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The Skyscraper of the Future: Integrating a Flexible Program with Energy Innovation

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Mr. Logan, AIA, specializes in implementing the designer's architectural intent through vigorous analysis and studies, presented in sketch form. His background is in performance requirements, fabrication technologies, testing and constructability issues. Developers and Architects depend on Mr. Logan's counsel on selecting cladding systems, design criteria and contracting parties across all building types, all over the world. He was the primary curtain wall consultant for the Twin Towers in Kuala Lumpur and International Finance Center in Hong Kong, two of the world's tallest and most complex buildings. Mr. Logan attended Princeton's School of Architecture and Harvard's Graduate School of Design.

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Abstract

New York is a city that's experienced more than 125 years of skyscraper development. The rich history of tall-structure development here creates both a cautionary tale and learning opportunity for the development in the rest of the world. Where initial challenges to this typology were structural and mechanical, new challenges are more complex and require solutions that accommodate flexibility. New York's skyscrapers are some of the largest contributors to the City's greenhouse gas emissions, but they can be re-conceived to efficiently use energy with passive design strategies, and actively generate electricity. As the City moves beyond mandates to a near zero greenhouse gas emissions future; its largest buildings will see another century of change. Incorporating strategic planning and integrated consulting expertise early-on at the program development phase will enable the developer, design team, and project consultants to clearly execute cross-disciplinary project goals.

Keywords: Adaptability; Energy; Façade; Integrated Design; Passive Design; Sustainability

A Living Monument to High-Rise Construction

Imagine a skyscraper designed to change. The radical challenges New York will face in the next 100 years will require flexibility in its high-rise development so its iconic skyline can continue contributing to the City's success. Innovative building solutions using new technology to provide old benefits for both new and existing skyscrapers: phase-change materials that act as thermal mass, triple-glazed insulating thermally-broken curtain wall systems that capture daylight and views, photovoltaic facades and building-integrated wind turbines that generate energy, and outrigger structural systems that are strong, but resilient. In addition to new technical solutions, the process of skyscraper development needs to be rethought; integrating specialty expertise at the programming phase to enable impactful results. Pairing flexible programming with energy innovation will empower New York City's high-rise efficiency, and ensure it will be a model for centuries to come.

Manhattan's streetscape has been punctuated with tall buildings since the late 1880's. A time when the waterfront was an active port, the Brooklyn Bridge was just opened, and the Statue of Liberty began greeting immigrants as they sailed to the City through the Upper Bay. The towers were built near the center of the island (see Figure 1) – far from its bustling docks; and used the latest innovations in structural and mechanical system design. After more than a hundred twenty-five years of growth, the City today is radically changed. No longer a major port, still a hub of commerce, the skyline is the icon that defines Manhattan, and waterfronts throughout the City's boroughs are the focus of new development. Buildings and infrastructure confront different risks and take on new responsibilities in an era where sea level rise and storm surges influence habitation at the water's edge. Now, the challenges posed by high-rise development in New York City are not primarily structural, instead they are functional and economic.

Figure 1. A 1911 view of Manhattan's skyscrapers looking west from Brooklyn. While the waterfront was full of active piers, much of the high-rise development was inland. (Source: Underhill, I., 1911. Library of Congress Prints & Photographs Online Catalog. [Online] Available at: http://www.loc.gov/pictures/item/2003677434/ [Accessed 15 05 2015])

The City's skyscrapers have experienced new trials in the past 20 years; terrorism, financial market turmoil, tightening sustainability standards, shifting demographics, and storm damage have each impacted New York's tall buildings. New York City administrations have acknowledged the City's vulnerability to climate change since the early 2000's. Any efforts to mitigate climate change require reducing the City's contribution to global greenhouse gas emissions, and nearly 70% of New York City's greenhouse gas emissions come from the energy used in its buildings (Shorris, 2014), but high-rise developers have been slow to adopt high-performance near zero energy or energy positive building practices. Since 2009, New York's large buildings have been encouraged to improve their sustainability by documenting their energy and water consumption annually. Under New York City Local Law 84, all buildings greater than 50,000 square feet must benchmark their energy and water consumption and their usage data is made available to the public. However, mitigation alone cannot protect the City's buildings.

During Post-tropical Cyclone "Hurricane" Sandy, towers in Lower Manhattan experienced storm damage firsthand when the surrounding streets, transportation infrastructure, and lower floors were flooded. Whole Manhattan neighborhoods were without power for a week. An estimated $15 billion in damage and lost revenues were incurred in New York City (Sledge, 2012). That's the equivalent cost to constructing 15 LEED Platinum One-Bryant Park towers, lost to a single storm that hit the City with less than a hurricane-force. Scientists predict that sea level rise and ever more intense storms will lead to a 10-15 fold increase in the frequency of current 100-year coastal floods by the 2080s (Annals of the New York Academy of Sciences, 2015) (see Figure 2). Within our lifetimes, New York City can expect a 100-year flood every 6-10 years. How can its towers adapt to the new circumstances they face?

High-rise innovation in New York is different than in the rest of the world – it is older. According to the Council on Tall Buildings and Urban Habitat's interactive database, in the last 20 years, 3,505 skyscrapers have been built or are proposed around the globe. Less than 10% of them have been proposed or built in the United States. New York has more than 250 buildings over 150 meters tall, and 69% of them are more than 20 years old; 43% of them are more than 40 years old (Anon., 2015). New York City is representative of the whole US market – with ratios in the ten largest US cities similarly skewing to older high-rise buildings. Many of these are out-of-date, in thriving markets, and opportune for repositioning. The rich history of tall-structure development here creates both a cautionary tale and learning opportunity for the development in the rest of the world.

In New York, several factors impact the adoption of high-performance building practices. Foremost of these is the short time horizon for the investments that most developers require. Many energy efficiency measures get eliminated when they aren't presented with a 5-10 year payback, even though the measure may have a very positive life cycle cost – it doesn't matter to a developer expecting to hold a property for 10 years or less. Additionally, many leases are structured so tenant energy use is separately metered and tenants pay for their own electricity. Why would developers make an investment that increases their upfront cost and delivers savings only to their tenants?

Where sustainability innovation in New York skyscraper typology is happening, it's often been driven by mandates. Battery Park City's dozen LEED-rated buildings likely would

Figure 2. This 2013 view of Lower Manhattan from the Manhattan Bridge Walkway looks over an area which may partially flood in a major storm. The waterfront edges of New York's boroughs are susceptible to 100-year floods and increasing frequency of storm surges. (Source: Nedwek, B., 2013. Flickr.com. [Online] Available at: https://www.flickr.com/photos/bnedwek/11215908074/ [Accessed 15 05 2015])

Figure 3. The Chrysler Building (photo center) has the world's tallest brick façade and operable windows, emblematic of commercial buildings in the first half of the 20th century. (Source: Gottscho, S., 1932. Library of Congress Prints & Photographs Online Catalog. [Online] Available at: http://www.loc.gov/pictures/item/gsc2004000010/PP/ [Accessed 03 06 2015].

Figure 5. A view of Midtown looking north toward 432 Park Avenue. Many of these structures have potential for efficiency upgrades and repositioning. (Source: Quintano, A., 2015. Flickr.com. [Online] Available at: https://www.flickr.com/photos/quintanomedia/16335452951 [Accessed 15 05 2015])

Figure 4. The Seagram Building, while an icon of modern skyscraper design, has three times the energy use intensity (EUI) per square foot than the Chrysler Building, according to 2013 Local Law 84 Benchmarking Data. (Source: Gottscho-Schleisner, I., 1958. Library of Congress Prints & Photographs Online Catalog. [Online] Available at: http://www.loc.gov/pictures/item/gsc1994027875/PP/ [Accessed 15 05 2015])

not be as innovative if it were not for the requirements of the Battery Park City Authority Green Guidelines. Although many of the buildings incorporate innovative energy systems: from combined heat and power to building integrated photovoltaics; water efficiency and water recycling; indoor air quality improvements and healthy building materials, these technologies have not been widely adopted in other Manhattan high-rises. Even the sustainable initiatives and LEED certification pursued at the current Hudson Yards development is a condition of the area Design Guidelines.

The strategies for addressing greenhouse gas emissions in new buildings are already known and proven, however, they still haven't achieved widespread implementation. In the case of new construction, it is not a question of what should be done – it's a matter of understanding who determines why it should be done. In New York, high-rise development is frequently just meeting code requirements for energy efficiency, which set a minimum baseline. It seems that unless change is mandated, it's easier for development in the City to follow the business-as-usual standard. Much more needs to be done to significantly reduce greenhouse gas (GHG) emissions and help the City and State meet their GHG reduction goals.

Existing buildings, in this context, are an even trickier problem. Unlike the blank slate opportunity a new building design represents, existing buildings face additional constraints: from handling existing tenant occupancies and leases, to outdated materials, and unknown structural and mechanical systems. Their renovation and restoration involves significant documentation, customization, and thoughtful integration in ways that new projects do not. Yet, in a city where existing buildings make up more than two-thirds of the skyscrapers, and no tower greater than 50 stories has ever been demolished, change is an inevitable challenge – and excellent opportunity.

The Future Requires a New Approach to Energy

According to reports, "energy efficiency is America's cheapest energy resource". It costs 2-3 times less than traditional power sources (Molina, 2014). Manhattan's oldest skyscrapers feature limestone, brick and terra cotta masonry facades with punched operable windows, that were constructed when buildings had to respond to their environment - the inherent thermal mass of their building envelopes and operability of the windows impacts their thermal performance, and makes them more energy efficient (see Figure 3). The 1950's-70's curtain wall, steel and concrete towers don't have that inherent efficiency because they were constructed with non-thermally broken aluminum frames, monolithic tinted glass, and were not panelized (see Figure 4). They do, however, offer the benefit of modular, standardized construction practices and non-structural facades. More radical changes can be made to these newer buildings.

Skyscraper design of the latter part of the last century was fueled by innovations in mechanical equipment that divorced the interior environment from the local climate. This allows New York offices to perpetually feel like the San Diego coast, 72 degrees and 30% relative humidity. The cost is born in utility bills, equipment maintenance, and limited localized occupant control. A new approach to energy can enable greater user comfort. Several technologies have been developed that allow for improvements, for instance, triple-glazed curtain wall systems allow for eliminating perimeter heating, while maintaining thermal comfort. User-defined climate control is becoming popular; in lieu of half the office sporting scarves in the summer and short sleeves in the winter, or worse – using operable windows and desk heaters or fans to compensate for overactive mechanical systems – and driving up the building's energy demand in the process.

Repositioning existing skyscrapers is becoming more common, as the wave of buildings developed in the 1950's-1970's are updated (Anon., 2015). City benchmarking through Local Law 84 shows those existing office buildings developed in the 1960's and 70's have both the highest Energy Use Intensity (EUI), and largest total square footage. Taming energy use in these buildings will have significant bearing on the City's greenhouse gas emissions (see Figure 5). Benchmarking shows a correlation between building size and increased EUI as well – the larger the building, the more energy it consumes per square foot. (Lee, 2014) The largest buildings in this age range have the greatest potential for improvement.

Figure 7. 1095 Avenue of the Americas is a 1970's office building that renovated its office space to Class A and re-clad its façade. (Source: Bastin, T., 2012. Flickr.com. [Online] Available at: https://farm9.staticflickr.com/8481/8191401072_83a54a4323_o_d.jpg [Accessed 15 05 2015])

Recently repositioned New York high-rises have focused on increasing the amount of vision glazing in the façade, updating old or malfunctioning mechanical systems, and upgrading to LED lighting –integrating these items when needed to meet Energy Code performance requirements (Figure 6). With a focus on refining the quality of older buildings to attract or retain Class A tenants, investments are made in upgraded the lobby, roof deck, or terrace spaces (see Figure 7). These are visible amenities that building occupants can enjoy. High-performance mechanical and electrical equipment can better address a building's greenhouse gas emissions, but they are relatively invisible upgrades. Few press releases or photo opportunities are made about super-efficient equipment in buildings, but a solution that incorporates both occupant-friendly visible and invisible energy efficiency measures is possible.

While repositioning mid-19th century buildings, savvy developers can capture the opportunity to consider their building's resiliency by addressing changes in its use, and reducing its energy consumption; all possible if they start with an integrated strategic plan.

What is a Flexible Skyscraper?

The skyline of Manhattan and other major global cities will be different in 125 years. Decisions made for each building today will likely remain in place for two generations. Are those decisions enabling resiliency? There is inherent risk in the real estate market, but is the risk of climate change being adequately considered? Are developers exploring the potential for reductions in greenhouse gas emission when they reposition or build new skyscrapers? Building stock will need renovation and repositioning, technologies that enable innovation in flexibility and sustainability, and integrate design methods that address a building's impact on not only its occupants, but also the city.

When initiating a new construction or significant renovation project, the developers are in the driver's seat. They have an opportunity to establish the proposed program and project goals, and to hire the design team that will execute their vision. To capitalize on this opportunity and engage a more informed design process, they should incorporate assistance from specialty consultants with building envelope and sustainability expertise to assist with establishing the program requirements. Knowledgeable consulting practices can assist developers with identifying a site or building's potential for solutions that maximize the value of their investment dollars. While major projects require branding and a vision for the property, an informed developer's program which specifies key metrics and integration strategies will enable the developer, design team, and project consultants to clearly execute cross-disciplinary project goals. As the marketplace shifts toward near zero and energy positive buildings, an integrated approach to envelope, structure, and systems

Before During After

Figure 6. Views before, during and after construction of an over-clad renovation at 475 Park Avenue South. (Source: Vidaris, Inc.)

is needed to implement the new vision of skyscraper development.

This is an era of unparalleled flexibility with regard to materials and methods of construction – building codes are moving to performance rather than prescriptive modes. Sophisticated energy modeling enables high-rise buildings to meet energy code requirements with full curtain wall facades and unprecedented amounts of vision glass. Buildings can be configured in numerous ways, but they often do not take advantage of the free resources available to them.

A tower's location is fixed to a site; the world around it changes, but some aspects are constant. Those elements should be studied to see what advantages they offer. The most significant of these elements, globally, is the sun. Each site has a particular solar exposure, regardless of its location in the world. The sun moves around the site in a predictable way, and as a result, becomes a resource that can be harnessed. Providing 23,000 terawatts of power globally per year, available solar power dramatically eclipses the 16 terawatts per year of annual world energy use. The sun doesn't act equally on all sides of a building, and a building's façade can choose to ignore or incorporate its variation. Capturing the sunlight's energy, or controlling it for selective passive heating, daylighting, and energy generation, are all strategies that utilize existing technologies.

While common practices for curtain wall façade solutions has been progressed to maximize material redundancy to keep production costs low by keeping all of the façades as similar as possible, conceiving of a skyscraper façade as a 50-year or 100-year investment changes the focus of this practice. Where redundancy may reduce upfront cost, it significantly increases life-cycle cost for the building by reducing energy efficiency. A façade system that recognizes solar orientation, and capitalizes on the free energy from the sun, will perform much better for the building over time. Studying the potential for integrating passive heating, cooling, ventilation, and daylighting to achieve occupant comfort in the tower, and establishing program parameters around such studies, can affect savings for the majority of cooling and heating seasons with limited to no additional costs.

Wind is another natural resource that can asset, or, be a nuisance. New York City's skyscrapers are designed for hurricane-force winds, and innovative envelope materials must be specially tested to be incorporated at the highest parts of a tower. This requires additional upfront cost, but can result in lifetime energy savings. Analysis is required to mitigate and reduce unwanted building movement. Additionally, outdoor spaces on rooftops and penthouse balconies can become uncomfortable if wind isn't carefully considered. Strategic integration of open floors in buildings is one method of reducing wind pressure by breaking the building into smaller segments. The setbacks at those openings create new opportunities for integrating mechanical space, public space or locating wind turbines.

New York's high-rise buildings will increasingly need to respond to threats from major storms and long utility outages (see Figure 8). Investments in the building envelope and electrical systems become valuable when they allow for occupancy of the building to continue during those events. When areas of Manhattan were without power for a week, all those businesses were closed or had to shift employees to work at other sites, at great costs. Some of the high-rises in Lower Manhattan were unoccupiable for months, while repairs were made to electrical systems that had been flooded.

Urban Green's Study, "Baby It's Cold Inside", looked at utility outages impact on New York City's residential buildings, and the results show that the performance of all-glass high-rise buildings is significantly less beneficial to sheltering-in-place during an outage than the traditional, brick high-rise skyscraper typology. However, creating a high-performance building solution by bettering the thermal resistance of the envelope, reducing solar heat gain and visible light transmission, providing less conductive envelope assemblies,

Figure 8. A night view looking north from Lower Manhattan. A large portion of this photo experienced extended utility outages during Hurricane Sandy. (Source: Quintano, A., 2015. Flickr.com. [Online] Available at: https://www.flickr.com/photos/quintanomedia/17032108315/ [Accessed 15 05 2015])

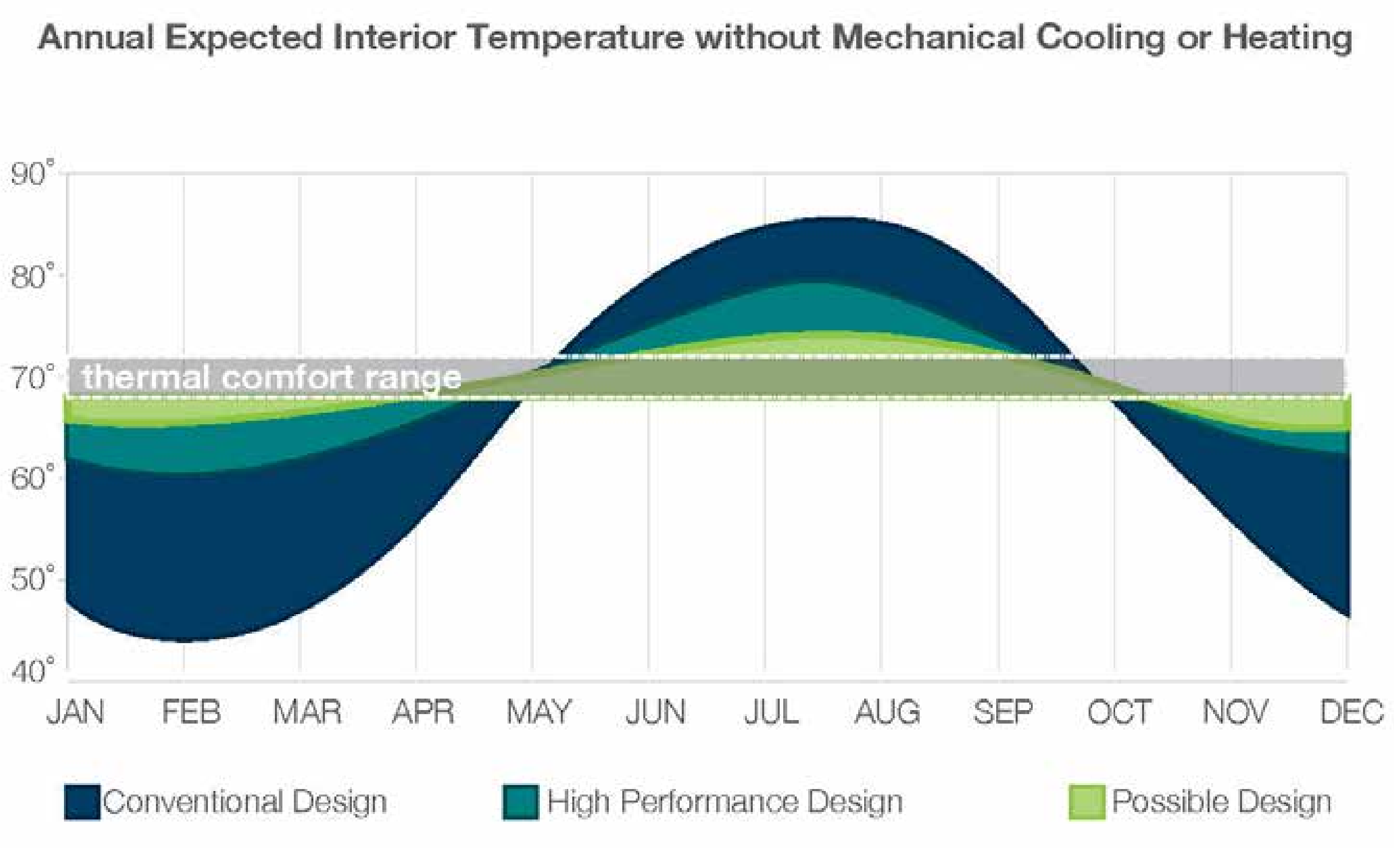

Figure 9. A study of expected interior temperatures in high-rise residential tower if no mechanical heating or cooling were used over the course of a year. For conventional glass skyscraper design, the period in which the occupants would experience thermal comfort is limited to a week in May and September. High-performance design extends the comfortable period to mid-April thru mid-May, and mid-September to early October. Using frameless structural spacers in triple-glazed IGUs and other building envelope improvements, the period extends from late March to June, and September to mid-October. The overall internal temperature swing, without mechanical equipment, in this possible design scenario is less drastic than for High-performance or Conventional Design. (Source: Vidaris, Inc.)

and reducing air infiltration, results in a significant improvement in the habitability of a glass skyscrapers during a power outage (Leigh, 2014).

One way to achieve this is with a curtain walls that includes frameless triple-glazed insulated glazing units with structural edge seal spacers. By minimizing thermal bridging, they have better insulative properties. Another is to use the façade to power some of the building. Vented spandrel units can be designed to incorporate solar photovoltaics that generate energy, creating an insulated "Energy Spandrel". Currently, 30% of the Federal Business Investment Tax Credits offsets the cost of glazing or spandrel units that incorporate PV, and the portion of the curtain wall system that supports them. Spandrel units can also be configured to integrate night sky radiation panels, to help passively cool the building. Integrating these and other strategies can result in a modern residential skyscraper that is habitable without mechanical cooling or heating for several months a year (see Figure 9).

Lower Manhattan has been a case study for converting office skyscrapers to residential use over the past decade, as new office towers lure tenants to the west side at the World Trade Center development, and while New Yorkers seek mixed-use neighborhoods. What if building envelopes and mechanical systems are created to accommodate changing from commercial to residential use and vice-versa? From an energy perspective, there are some interesting symbioses between residential and commercial uses; their respective peak usages occur at opposite times. Commercial uses are often internal-loaded, requiring air conditioning, while residential uses have higher heating requirements. Mixed-use skyscrapers not only benefit the urban context of a mixed-use neighborhood, however, if strategically designed, they also benefit from energy efficiency because of their combination of occupants.

Where current construction practices are very material, energy and greenhouse gas intensive, integrated design can reduce the amount of those elements that are consumed in a building's lifetime. Developing a building's façade system around a strategy focused on future change, provides additional advantages. Residential and commercial uses can be combined by floors or segments of a tower by providing operable vents on all elevations, which fulfill the building code's fresh air requirement for residential use and provide nighttime heat exhaust for office spaces. Cladding can be planned to anticipate a future swap-out that has no impact to the interior space. And furthermore, organizing the structure of the building to these advantages of flexibility.

A high-rise segmented by vertical blocks with intermittent open floors can enable flexibility in several ways (see Figure 10). They can aid in segmenting the building for multiple uses; should a segment need to change from commercial to residential use in the future. Construction or renovation could be organized by block with minimal effect on the rest of the building. Creative outrigger structural support systems can improve thermal performance and reduce overall floor-to-floor heights while retaining high ceilings. Integrating phase change materials that are tuned to specific temperature changes can enable lighter structural slabs to function as thermal mass. The intermittent open floors can be used for compact mechanical systems with short

Figure 10. 432 Park Avenue includes 12-story clusters of apartments, separated by mechanical floors that act as gaps to reduce the wind pressure on the building. (Source: Suzuki, S., 2015. Flickr.com. [Online] Available at: https://farm6.staticflickr.com/5446/16572156763_6537afeecb_o_d.jpg [Accessed 15 05 2015])

runs of ductwork and piping, leaving more room for occupiable floor space. Other space on these intermittent floors could be multi-purpose: providing opportunities for integrating amenity and green space, energy generation with wind turbines or solar panels, and interconnectivity or bridging points between towers in the case of a fire or flood that limits ground-level ingress and egress. Inevitably, some waterfront towers will have to radically engage their sites to address sea level rise and storm surge levels, which will rise as well. If buildings have to adapt to change, let's build that flexibility into them from the beginning.

New life in the concrete jungle

The skyscraper of the future – whether new or renovated – will require greater flexibility. Its life is not limited to 50 or even 100 years, and it will undergo change. Imagine a skyscraper designed to give its current occupants the best possible environment, one that anticipates modification over time to keep it relevant for future use. New technologies will enable our buildings to be flexible; for varying occupancies, changing components, and challenges we cannot yet expect. Technology is only part of the answer, however. The real change will have to come in the way we conceive of, and design our skyscrapers. Developers drive project vision and implementation, and the process they take should include integrated design thinking at the programming stage, to maximize the impact of their investment, both for their near-term bottom line, and for the City's resilience.

References:

Annals of the New York Academy of Sciences, 2015. **New York City Panel on Climate Change 2015 Report Executive Summary**, New York: John Wiley & Sons, Ltd..

Anon., 2015. The Skyscraper Center: **The Global Tall Building Database of the CTBUH**. [Online] Available at: http://skyscrapercenter.com/interactive-data [Accessed 15 May 2015].

Lee, J., 2014. PLANYC **New York City Local Law 84 Benchmarking Report**, September 2014, New York: The New York City Mayor's Office of Long-Term Planning and Sustainability.

Leigh, R., 2014. **Baby it's Cold Inside**, New York: Urban Green Council.

Molina, M., 2014. **The Best Value for America's Energy Dollar: A National Review of the Cost of Utility Energy Efficiency Programs**, Washington, D.C.: The American Council for an Energy-Efficient Economy.

Shorris, A., 2014. **One City Built to Last, New York: The City of New York**.

Sledge, M., 2012. **Hurricane Sandy Damage in New York By-The-Numbers**, New York: Huffington Post.