tallest structure ever intentionally demolished.[x] Its removal, however, apparently did not include any salvage or reclamation operations. The Deutsche Bank Building is of the type and vintage of the buildings in this study. Its deconstruction is a problematic model for good practice, as an number of mistakes occurred during its removal, and the resulting as yet unresolved litigation has made the salvage/recycling data unavailable.

In any scenario, however, it should be noted that for a building of the era being considered for replacement the following hazardous materials are likely to be encountered and will require removal to authorized waste storage facilities: asbestos-containing materials, such as coatings, filler panels, and possibly floor tiles; poly chlorinated biphenols, found in lighting ballasts and transformers; lead, found in paint. For these materials the energy cost of removal will be primarily in their transportation away from the building site.

Embodied Energy of Deconstruction

STEIN-HANNON DATA (1979) - 1,642 KBTU/SF*			
Labor Contribution to EE	**Labor EE (kBTU)**	**Material Proportion**	**Net Material EE**
Labor costs (Low Estimate - 55%)	903.1	738.9	591.12
Labor costs (High Estimate - 60%)	985.2	656.8	525.44

**Assumption: 80% of material is recycled*

Let us suppose that the labor required to deconstruct is equivalent to that required to construct:

Therefore: the EE owing to labor to deconstruct has a range between 903.1 and 985.2 kBTU/sf

However, the recycled and/or reclaimed material energy ranges between 591.12 and 525.44 kBTU/sf

So the net EE to deconstruct is the labor EE minus the recycled content EE, or a range between 311.98 and 459.76 kBTU/sf

The average of values for the Stein-Hannon data is a deconstruction energy cost of **385.87 kBTU/sf.**

Therefore, the deconstruction energy cost of the existing building would be 293,117 sf x 385.9 Deconstruction EE kBTU/sf, or:

113,113,900 Total net kBTU deconstruction energy demand

JAPANESE DATA (1996) - 927.2 KBTU/SF*			
Labor Contribution to EE	**Labor EE (kBTU)**	**Material Proportion**	**Net Material EE**
Labor costs (Low Estimate - 55%)	509.96	417.24	333.79
Labor costs (High Estimate - 60%)	556.32	370.88	296.70

**Assumption: 80% of material is recycled*

Therefore, the EE owing to labor to deconstruct has a range between 509.96 and 556.32 kBTU/sf

However, the recycled and/or reclaimed material energy ranges between 333.79 and 296.70 kBTU/sf

So the net EE to deconstruct is the labor EE minus the recycled content EE, or a range between 176.168 and 259.616 kBTU/sf

The average of values for the Japanese data is a deconstruction energy cost of **217.892 kBTU/sf.**

Therefore, the deconstruction energy cost of the existing building would be 293,117 sf x 217.9 Deconstruction EE kBTU/sf, or:

63,870,194 Total net kBTU deconstruction energy cost.

ENDNOTES

[i] Assessing the energy conservation benefits of historic preservation: Methods and Examples Advisory Council on Historic Preservation, 1979 Online at: http://www.achp.gov/1979%20-%20Energy%20Conserv%20and%20Hist%20Pres.pdf. Prepared in support of Section 106 of the National Historic Preservation Act and Title I of the Public Buildings Cooperative Use Act.

[ii] R.G. Stein, C. Stein, M. Buckley and M. Green, *Handbook of Energy Use for Building Construction*, The Stein Partnership, New York, NY, 1981 prepared under contract to the U.S. Department of Energy – DOE /CE / 20220-1

[iii] *New Energy from Old Buildings*, National Trust for Historic Preservation, Washington DC, 1981, ISBN-13:9780891330950

[iv] In emails between Carl Stein and the authors, 30 August 2012, Mr Stein notes: "The Handbook contains both aggregated and disaggregated data. These are clearly described in the introduction. The information on energy use per square foot of building type is national average information that was derived from (a) the Leontief – BEA Input/Output (I/O) matrix of the US economy with Bruce Hannon's energy intensity factors that convert dollar flow-through to energy flow-through plus the addition of raw energy resource input and final end-use output; (b) the expansion of the Construction Industry sectors from four – in the 99 sector breakdown, to 32 sectors – in the 399 sector breakdown (Chapter 2); (c) the identification and quantification of all non-construction sectors in the 399 sector breakdown that contribute more than 0.1 percent to any of the 32 Construction sectors. This was then presented in several different formats (Chapters 3 and 4). As is noted in the introduction, all of these figures are averages, taken across the entire U. S. economy; however, at last look, this is still the most comprehensive overview of energy embodied by the construction industries. None of the information for embodied energy per square foot of building type is based on actual take-offs.

"For example, the figure of 1,667,111 Btu/Sf for office buildings is derived by taking the total direct and indirect energy that flows into that sector and dividing it by the square feet of construction of that type completed in the reference year. It is a national average. As is noted in Handbook, there will be considerable variation within this or any sector; however, from a policy setting point of view, it provides a handle on the impact of committing to certain types of construction. It also provides a baseline to compare against individual buildings for which detailed energy take-offs are performed.

"I would also note here that these figures are based on 1967 Bureau of Economic Analysis (BEA) figures. While the methodology as well as a number of the specifics remains valid, other specifics have changed considerably due to technology and manufacturing changes. For example, when the analysis was done, relatively little aluminum was recycled. Virgin aluminum is a very energy intensive material; however, recycling has significantly reduced the embodied energy in aluminum used in construction – as an average. When we did the work, these were the most current figures available as it takes a number of years for the BEA to compile and organize data. Computing should have significantly reduced the effort required to organize the relevant data; however, it is my understanding that staff devoted to this work has been dramatically cut.

"The energy use per unit of building material (Chapter 6) is based on creating a new set of product-specific factors that allow converting the dollar cost figures for building materials and systems into energy cost. These were organized into CSI format to facilitate an embodied energy cost estimate to be prepared in the same way as a dollar cost estimate. Chapter 7, "Energy in Typical Building Assemblies" has a few typical case studies that show how the information in Chapter 6 could be applied. Note that these are for isolated building assemblies, not complete buildings.

"Chapter 8 presents some simple cost/benefit studies comparing energy payback against the added energy to achieve savings. Chapters 9 and 10 deal with tools to assist policy decision-making. Chapter 11 uses labor intensity factors to create units of embodied labor in building material and systems.

"The methodology is described in Appendix A. The actual energy intensity factors, which are the basis for the conversion of dollar cost into energy cost, are all listed in Appendix B.

"It's also true that as of 1967, at least, the U. S. steel industry was notoriously outdated and energy-inefficient. This was true both for the initial smelting process, where both Swedish and Japanese systems operated with far less fuel per ton, and in plant integration where hot steel ingots go directly to the rolling facilities rather than having to be reheated. There is also the saving in transportation energy with integrated plants."

[v] G. P. Hammond, and C. I. Jones, *Inventory of Carbon & Energy (ICE), Version 1.6a*, Sustainable Energy Research Team, Department of Mechanical Engineering, University of Bath, Bath UK, 2008.

[vi] CO_2 Calculations as a basis for Embodied Energy supplied by Skanska USA.

[vii] T. Oka, M. Suzuki and T. Konnya, "The estimation of energy consumption and amounts of pollutants due mto the construction of buildings," Energy and Buildings 19, pp. 303-311 (1993) cited by Raymond J. Cole and Paul C. Kernan in "Lifecycle Energy Use in Office Buildings," *Building and Environment*, Vol. 31, No. 4, pp. 307-317, Elsevier Science Ltd., 1996.

[viii] Athena Sustainable Materials Institute "EcoCalculator" – Excel™ spreadsheet tool, downloadable at http://calculatelca.com/software/ecocalculator/

[ix] Pozzotive™ is a finely ground glass powder used as a replacement for Portland cement in high-strength concrete, similar to the use of fly ash. Presently manufactured by Kingston Block and Masonry Supply LLC, located in Kingston, NY, the product uses discarded glass – primarily green and brown bottles – "harvested" from the New York City refuse stream. Kingston Block uses Pozzotive in concrete masonry units and provides the additive for use in cast-in-place structural concrete.

[x] Christopher Gray, "Once the Tallest Building, but 1967 a Ghost," New York Times, January 2, 2005. http://travel.nytimes.com/2005/01/02/realestate/02scap.html?_r=0\

APPENDIX H: NATIONAL AVERAGE ENERGY USE INTENSITY BY VINTAGE

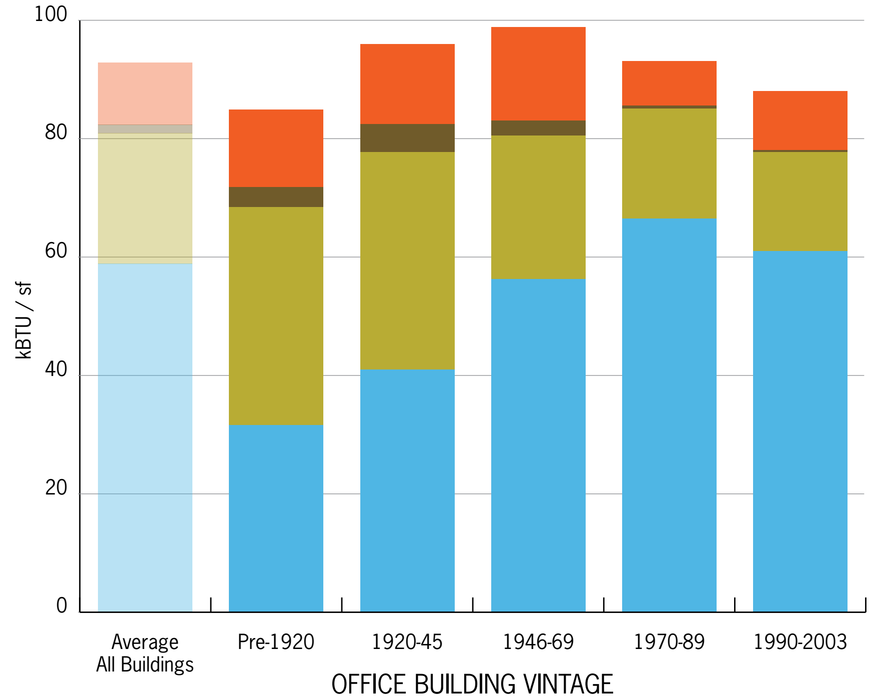
The following data is from the Department of Energy's Commercial Buildings Energy Consumption Survey (CBECS) 2003. The data was extracted from the Buildings Energy Data Book tool, available at: buildingsdatabook.eren.doe.gov/. This website was accessed Oct. 4, 2012, and was filtered by "Office" and the appropriate years.

NATIONAL AVERAGE EUI BY BUILDING VINTAGE

SITE ENERGY

- Other
- Fuel Oil
- Natural Gas
- Electricity

Data Collected from U.S. Department of Energy Commercial Buildings Energy Consumption Survey (2003)

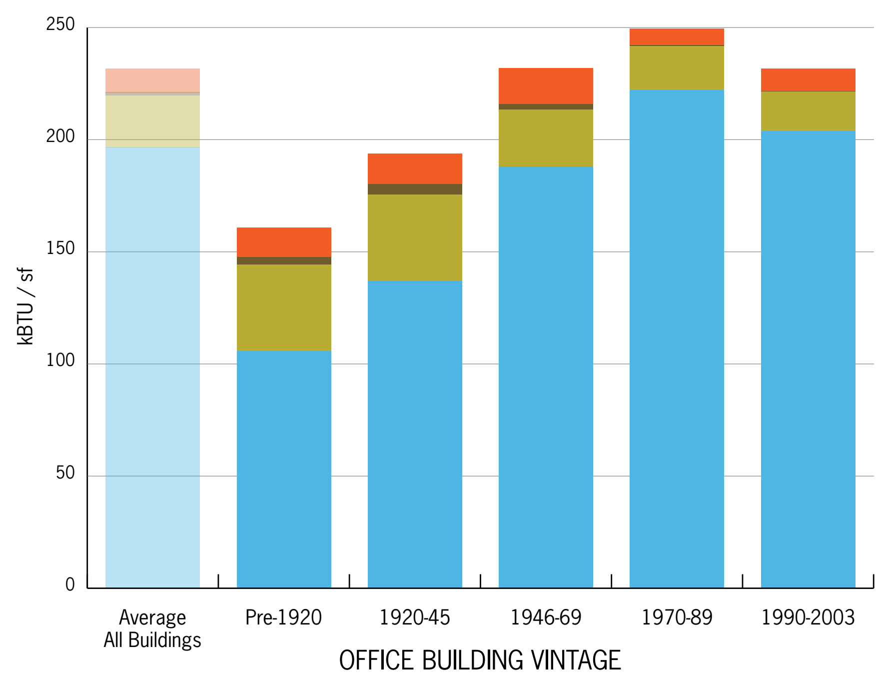


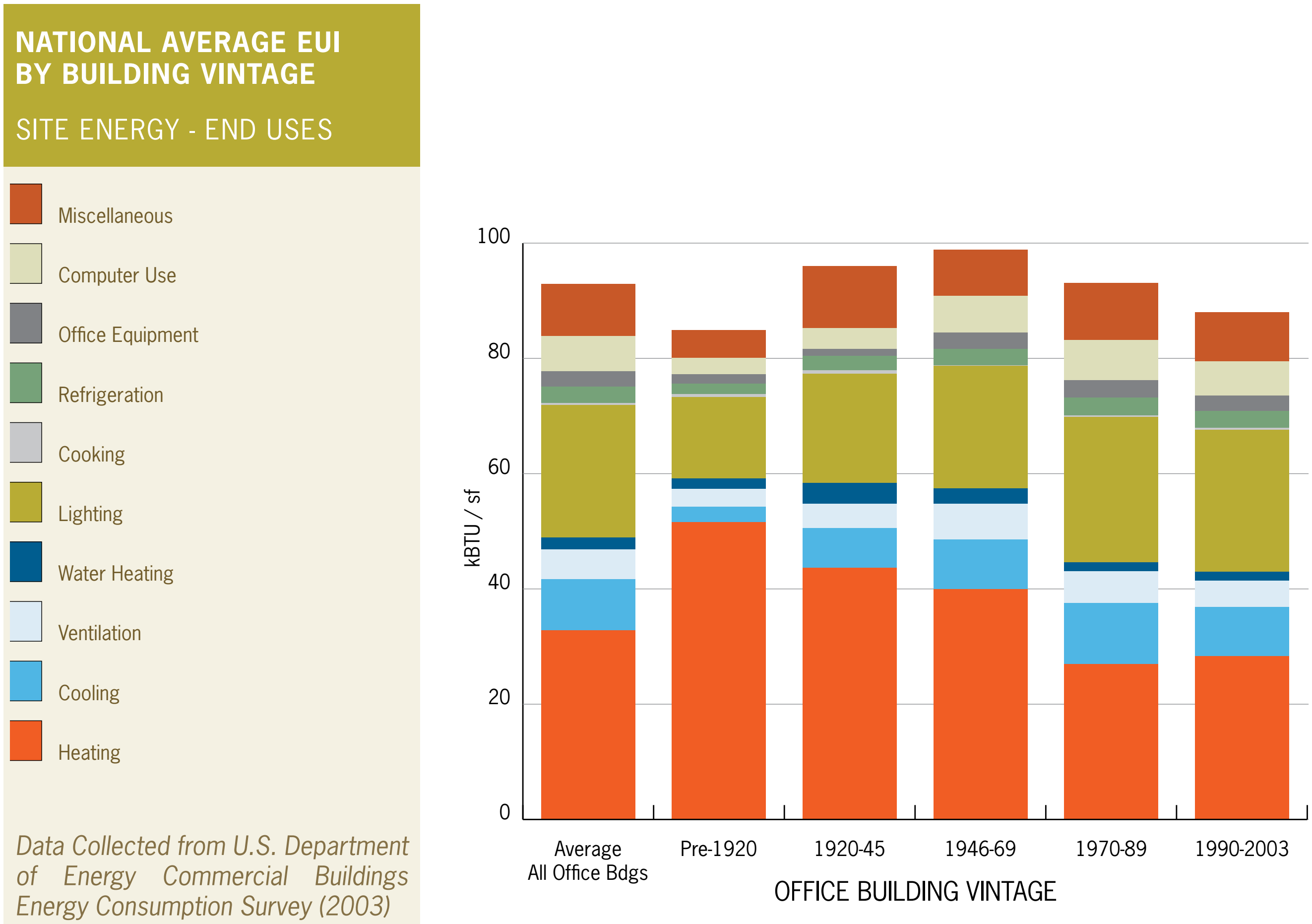
NATIONAL AVERAGE EUI BY BUILDING VINTAGE

SOURCE ENERGY

- Other
- Fuel Oil
- Natural Gas
- Electricity

Data Collected from U.S. Department of Energy Commercial Buildings Energy Consumption Survey (2003)




NATIONAL AVERAGE EUI
BY BUILDING VINTAGE
SITE ENERGY - END USES
Miscellaneous
Computer Use
Office Equipment
Refrigeration
Cooking
Lighting
Water Heating
Ventilation
Cooling
Heating
Data Collected from U.S. Department of Energy Commercial Buildings Energy Consumption Survey (2003)
100
80
60
40
20
0
kBTU / sf
Average
All Office Bdgs
Pre-1920
1920-45
1946-69
1970-89
1990-2003
OFFICE BUILDING VINTAGE

Printed locally on 100% post-consumer recycled paper using non-toxic inks and wind-powered energy.

TERRAPIN

BRIGHT GREEN

2105 O STREET NW
WASHINGTON DC 20037
+1.202.470.0401

641 SIXTH AVENUE
NEW YORK CITY NY 10011
+1.646.460.8400

TERRAPINBRIGHTGREEN.COM
INFO@TERRAPINBG.COM